Feasibility study for the removal of black rats *Rattus rattus* from the island of Sušac, Croatia

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Action A.5: Complete a feasibility study for invasive mammals eradication at seabird colonies on Sušac island within the SPA “Lastovsko otočje”

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Seabird Conservation Network in the Adriatic

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Front cover illustrations: Sušac island as seen from the lighthouse (Dries Engelen)

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EXECUTIVE SUMMARY

1. The island of Sušac has an area of 403ha and is situated in the Lastovo archipelago, some 23km from Lastovo and around 50km from the Croatian mainland. Black rats *Rattus rattus* are present on Sušac, as well as on many other islands in the archipelago. Efforts to control (i.e. reduce the population) or eradicate (i.e. remove completely and permanently) rats have taken place on many of the islands around Lastovo since 2019 as part of the ongoing LIFE Artina project.

2. Rats are causing significant negative impacts on Sušac and other nearby islands. As well as predating upon a wide range of animal and plant species, including the islands' iconic species such as Yelkouan shearwaters *Puffinus yelkouan*, Scopoli's shearwater *Calonectris diomedea* and Eleonora's falcon *Falco eleonorae*, they are known to carry a variety of diseases, to damage buildings and to consume or contaminate human and animal food.

3. **Eradicating rats from Sušac in a ground-based project is feasible but presents a number of logistical difficulties.** These include the need for extensive climbing work to reach all vegetated areas of the island's cliffs, effort required to cut approx. 74 km of trails in order to lay out a grid of rodenticide bait stations and logistical issues around supporting a team of c. 20 people for around seven months on an island currently without suitable accommodation or fresh water.

4. Photos have been used to identify several vegetated cliff ledges requiring baiting, as well as potential abseiling and via ferrata routes. However, it is essential that these sites are all surveyed on the ground with a certified rope access professional also able to do the necessary bolting work to create safe anchor points.

5. The alternative to a wholly ground-based project is for a combination ground and aerial project, using a helicopter to distribute bait over some of the slopes, thus reducing the amount of climbing work. A third option is to carry out the entire project as an aerial project. These options are outside the scope of this report but island managers may wish to pursue these avenues with experts in the field of aerial rat eradication projects.

6. The timing of the eradication is yet to be determined but is likely to be over the autumn/ winter months. To assess the best time to carry out the eradication year-round information is needed about rat population indices and breeding activity. Information is also required on the availability of rat food sources, especially plants. This will require stomach content analysis of rats, as well as surveys by an expert in local botany.

7. The biggest risk to the long-term sustainability of the project is the likelihood of reinvasion, most likely in supplies coming from Lastovo or mainland Croatia. An effective and costed biosecurity plan for the island and strategies for securing the necessary ongoing funding must be developed before any proposed eradication project proceeds. The costs of ongoing biosecurity are not included in the costs given here for the eradication project. However, it is

anticipated that the majority of the equipment needed will come from the eradication project, which will offset ongoing biosecurity costs to a significant degree.

8. **Community support will be important for any such project to proceed. The views of <u>all</u> stakeholders will need to be collected before the project can proceed to the full operational planning stage.**

9. The majority of biosecurity measures should be in place prior to the start of the eradication. All supply boats should have sufficient measures in place both in harbours and onboard, and all livestock feed, food and most importantly food waste on the island should be stored in rat proof storage. A system for the prompt and frequent shipping of waste from the island should be set in place, especially for the duration of the eradication process, when the number of people and amount of waste generated will be higher.

10. The estimated operational cost of eradicating rats from Sušac comes to €950636 (€1140763.64 when including the recommended 20% contingency buffer). This includes costs of the preparation, poisoning and intensive monitoring phases, followed by two years monitoring and a final check to ascertain rat-free status. Note that this is a very provisional figure and may increase significantly. The estimated budget does not cover surveys by rope access experts and botanists nor stakeholder engagement which should all be carried out prior to the project.

11. There is considerable capacity within Europe for planning and carrying out projects of this kind, including personnel from Malta, Italy and the UK. It would also present an excellent opportunity to develop Croatia's experience in this field. However, a world class Operations Manager will need to be recruited to oversee the actual eradication phase.

12. The main goal of a rat eradication project on Sušac is to help restore a functioning island ecosystem through the process of eradicating non-native populations of black rats. However, this could be one of several measures, as part of a wider ecosystem restoration project. These could include soil restoration and revegetation at sites where erosion is occurring, promoting vegetational succession on parts of the island by fencing off goats and sheep and promoting expansion of seabird colonies to currently unoccupied but suitable parts of the island. The potential project should evaluate the possibility to remove other feral and non-native species such as rabbits and cats, which might prevent the ecosystem from restoring fully, by damage to vegetation and by predation of native fauna respectively. Separate feasibility studies would be needed for any additional species considered for eradication and any restoration measures other than rat eradication would be over and above what is planned and budgeted for under this report. Indeed, however, including more conservation actions into one project might be more cost-effective in the long run.

13. **It is important to investigate the possibility of rodenticide resistance as this will affect which active ingredient(s), if any, are suitable for using in the proposed project.** This should be done 1-2 years before the likely start of the project (so, once funding and other support is in place). Testing too early may miss resistant rats turning up from the mainland, or resistance

later developing in existing populations. Rodenticide resistance testing will involve collecting tissue samples from rats on Sušac, as well as from likely sources of reinvasion (Lastovo and any relevant ports on the Croatian mainland).

14. This feasibility study covers preparation, eradication, two years of monitoring and a final check. Other work will also be needed to carry out a successful rat eradication in accordance with current best practice guidelines, including community engagement activities and a programme of ecological survey work designed to detect the impacts of removing rats on the island ecosystems. Note that this work is not included in the draft budget presented here.

15. Expert opinion should also be sought from construction workers and technicians in off-grid desalination systems experienced with remote island work, on the various options available for creating accommodation, storage and workshop space as well as supply and storage of fresh water.

16. The project can only be a success with reliable transport between the island, Lastovo and the mainland. This can in part be achieved by hiring services from existing companies supplying remote islands in Croatia, but given the need to make frequent crossings to the island with personnel and supplies including during the windier parts of the year, the project should consider purchasing their own vessel.

1 INTRODUCTION

LIFE Artina (LIFE17 NAT/HR/000594) aims to improve the conservation status of Yelkouan shearwater, Scopoli's shearwater and Audouin's gull *Larus audouinii* in the Lastovo Archipelago, Croatia. One of the main actions is to eradicate or control invasive predators, which impact breeding success of these birds through predation. The main predator in this archipelago is the black rat. LIFE Artina is running between 2018 and 2023, and through the implementation of predator management on several islets has already demonstrated increased breeding success of nesting seabirds. The largest islet from which eradication has so far been attempted under LIFE Artina is Petrovac at 9ha.

The aim of this report is to assess the feasibility of eradicating black rats, through ground-based methods from the island of Sušac, in order to maintain it rat free into the foreseeable future for the benefit of native wildlife. As has been recorded on several other islands, invasive predators can have a disproportionate impact on native fauna, including predation of shearwaters and other burrow-nesting seabirds. Sušac holds small colonies of both Yelkouan shearwater (50 -200 breeding pairs) and Scopoli's shearwater (50 – 80 breeding pairs), but at 403ha this relatively large and rugged island is perhaps underexplored and might have several undiscovered nest sites. Moreover, there seems to be definite potential for population increase, if major threats such as predation by rats are removed. In 2020, localised and seasonal rat control was carried out for the first time around the known Yelkouan shearwater nests on Sušac, as part of LIFE Artina. This led to higher breeding success than that registered in 2019.

Eradication would permanently remove rats from the island, and in the long term should be more cost effective than annual control, as well as killing fewer rats overall. Complete eradication would also benefit all current and potential shearwater nesting sites across the island, across a larger spatial extent than is feasible with seasonal control. Shearwaters nesting on Sušac would benefit immediately from decreased predation pressure, as would other fauna such as lizards, invertebrates and other bird species, as well as plants impacted by herbivory and seed predation.

Sušac is 11.7km from the next nearest landmass, well beyond the known swimming distance of rats, there are relatively few visiting boats, no permanent residents and the lighthouse is the only establishment offering tourist accommodation. Therefore, it is likely that it can be kept rat free with proper biosecurity measures in place, in the event that eradication is carried out successfully.

The eradication of rats from the island of Sušac, is envisaged to happen as a separate project to LIFE Artina, due to the considerable resources needed for such a project. It should probably focus entirely on the island of Sušac, but could involve other restoration activities apart from rat eradication such as soil restoration and revegetation. Those activities are beyond the scope of this study.

National and International site and species designations

All of the Lastovo Archipelago is part of the Natura 2000 network, designated as a Special Area of Conservation (SAC) and Site of Community Importance (SCI) with site code HR5000038, and as a Special Protection Area (SPA) with site code HR1000038 and name Lastovsko otočje. It is managed by the Public institution Nature Park Lastovsko otočje.

The terrestrial vegetation on the Lastovo archipelago is very biodiverse, and several habitat types under the Habitats Directive 92/43/EEC are present. The *Oleo-Euphorbietum dendroidis* community is particularly well preserved on Sušac.

Yelkouan shearwater and Scopoli's shearwater nesting on Sušac would be the main conservation targets of an eradication of rats and are both Annex I species under the EU Birds Directive 2009/147/EC. Another species of conservation concern which nests on Sušac and which is likely to benefit from rat eradication through reduced nest predation risk, is the Eleonora's falcon.

Target audience of the Feasibility Study

The current feasibility study aims to guide conservation organisations, such as BIOM, and the park prirode Lastovsko otočje management which could potentially seek funding to undertake an eradication on the island of Sušac. While this report is specific to Sušac, the experiences gained through undertaking this process for Sušac, can be applied to other similar islets in Croatia if the interest or need should arise.

Template used for writing up this report

In order to write up this feasibility study the template given in UK Rodent Eradication Best Practice Toolkit by Thomas et al. (2017) was used. Additionally, several reports and published papers were referenced and can be found in the reference list of this report.

The initial background work for this study, starting off with a preliminary field visit in May, was carried out in 2019 and outlined the work required to inform a feasibility report (Varnham & Austad 2019). During 2020 much of the required data has been gathered and is presented as part of this report. On site data collection was carried out by BIOM, while park management provided details on inhabitants and visitor frequency.

1.1 The Site: Sušac

A summary of the assessed physical, anthropogenic and biological characteristics of the island are presented in Table 1 and average weather data across the year is given in Table 2.

Table 1: *Sušac island summary*

Number of Islands	One
Coordinates	42.765457°N 16.510675°E
Area	403ha
Distance from closest islands	11.7km to Bijelac (no permanent vegetation); 14.2km to Kopište (permanent vegetation; uninhabited) and ca.23km to Lastovo (inhabited) (Fig. 1)

Highest point	239masl
Terrain	The coastline is dominated by rocky shorelines and cliffs, which in places are over 40m high. The north slope is especially steep and rugged and so are some valley formations, but the island is more gently sloping on the west part. (Fig. 2 & 3)
Vegetation	Mediterranean successional vegetation from open sparsely coastal garrigue to woodland dominated by *Quercus ilex* and *Olea europaea*. Large parts of the island dominated by *Rosmarinus officinalis, Pistacia lentiscus*, and *Juniperus ssp.* forming very dense garrigue and maquis
Protection Designations	SPA, SCI & SAC as part of Natura 2000 network (HR5000038 & HR1000038)
Ownership/jurisdiction	Government of Croatia
Inhabited	No permanent residents. One/two shepherds present seasonally (April – November), residing in small simple dwellings, while sheep and goats are kept all year round on the island. The lighthouse is permanently manned, lighthouse keepers staying in shifts of a month each. The lighthouse can also accommodate tourists. Both shepherds and lighthouse keepers have domestic animals such as cats, rabbits & chickens which are partly freely roaming. Apart from animal husbandry there is no active agriculture of note on the island. Some abandoned buildings having previously had a military purpose are no longer in use. The location of these buildings is shown in Figure 2. Three to four fishermen visit the island and surrounding waters at a frequency of around once a fortnight.
Transport & accessibility	There is no ferry connection and a private boat is required to reach the island. The lighthouse management company (Plovput) supplies water and supplies to the lighthouse every two weeks. Two small jetties are present on the south-east side of the island, one of which was upgraded in 2020. A third, poorly maintained and small jetty is found on the west side of the island.

Tourism	A few visits by private vessels (yachts) are made, mostly between June and September, with a frequency of two to three per day including going ashore. Two apartments are available for rent at the lighthouse for which Plovput provides transport. Additionally, some visits are made by scuba-diving operators which might not necessarily land on the island.
Climate	The climate of Sušac is typically Mediterranean and is summarised in Table 2 (Source: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/lastovo_croatia_3196754)

Target species for eradication	Black rat, *Rattus rattus*
Food sources for target species	Natural vegetation & seeds including olives and some *Pinus halepensis* are present on the island. All waste generated by humans is kept on the island and incinerated. It is not known if domestic animals are given feed or if they rely entirely on grazing.
Other non-native species known or suspected to be present	Wood mouse *Apodemus sylvaticus* (possibly native), cat *Felis catus* (domestic/feral); European rabbit *Oryctolagus cuniculus* (domestic, possibly also feral), goat *Capra aegagrus hircus,* sheep *Ovis aries* and domestic chicken *Gallus gallus domesticus*. No dogs *Canis lupus familiaris* are known to be permanently on the island but some tourists have dogs with them and they are left to roam freely. The brown rat *Rattus norvegicus* is not known to be present on the island.
Reptile species present	Italian wall lizard *Podarcis sicula,* sharp-headed lizard *Dalmatolacerta oxycephala,* Turkish gecko *Hemidactylus turcicus* (Vervust et al. 2009)
Avian species present	(This is not an exhaustive list but only includes species of highest conservation value or those that might be impacted by an eradication project): Scopoli's shearwater, Yelkouan shearwater, Common buzzard *Buteo buteo* (1+ pair), Honey buzzard *Pernis apivorus* (migrant), Marsh harrier *Circus aeruginosus* (migrant), Peregrine falcon *Falco peregrinus* (1+ pair), Eleonora's falcon (10-15 pairs), Common kestrel *Falco tinnunculus* (migrant/breeding), Eurasian sparrowhawk *Accipiter nisus* (migrant/breeding), Yellow-legged gull *Larus*

	michahellis (breeding), Raven *Corvus corax* (breeding/visiting), Hooded crow *Corvus cornix* (visiting)

***Table 2**: Summarised weather information from Lastovo archipelago as sourced from Meteoblue 2020*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (High) (C)	10	11	14	18	23	27	30	30	25	20	15	10
Temperature (Low) (C)	2	2	4	8	12	15	17	17	14	11	7	3
Rainfall (mm)	127	119	109	101	50	33	18	18	70	107	177	148
Precipitation days	11	11	11	13	11	8	7	5	8	10	13	12
Days with sunshine	19	17	20	20	26	28	29	29	30	26	17	19
Days with wind stronger than 19km/hr	10	11	12	10	6	7	3	2	4	6	10	11

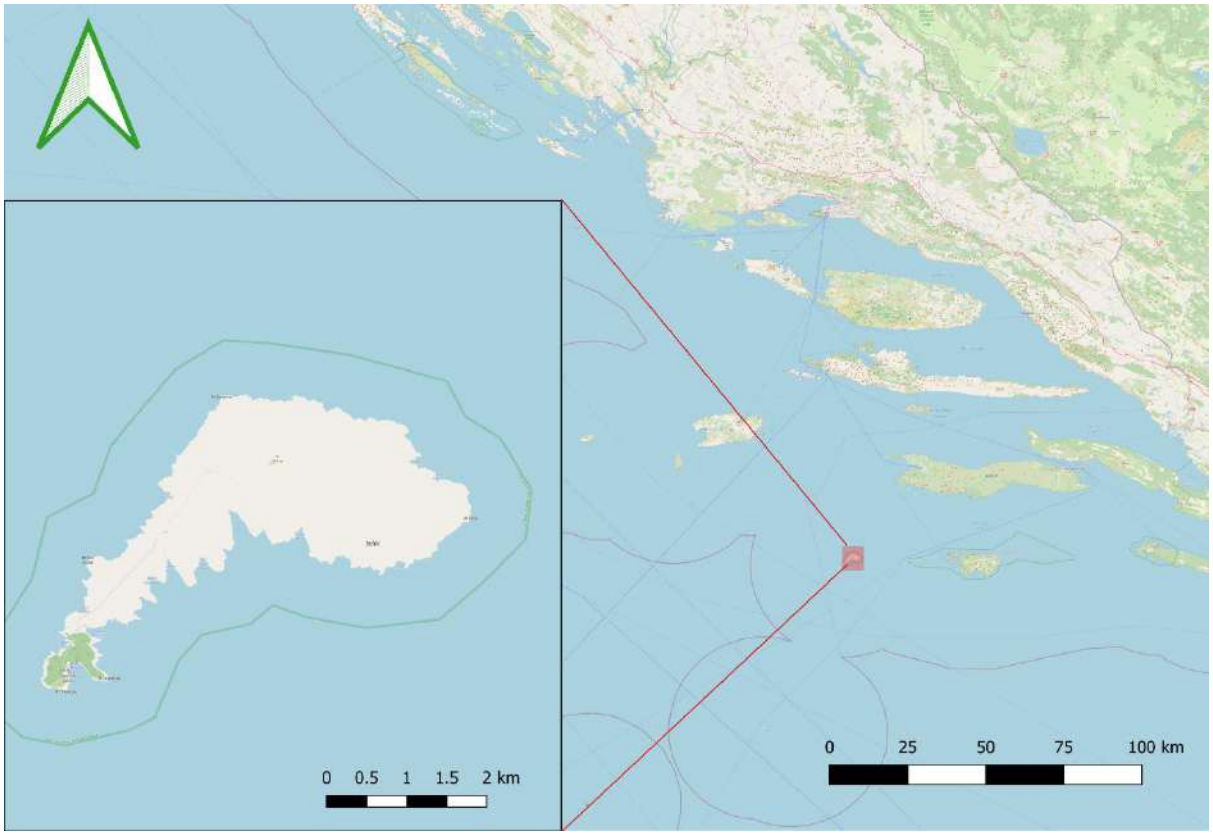

***Figure 1**: Map of Sušac, 14km west of the closest vegetated island and around 23km west of Lastovo island part of the Park prirode Lastovsko otočje outlined in green.*

Figure 2: *Location of lighthouse, its jetty, shepherd buildings and old abandoned military buildings on Sušac, overlaid satellite imagery*

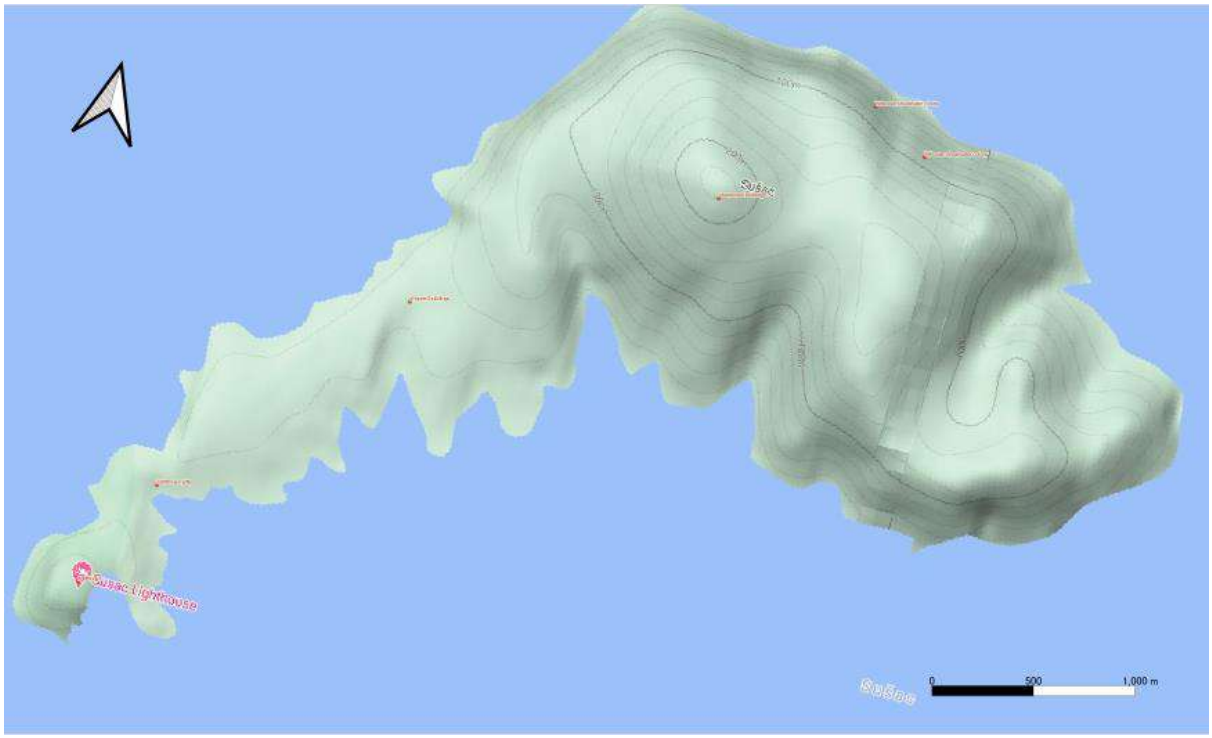

Figure 3*. Terrain map of Sušac, showing contour lines of 20m each, with bolder lines marking 100m and 200m contours, the highest point on the island is 239m.*

1.2 Target Species: Black Rat *Rattus rattus*

The native range of the black rat is South-east Asia and India, and it is globally one of the most prevalent introduced invasive predators (Russell et al. 2017). It is an omnivorous species and feeds on and impacts a wide range of species of flora and fauna. Home range studies through radio tracking on Italian islands have found an average home range to be around 1600m^2 (Capizzi et al. 2016).

Populations of rats on Mediterranean islands seem to vary seasonally, between years and between islands and one should be wary of generalising (Capizzi et al. 2016). In Malta, where rat control occurs annually around seabird colonies between February and July (Lago et al. 2019), bait consumption tends to increase in May (LIFE Arċipelagu Garnija unpublished data). Capizzi et al. (2016) also found the proportion of juveniles in the population of black rats on islands to vary seasonally and between islands. However, a general, tentative trend is that lower population densities and a lower proportion of juveniles are present during the winter months (Capizzi et al. 2016).

Index Trapping

In September 2019, LIFE Artina BIOM fieldwork staff carried out index trapping following the transects shown in Fig. 4 over three consecutive nights. Three transects were carried out, one in each of the following habitat categories outlined in Varnham & Austad (2019) (cat. 1: sparse, low; cat. 2: low-medium and cat. 3: medium-high vegetation). Each transect had 25 trapping sites, 2 traps per site, sites spaced 25m apart. There were several sprung traps without captures, hence lost trap nights, but the corrected number of trap nights was still around the required minimum level of 100 for each habitat type (Cunningham & Moors, 1996). The highest relative abundance was found in the coastal transect with sparse vegetation (Table 3). Ten wood mice were also captured during the index trapping with highest density in medium to high maquis (none in cat. 1, one in cat. 2, 9 in cat. 3).

Table 3: *Relative abundance of rats and mice calculated on index trapping in three habitats on Sušac during September 2019*

Habitat type	Trap nights	Lost trap nights	Corrected trap nights	Relative abundance of rats (captures/100 trap nights)	Relative abundance of mice (captures/100 trap nights)
Low-sparse (Coastal)	150	54.5	95.50	13.61	0
Low-Medium	150	36	114	5.26	0.88
Medium-high	150	45	105	7.62	8.57

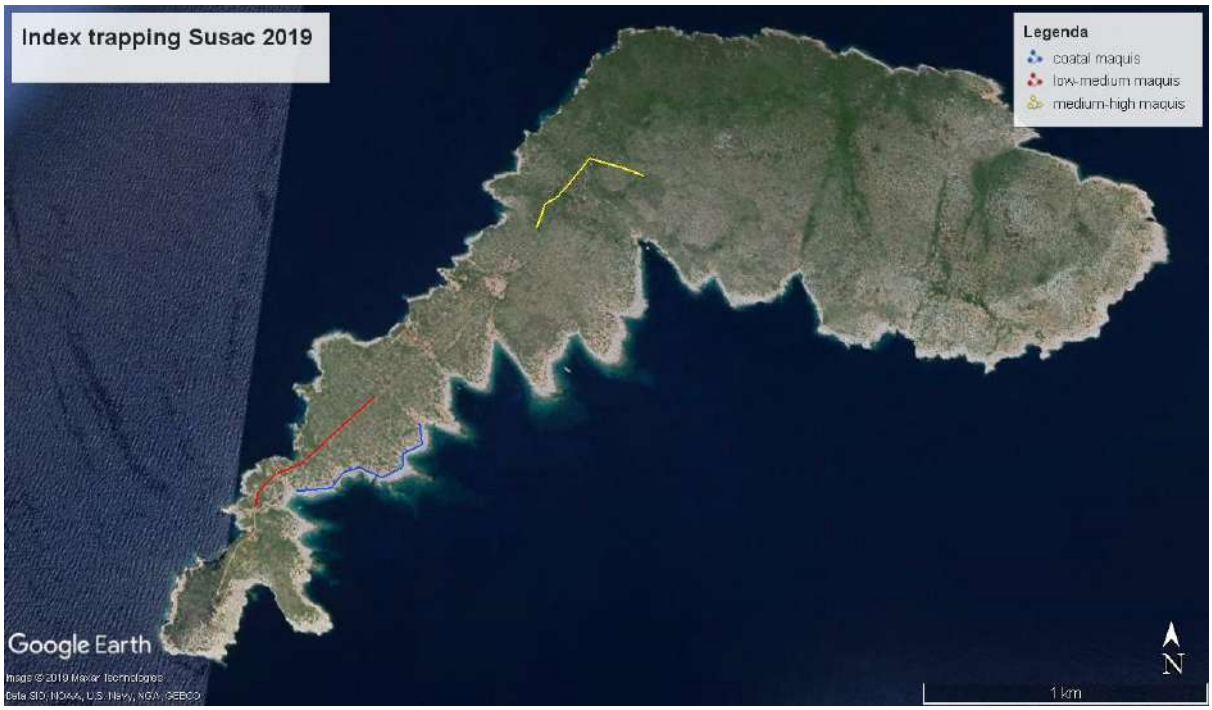

Figure 4: *The three transects followed for index trapping of rat density (red, blue and yellow lines) in different habitat categories on Sušac, September 2019*

Current predator management

Between February and June 2020, rat control was carried out around the two sites with Yelkouan shearwater nests (Fig. 2). Twenty bait stations were deployed in total, each with eight blocks (160g) of 'Brodilon parafinski blok', containing the active ingredient bromadialone (0.005%), a second generation anticoagulant rodenticide. Bait checks were made on the 24.02.2020, 11.03.2020, 30.03.2020, 17.04.2020, 5.05.2020, 23.5.2020 and a final visit on the 13.06.2020 when bait stations were retrieved. On all visits all bait had been consumed by rats and was fully replaced.

DNA & rodenticide resistance sampling

In 2019-2020 samples from rats were collected from the Lastovo archipelago for future analysis of genetics. One sample was collected from Sušac, and nine from the neighbouring Kopište island group. More samples should be collected from Sušac itself prior to an eradication attempt, as a comparison reference in case of later incursions. Samples are also required from main islands such as Lastovo. Specimens of wood mice can also be collected in case a comparison with mainland population is desirable or future incursions are suspected.

Another important reason for collecting more rat samples from Sušac is for rodenticide resistance testing. Any resistance identified should guide the type of rodenticide selected and therefore a balance in timing for this sampling should be found. It needs to allow for sufficient time to make the decision of bait type and for its purchase, but not be too far ahead of an eradication to increase risk for potentially resistant rats to incur and spread in the population. A two-year timeframe ahead of eradications is usually a good compromise.

1.3 Target Species Impacts

Predation by rats affects the breeding success of shearwaters on Sušac. Predation of Yelkouan shearwater eggs was confirmed in May 2019 and March 2020 with one case each. In 2019 a sample of five Yelkouan shearwater nests was monitored throughout the breeding season, out of a total sample of 20 nests identified as active that year. Only one of these nests (20%) contained a nestling on the last visit in June 2019.

In 2020 a larger effort was made to monitor and locate shearwater nests on Sušac. In total 40 nests were identified with active breeding attempts in the two areas indicated on the map in Figure 2. 70% to 76% of a sample of 37 nests monitored were successful in raising a nestling (last visit on 13th June 2020). High breeding success can be at least partly attributed to the rat control being carried out around the nests in 2020 but more years of monitoring are required.

In both 2019 and 2020, it was not possible to fully monitor Scopoli's shearwater nests on Sušac but a handful of nests were found in the same location as Yelkouan shearwaters nests in both years.

While there is no specific evidence from Sušac, rats are also known to predate on Eleonora's falcon nests (Ristow & Wink 1985). Rats are also having a detrimental impact on the herpetofauna of the Lastovo archipelago wherever rats are found in large numbers (Vervust et al. 2009), and this presumably includes Sušac.

Taken that Sušac is largely uninhabited the economic, social and health impacts of the target species are deemed to be low, except potential damage to food and animal feed stores at the shepherd dwellings and at the lighthouse. Contamination of water storage containers if not properly closed, is also a risk.

Justification for eradication and case studies similar to Sušac

Successful eradications of *Rattus* spp. have been carried out successfully using anticoagulant rodenticides on several islands with similar size and or topography to Sušac (Table 4). In the Mediterranean alone, 75 out of 105 attempted *R. rattus* eradications are known to have been successful, while a further 14 of these are in progress or still to be confirmed (Capizzi 2020). In most cases rodenticide was deployed inside bait stations through ground-based operations but in 12% (of 105 projects) rodenticide was hand broadcast and in 7.5% (of 105 projects) aerial drop of bait from helicopters was used. All the latter aerial broadcast projects were successful (Capizzi 2020; Sposimo et al. 2019).

Table 4: *Islands of similar size and/or topography to Sušac from which* Rattus *spp. have been successfully eradicated, or still pending confirmation of rat free status.*

Island Name & Location	**Eradication Method**	**Island Size (Ha)**	**Topography**	**Success**	**Citation**
Lundy, UK	Ground based, bait stations	430	Some cliffs	Yes	Appleton et al. 2006 & DIISE 2018
Canna, UK	Ground based, bait stations	1310	Cliff slopes	Yes	Appleton et al. 2006 & DIISE 2018

Shiant Isles, UK	Ground based, bait stations	176	Cliff slopes	Yes	DIISE 2018
Redonda, Antigua und Barbuda	Ground based, bait stations & hand broadcast*	63.2	Cliff slopes	Yes	DIISE 2018
Molara, Italy	Aerial broadcast	347.9	Some cliff (158masl)	Yes (reinvaded)	Capizzi et al. 2016 & DIISE 2018
Montecristo, Italy	Aerial broadcast	1080	Mountainous (645masl)	Yes	Sposimo et al. 2019 & DIISE 2018
Tavolara, Italy	Aerial & hand broadcast	592	Cliff slopes (565masl)	Yes	DIISE 2018
Palmarola & Zannone, Italy	Bait station**	120 & 106	Cliff slopes	To be confirmed (2018) & Yes	Capizzi 2020 & DIISE 2018
Dragonada & Gianysada, Greece	Ground based, bait stations	214 & 282	Some cliff	To be confirmed (2017)	DIISE 2018

*hand broadcast from a helicopter

** Bait inside biodegradable bait containers lowered from helicopter in inaccessible sites (Sposimo et al. 2019, Capizzi 2020)

Successful eradication of invasive mammals immediately removes the risk of nest predation to shearwaters and Eleonora's falcon on Mediterranean islands (Capizzi 2020). Assuming long-term population increase, however, is less predictable, depending on other threats which might cause high immature and adult mortality at sea (Oppel et al. 2011). The habitat availability on Sušac does not seem to be a limiting factor to the population of shearwaters and indeed it is expected that suitable nesting sites are currently unoccupied. One Mediterranean success case following rat eradication is Zembretta, Tunisia, with 10.4 and 8.5-fold increases in occupied nests found late in the breeding season, two and three years after eradication respectively (Bourgeois et al. 2013). Similar cases have been recorded for the closely related Manx shearwater *Puffinus puffinus* in the UK, with a ten-fold increase in the breeding population on Lundy a decade after rat eradication (Booker & Price 2014), and a five-fold increase on Ramsey almost two decades after eradication (Bell et al. 2019a)

Rat eradication, if feasible, is usually more sustainable, economically viable and ethical in the long-term than ongoing control (Russell et al. 2017). Complete eradication would moreover benefit all current and potential shearwater nesting sites across Sušac, on a much larger spatial extent than would be feasible with seasonal control. Eradication also tends to bring about more benefits to island biodiversity other than increased reproductive success of bird species. Several case studies have

shown resurgence of native island flora, invertebrates and reptiles, and even populations of non-target species including gulls and corvids that might initially be impacted generally recover (Jones et al. 2016; Sposimo et al. 2019). Population levels of lizards and geckos were found to increase on Italian islands after rat eradication (Capizzi et al. 2016). Both Scops owl *Otus scops* and European nightjar *Caprimulgus europaeus* nest on Lastovo archipelago and are expected increase on Sušac in line with observations made on Montecristo (Sposimo et al. 2019). European storm petrel *Hydrobates pelagicus* is not currently known to breed in the Lastovo archipelago, but the sea caves on Sušac would be suitable for the species if rats are removed completely. Several projects have successfully attracted small petrel species post eradication through regular playback of calls, such as the Shiants, UK, and Berlengas, Portugal. On Ramsey, UK, the species also established itself after eradication (Bell et al. 2019a.)

2. GOAL, OBJECTIVES AND OUTCOMES

Goal

The main goal of a restoration project on Sušac is to restore a functioning island ecosystem through the process of eradicating non-native populations of black rats. Removing this omnivorous rodent is highly likely to lead to enhanced populations of native species, including self-sustaining shearwater and Eleonora's falcon breeding colonies.

Objectives and outcomes

The objectives that this project aims to achieve, and the outcomes that will be seen as a result of achieving these objectives, are described in Table 5. These objectives relate specifically to the operation to remove rats, which will be a subset of any wider island restoration project.

***Table 5**: Project objectives and outcomes*

Objectives	**Outcomes**
1. Eradicate black rats (*Rattus rattus*)	1.1 No black rat population remaining on the island
	1.2 Increase in population size of Scopoli's and Yelkouan shearwaters and Eleonora's falcon in existing colonies
	1.3 Recolonization by shearwaters and Eleonora's falcon in areas with suitable habitat
2. Safeguard native populations of conservation interest/importance	2.2 No mortality of birds of prey attributable to rodenticide use
3. Safeguard and enhance the livelihoods of island inhabitants and visitors and the safety of pets and livestock	3.1 Livelihoods of island users enhanced, as measured by pre- and post-eradication questionnaires

	3.2 No mortality of pets or livestock attributable to rodenticide use
4. Improve the capacity of partner organisations to undertake complex eradication projects	4.1 Partner organisation staff have skills to lead eradication projects of a similar size and complexity to current project
5. Maintain invasive-rodent-free status of island via appropriate biosecurity measures	5.1 Island remains free of invasive rodents

3. FEASIBILITY

In this section we present and analyse the information available for each of seven criteria to enable the feasibility of eradicating black rats from Sušac to be determined. The criteria to be met are as follows (Thomas et al. 2017):

- Technically feasible – that the eradication could be achieved using currently available methods
- Sustainable and biosecure – that the rat-free status of the island could be protected by preventing new populations of rats from becoming established
- Socially viable – that the project is acceptable to the people of Croatia, particularly the Lastovo region
- Politically and legally viable – that the project meets the requirements of Croatian & EU law
- Environmentally viable – that rats can be eradicated without causing unacceptable harm to other aspects of the environment
- Sufficient capacity – that the relevant personnel can be found and can commit to the duration of the project
- Financially viable – that the necessary funding can be sourced to cover the entire project

3.1 Technical feasibility

Note that this study only considers the feasibility of a ground-based project. Some projects use helicopters to drop bait across part or whole of the island but this is beyond the scope of the present study.

Eradicating rats from Sušac in a fully ground-based project is feasible but presents a number of logistical difficulties that will need to be adequately addressed to ensure the safety of staff and maximise the chances of success of the project. Sušac is less steep and of lower relief than islands tackled by entirely aerial bait drop operations in the Mediterranean, with the exception of Molara (Table 4). However, parts of the island will pose a considerable challenge for regular ground-based baiting as extensive areas of cliffs and steep boulder screes will need to be covered. Therefore, feasibility of a fully ground-based project is conditional on the approval of a professional rope access specialist surveying all routes and anchor possibilities on the ground, as so far cliff access has only been assessed from images. Considerable costs will go into anchor bolts for abseils, via ferrata routes (rungs and cable secured to the rock allowing workers to be clipped on at all times in steep sections), abseiling gear as well as recruiting a large enough team of climbers certified in rope access to carry

out the cliff baiting in shifts to avoid fatigue. The complete team on the ground is estimated to be up to 18 persons at a time and adequate facilities for them to live on the island for around seven months would need to be provided. Another major logistical issue is the vast baiting grid that would need to be cut through dense vegetation, estimated to involve over 70km of trails.

Island access

The island of Sušac is reached by boat. At least two jetties exist on the island, with the one managed by the lighthouse having been upgraded in 2020. The closest harbour to reach Sušac is 28 kilometers away at Pasadur, Lastovo. Therefore, field operators during an eradication attempt would have to be temporarily living on Sušac, because making the trip on a daily basis would be costly and not possible on several days with adverse sea conditions.

Sušac does not have a helipad, but there are open areas sufficient for a helicopter to land on in the case of emergency. An official heliport exists on the main island of Lastovo and could potentially be used to load bait from, in case of a hybrid approach including aerial broadcast of bait. However, this heliport does not have refuelling facilities, and the closest one that does is in Split (Fig. 1), resulting in longer total flight time and costs.

On the island itself paths are established between the lighthouse, shepherd dwellings and jetties. However, otherwise the vegetation is rather dense and would require trail cutting along baiting grid lines (see next section for details of proposed grid network). Rugged steep sections on the north slope of the island would best be accessed by installing a via ferrata setup to ensure that fieldworkers are continually attached. Some sections of the coastline have cliffs with vegetated ledges and/or caves, which would also require baiting. Further details are discussed in section 3.1.2.

There are no offshore stacks or satellite islets that would require baiting.

The correct sized baiting and monitoring grid required

A baiting grid of 40m by 50m would be sufficient to eradicate black rats, a density of 5 bait stations per hectare. Across 403ha Sušac, this would entail a minimum of 1860 bait stations. However, the topography and vegetation of Sušac is very varied, and the actual number of bait stations deployed would need to be increased considerably to account for this. We consider that up to 25 percent more bait stations than that estimated on a two-dimensional grid will be needed across steeper areas. In coastal areas, which index trapping indicated to have higher rat density and in boulder screes with colonies the grid size might have to be reduced to 25m by 25m (Thomas et al. 2017; Main et al. 2019). Implementing a 25m by 25m grid in the boulder scree area around the colonies of Yelkouan shearwaters on Sušac would add around 150 bait stations. Additionally, bait stations would be placed inside all dwellings. The costings and resource calculations used in this study are based on a likely upper limit of c. 2500 bait stations. The baiting grid will also act as the basis for a monitoring grid, kept at least at the same density during the intensive monitoring phase, establishing whether any rats have survived the initial eradication effort.

Similar projects that have been successful

Table 4 gives some examples of islands similar to Sušac in size and topography from which black rats have been successfully eradicated. However, not all of these solely used ground-based methods. In the examples provided, cliffs and rugged terrain were either overcome by abseiling or hand broadcasting in ground-based operations. Lowering down bait stations on fixed cables would be more feasible rather than hand broadcast if the aim is to target specific narrow ledges in an otherwise entirely ground-based approach.

The DIISE database records only four islands larger than Sušac in the Mediterranean region on which black rat eradication has been attempted (DIISE 2018), three of which are known to have been successful. Of these, aerial drops were used on Tavolara and Montecristo (Table 4), methods are not specified for Gran Cabrera, Spain and bait stations were used on Linosa, a project for which the outcome is still to be confirmed. In addition to the islands in DIISE database, eradication using bait stations was attempted in 2017 on 1026ha Pianosa, Italy, where the outcome is still to be determined. This island, however, is relatively flat with a maximum altitude of 30masl (Sposimo et al. 2019).

Additional trials and data gathering requirements

Rat control was carried out specifically around the shearwater colonies on Sušac from February to June 2020 using the anticoagulant rodenticide 'Brodilon parafinski blok', containing 0.005% bromadiolone, which demonstrated a high bait palatability with complete consumption in all cases. However, the seasonal overlap with a potential eradication project was limited and it is not known how this bait block formulation will perform in different weather conditions. Moreover, it is unlikely that this bait block formulation has been previously used successfully in large scale eradication projects, and it is unknown whether the manufacturing company would be able to produce the amounts required.

Trials with wax block formulations previously deployed successfully in large scale projects, have as yet not been carried out on Sušac. The Shiants and Scilly Isles eradication projects used cereal-based wax blocks 'Contrac All-weather Blox' (Main et al. 2019, Bell et al. 2019b), while various eradications on Italian islands used 'Notrac All-Weather Blox' (Capizzi et al. 2019), both products manufactured by Bell Laboratories and containing 0.005% of the anticoagulant bromadiolone.

3.1.1 Choice of method

Table 6 presents the various alternatives in reducing the impacts of black rats from not taking any action to a one-time eradication of all the rodents, while Table 7 presents the various methods available to manage the rodent population. Tables 6 to 8 are adapted from previous work by Elizabeth Bell of New Zealand-based company WMIL, which has carried out most of the rat eradication projects on UK islands in recent years.

Table 6: *Alternative options for reducing the impacts of black rats on the ecosystem of Sušac*

OPTION	OUTCOME FOR SUŠAC	DECISION
Do nothing	The natural ecosystem of Sušac will continue to degrade, especially the survival of	UNACCEPTABLE

	breeding seabirds on the islands. This would also contravene both national and international obligations.	
Undertake long-term rodent control	This would ensure the persistence of seabirds on Sušac by controlling the rat populations through lethal or non-lethal means. However, targeted rat control measures would have to take place prior to and throughout the seabird breeding season (or year-round) in perpetuity. • This would incur an ongoing welfare cost. The cumulative effect could be greater than a one-off eradication operation in the long-term. • This would incur an ongoing financial cost. Implementing a regular rat control programme would require personnel and equipment to be present for at least six months on the islands. • There would be an ecological and environmental cost, with the risk of resistance and persistence of toxin being greatly increased.	IMPRACTICAL (AND POTENTIALLY UNACCEPTABLE)
Relocate the entire rodent population	The safety of breeding seabirds and the island's ecosystem would be protected while trying to ensure the highest standards of rodent welfare. However, every rat would have to be captured and relocated (if any rats remain, the population would quickly increase, rendering any biodiversity gains only temporary). Eradication via trapping alone is not a viable technique for rodent eradication on islands of this size. In addition, it would be difficult to find an appropriate island or obtain permission to relocate the rats that would satisfy community, conservation, disease and welfare concerns.	NOT FEASIBLE

Eradicate the entire rodent population	This involves lethal eradication of all rats on the islands included in this proposal. Although the one-off welfare cost of this option would be high, it offers a sustainable and financially cost-effective solution with possibly fewer welfare costs to rats and non-target species in the long-term than ongoing control. Table 7 considers the different eradication methods available	PRACTICAL (RECOMMENDED)

Table 7: *Options considered for black rat management on Sušac*

OPTION	ADVANTAGES	DISADVANTAGES	OUTCOME FOR SUŠAC
Prevention (i.e. rat-proofing around areas of conservation value)	• Non-lethal • Environmentally clean • Proofing areas prevents damage and effects of rats • Useful for buildings and small areas only	• Does not deal with rats already present (which can still cause damage or have impacts) • Rat-proof fencing expensive • Non-lethal; can move problem to another location • Usually combined with other methods • Best suited for small areas, very difficult to achieve around areas used by cliff-nesting birds • Little value alone	INEFFECTIVE
Rodent dogs	• Targeted control with trained dogs • Environmentally clean • Can also use for detection of surviving rats	• Labour intensive • Expensive • No known appropriately-trained dogs in Croatia • Untested for island-wide eradication projects	NOT POSSIBLE (Indicator dogs may have role in detecting surviving/ newly arriving rats)
Repellents	• No welfare impacts • Sound or chemical options • Non-lethal • Targeted control	• Little to no success (Mason & Littin 2003) • Rats habituate to repellent • Non-lethal • Can move problem to another area • Little to no use on an island-wide situation	INEFFECTIVE
Aluminium phosphide (Fumigation)	• Targeted control (burrows only) • Lethal method	• Needs knowledge of habitat and location of rat burrows • Risks to general public • Risks to non-target species, particularly burrow-nesting seabirds • Currently unauthorised in Croatia • Outdoor use only • Untested for island-wide eradication projects	INEFFECTIVE
Immunocontraception	• Could be long-term solution • Humane	• At research stage only • Concerns regarding loss of control	IMPRACTICAL

	• Environmentally clean	• Non-target species concerns • Irreversible • Public concern	(EXPERIMENTAL ONLY)
Biological control	• Long-term solution	• Involves releasing another possible problem animal • Non-target impact concern • Ethical concerns • Legal issues • Requires years of study to find effective, target-specific agent	IMPRACTICAL
Kill traps (i.e. snap, spring or break-back traps)	• Lethal (rapid death) • Humane • Targeted control • Environmentally clean • Can be used by general public • Range of traps commercially available	• Labour-intensive • Expensive • Welfare issues and ethical concerns • Should be checked twice daily (set in the evening, disarmed in the morning) to minimise risks to diurnal non-target species • Only legally-approved traps can be used • Experienced trappers required for large-scale operations • Requires good accessibility – will be a big challenge in Sušac's steep terrain • Non-target issues • Untested for island-wide eradication projects • Risk to non-target species (particularly lizards)	IMPRACTICAL (LEGALITY ISSUES & UNTESTED)
Live trapping	• Humane • Environmentally clean • Non-target species can be released unharmed • Targeted control • Range of traps commercially available • Can be used by the general public • Rats can be released to an alternative location	• Labour-intensive • Expensive • Need experienced trappers for large-scale operations • Requires good accessibility – a problem on Sušac • Welfare issues (i.e. while animal in trap and kill method)	IMPRACTICAL (LEGALITY ISSUES & UNTESTED)

		• Need to be checked twice daily (set in the evening, disarmed in the morning) to minimise risks to diurnal non-target species • Only legally-approved traps can be used • Rats should be humanely killed (if not released elsewhere) • Untested for island-wide eradication projects • Release of rats may have impacts at release site or welfare issues for animals • Ethical concerns	
Glue boards	• Targeted control • Environmentally clean • Non-toxic	• Labour-intensive • Welfare issues and ethical concerns • Need to be checked twice daily (set in the evening, disarmed in the morning) to minimise risks to diurnal non-target species • Animals must be killed humanely • High risks to non-target species • Untested for island-wide eradication projects • May be removed from international markets shortly as perceived to be inhumane	ILLEGAL & UNTESTED
Alphachloralose	• Humane	• Use of toxin • Non-target impacts • Ethical concerns • Untested for island-wide eradication projects	UNTESTED
Shooting	• Targeted control • Non-toxic • Humane (if skilled marksmen are used) • Environmentally clean (providing appropriate pellets are used)	• Potential risks of gunshot injury to non-target species and people • Risks to marksmen of shooting at night in difficult terrain • Will not target entire population	IMPRACTICAL & INEFFECTIVE AGAINST ENTIRE POPULATIONS
Cellulose pellets	• Humane • Unlikely to cause secondary poisoning • No toxin	• Untested for island-wide eradication projects • Ethical concerns • No detailed clinical data on efficacy, humaneness, welfare or other effects	IMPRACTICAL (UNTESTED)

Anticoagulant rodenticides	• Efficient • Large areas covered quickly • Most widely used approach to control rats • Most cost-effective method of controlling substantial infestations • Tested and successful method for one-off island-wide eradication projects • Range of application methods • Can be used in bait stations to reduce risk to non-target species • Antidote available • Range of rodenticides available (e.g. first generation or second generation) • Range of formulation available (e.g. grain, wax block, pellets etc.)	• Use of toxin • Persistence in environment (toxin dependent) • Non-target impacts • Ethical concerns • Resistance issues with prolonged use • Legal requirements for certain rodenticide use (i.e. certain rodenticides are restricted to indoor use only, bait station use required for some rodenticides, etc.) • Implies coverage of whole area • Requires use of adequate baits and bait stations • Disposal requirements • Health and Safety concerns	RECOMMENDED (TESTED AND EFFECTIVE)

The methods assessment in Table 7 shows that anticoagulant rodenticide is the only feasible primary method to eradicate black rats on the scale of Sušac island. If a few rats avoid rodenticide, then traps might be used to target these specifically (Thomas et al. 2017). Table 8 presents the different rodenticides that could potentially be used although some might be illegal for use outdoors in open areas in Croatia. Rodenticide with bromadiolone as the active ingredient is currently being used by LIFE Artina in control efforts, and has been used successfully in a number of eradications around the world. A second formulation of rodenticide wax block should also be available for the eradication, usually one with a different active ingredient but not necessarily so, as a backup in case any rats are found not to consume the main one deployed (Thomas et al. 2017).

Table 8: *Different rodenticides considered for the black rat eradication on Sušac*

Refer to ECHA database: https://echa.europa.eu/hr/home

TOXIN	ADVANTAGES	DISADVANTAGES	OUTCOME FOR SUŠAC
FIRST GENERATION			
Warfarin	• Low potency (lower risk to non-target species) • Delayed onset of symptoms (i.e. prevents neophobia and bait shyness) • Less persistent than second generation anticoagulants • Reduced risk of non-target poisoning • Reduced secondary poisoning risk • Very low risk to raptors • Cheaper than second generation anticoagulants • Antidote available • Insoluble in water	• Low potency • Multiple feed • Large quantity required • Repeated applications required • Longer access to bait required • Non-target species have longer to access bait (i.e. competition with rats) • Low persistence (metabolised quickly) • Resistance issues • No appropriate formulations registered for use in Croatia	NOT RECOMMENDED (UNLIKELY TO BE SUFFICIENTLY EFFECTIVE)
Pindone	• Low potency (lower risk to non-target species) • Delayed onset of symptoms • Less persistent than second generation anticoagulants • Reduced secondary poisoning risk • Reduced risk of non-target poisoning	• Unregistered in Croatia • Low potency • Moderate risk to birds • Multiple feed • Large quantity required • Repeated applications required	UNREGISTERED

	• Cheaper than second generation anticoagulants • Antidote available • Low solubility in water • Binds strongly to soil and breaks down slowly	• Non-target species have longer to access bait (i.e. competition with rats) • Low persistence (metabolised quickly) • Untested for island-wide rat eradications	
Diphacinone	• Low potency (lower risk to non-target species) • Delayed onset of symptoms • Less persistent than second generation anticoagulants • Reduced secondary poisoning risk • Reduced risk of non-target poisoning • Low toxicity to raptors (and mice) • Used successfully on island eradications in UK and elsewhere • Cheaper than second generation anticoagulant • Antidote available	• Unregistered in Croatia • Low potency • Repeated applications required • Longer access to bait required • Less persistent (metabolised quickly) • Non-target species have longer to access bait (i.e. competition with rats)	UNREGISTERED
Coumatetralyl	• Low potency (though higher than warfarin and pindone) • Delayed onset of symptoms • Less persistent than second generation anticoagulants • Reduced secondary poisoning risk • Reduced risk of non-target poisoning • Cheaper than second generation anticoagulants • Antidote available • Binds to soil and breaks down slowly	• Low potency • Multiple feed • Repeated applications required • Longer access to bait required • Less persistent (metabolised quickly) • Non-target species have longer to access bait (i.e. competition with rats) • Few successful island-wide eradications	NOT RECOMMENDED AS ONLY TOXIN (could be used with backup second generation agent)
SECOND GENERATION			
Bromadiolone	• Moderately potent • Single feed • Delayed onset of symptoms • Effective on rats (*Rattus norvegicus* in particular)	• Previously successfully used in rat eradications • Persistence issues (> 9 months in some species) • High secondary poisoning risks	RECOMMENDED

	• Antidote available • Not readily soluble in water • Binds strongly to soil and breaks down slowly • Registered for use outdoors in open areas in Croatia by professionals	• Slightly less potent than brodifacoum and flocoumafen • Some resistance issues suspected • Limited data on non-target impacts	
Difencaoum	• Moderately potent • Single feed • Delayed onset of symptoms • Effective on rats • Antidote available (but long-term treatment required) • Insoluble in water • Binds strongly to soil and breaks down slowly	• Previously successfully used in rat eradications • Persistence issues (> 9 months in some species) • High secondary poisoning risks • Limited data on non-target impacts • Slightly less potent than bromadiolone • Less potent than brodifacoum and flocoumafen	UNREGISTERED
Flocoumafen	• Very potent • Single feed • Delayed onset of symptoms • Effective on rodents • Good availability • Antidote available (but long-term treatment required) • Not readily soluble in water • Binds strongly to soil and breaks down slowly	• Not widely used in eradications • Persistence issues (> 9 months in some species, and can be longer than with brodifacoum) • High secondary poisoning risks • Limited data on non-target impacts • Expensive	NO ADVANTAGES OVER BRODIFACOUM
Brodifacoum	• Very potent • Single feed • Delayed onset of symptoms (i.e. prevents neophobia and bait shyness) • Very effective on rodents • Insoluble in water • Binds to soil (slowly degraded) • Widely used in eradications	• Persistence issues (> 9 months) • High secondary poisoning risks • Non-target impacts recorded • Expensive	ALTERNATIVE TO BROMADIOLONE

	• Successfully used in island eradications worldwide • Efficacy data widely available • Non-target impact data widely available • Widely available • Range of bait formulations available • Registered for aerial applications • Antidote available (long-term treatment required)		

3.1.2 Logistics

Vertical cliff access assessment

A large proportion of the coastline of Sušac is dominated by cliffs, and the vegetated ledges on these cliffs would require baiting. In some cases, it might be possible to lower bait stations on a thin rope, but if not, rope access by fieldworkers would be required. In 2020 all of the Sušac coast with cliffs was photo-mapped and sections with vegetation or caves needing baiting were marked. This would potentially require 22 to 30 abseil routes, as identified through photos (Appendix 1, Figure 1). All of the potential routes would need evaluating by expert rope access personnel in the field. Some locations are likely not to have natural (rock) anchors and would need pitons or bolts fixed by certified personnel. Estimation of the time required per route would also best be done on site. Very approximately one can estimate an hour each, excluding time needed to reach the anchor point which is often over rugged terrain.

Furthermore, there are nine caves that might require abseiling to, or access from the sea. If these are large enough and found to hold rats through monitoring using flavoured non-toxic wax blocks, they would also require regular baiting during an eradication project and therefore additional abseils.

All the above are thought to be direct (one pitch) routes without significant obstacles. However, one location (Appendix 1, Figure 2) with inland cliffs on the north slope of Sušac appears to be much harder to access. Trees grow on some of the ledges which would potentially mean entanglement of ropes during abseiling. This can probably be solved by installing a via ferrata system, with rungs and cable secured to the rock ensuring that fieldworkers are always attached while moving around on narrow ledges and steep scrambles.

Finally, another twelve locations are thought to require scrambling without need of abseiling, but on inspection on site it might turn out that rope access would increase safety.

Habitat mapping and trail cutting

The vegetation on Sušac is, for the most part, very dense Mediterranean garrigue and maquis. In order for field operators to easily deploy and regularly check bait stations in the case of a ground-based eradication attempt, vegetation would need to be cut to form trails. In order to estimate the number of hours required for trail cutting we adapted the habitat categories identified in Varnham & Austad (2019):

1) Sparse, low vegetation (0,3-1,0 m) with *Juniperus ssp*. and some *Pistacia lentiscus* (Appendix 2, Figure 1)
2) Low – medium vegetation (0,5-1,5 m) with *Juniperus ssp*., *Pistacia lentiscus* and *Rosmarinus officinalis* (Appendix 2, Figure 1)
3) Medium - high vegetation (1,0-3,0 m) with *Rosmarinus officinalis, Pistacia lentiscus*, *Quercus ilex, Olea europaea* and some *Juniperus ssp* (Appendix 2, Figure 2)
4) High vegetation (<3m) mostly with *Quercus ilex and Olea europaea,* but also *Euphorbia dendroides* (Appendix 2, Figure 3)

The extent of each habitat category was mapped using satellite imagery and GIS software (Figure 5 and verified on the ground at 12 points as well as expert knowledge of the island from BIOM). Verification showed that the habitat mapping was reliable to deduce vegetation density. Categories 2 and 3 were grouped together, requiring a high amount of trail cutting effort due to being the densest.

Category 1 requires some trail cutting, while Category 4 requires little to no trail cutting. Using the time taken to cut trails with a pair of long-handled garden loppers (Appendix 2, Figure 4) during the eradication on Petrovac it was estimated that trail cutting proceeds at:

120 metres per hour in categories 1 & 4

80 metres per hour in categories 2 & 3

In all category types two people are required to work simultaneously on a trail, one cutting the vegetation and the other person removing the cut brush from the trail and making sure that cutting is following the marked trail on a GPS device.

Complete workings and example images of typical vegetation on Sušac are presented in Appendix 2, but the complete number of hours estimated for trail cutting by a team of two persons in a completely ground based project based on a 40 by 50m grid are:

- Approximate total time cutting trails for all bait stations in habitat category 1 & 4: 245 hours (61 team-days, assuming four hours* cutting per team of two persons per day)
- Approximate total time cutting trails for all bait stations in habitat category 2 & 3: 561 hours (140 team-days, assuming four hours* cutting per team of two persons per day)

*These four hours do not include updating maps on GPS, cleaning equipment, and reaching the trail.

The process might be made faster by using motorised tools such as petrol-powered brush cutters, but then the disturbance created is higher. Use of motorised tools requires certification in Croatia. Even so, we recommend carrying out a trial with such tools and if found to be more efficient, to re-estimate the total time needed for trail cutting on Sušac. It is likely that a combination of tools will be useful.

However, one point to strongly consider is the amount of dry vegetation that will be generated from such a trail cutting exercise, which might lead to an increased fire risk hazard. Solutions to this might include collecting the brush and burning or decomposing it in controlled conditions, although this could have other environmental concerns. It could be transported off the island and passed through a wood chipper but this would add to the costs of the project.

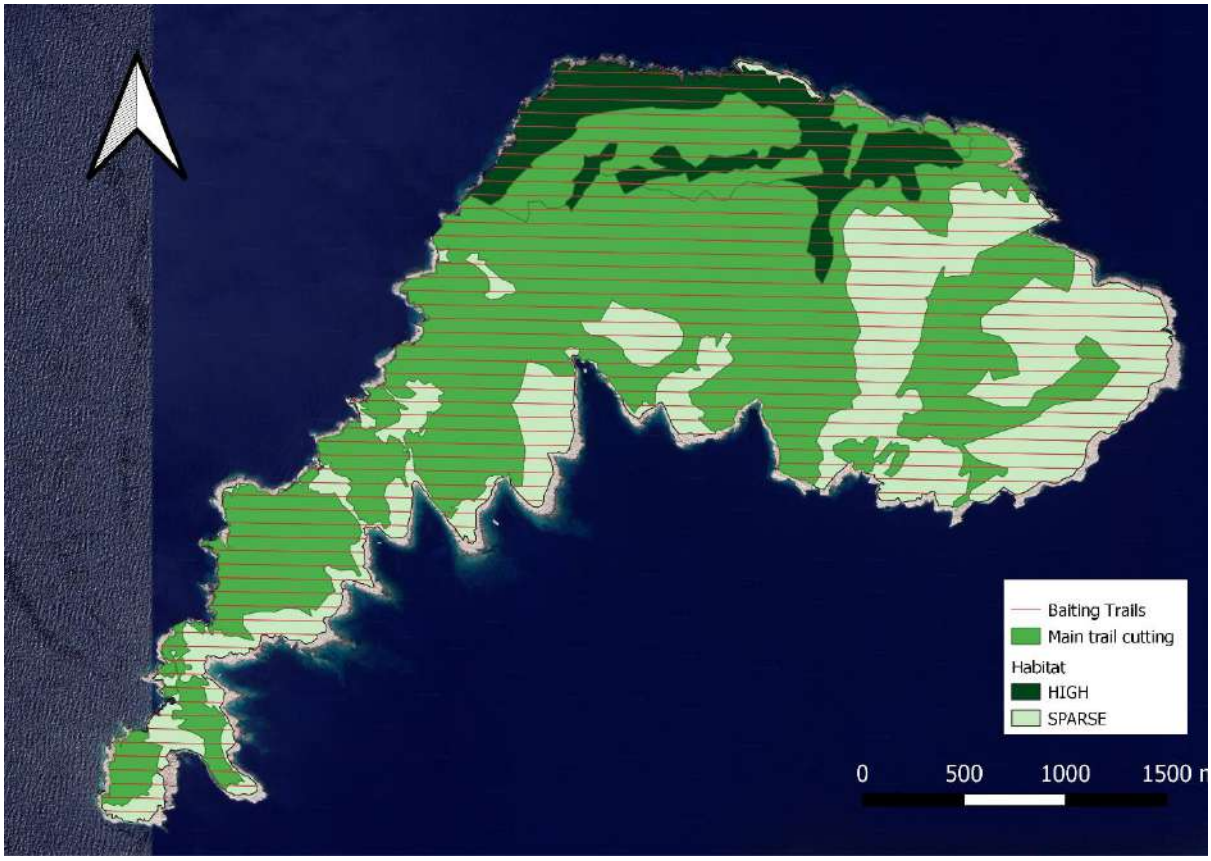

Figure 5: *Habitat categories based on vegetation density as deduced from satellite imagery, with category 2 and 3 grouped together into the main trail cutting category. Horizontal lines are the trails needed in a ground-based eradication setup with bait stations deployed across a 40 by 50m grid (i.e trails 50m apart, along which bait stations will be placed every 40m).*

Transport and Accessibility

Any field crew stationed on Sušac would need to be equipped with food and freshwater storage for at least three weeks due to the risk of inclement weather not allowing boats to reach the island from Lastovo. An eradication project, especially if completely ground-based, should include a seaworthy vessel, and an accompanying hired skipper, to make the trip in most conditions and large enough to carry staff and equipment. This vessel could then be used for routine biosecurity after the eradication is complete (note that the budget given here only includes ongoing biosecurity for two years after the end of the operational phase. Alternatively, the main transportation of supplies and personnel could be carried out in agreement/partnership with the lighthouse company Plovput. While this is probably handy for more bulky supplies, the project should have a vessel and skipper at hand at all times.

Timing

It is very likely that any scenario would overlap with the windiest conditions of the year, with eradication efforts most likely starting in September/October or in December/January. Eradications in the Mediterranean have followed both these timings successfully (Sposimo et al. 2019; Evangelidis et al. 2012). Most eradication efforts on Italian islands have started in December/January (D. Capizzi, pers. comm. 21st November 2020), due to rat densities generally being at their lowest then (Capizzi et al. 2016). However, exceptions exist and depend on the climate of the island. Winter index trapping of rats is recommended for Sušac, to estimate density and breeding activity in this period. The stomach content of any rats trapped should be analysed for an indication of diet and available food sources.

In addition, it would also be beneficial to survey the island with a botanical expert to determine the period of the year when the least amount of seeds and vegetation is available to rats to feed on. The reduced amount of natural food for rats will increase bait uptake and chances of eradication success. The extensive population of olive trees on the island might have an especially large effect on timing, since rats feed on the olive pits and these remain available for a large part of the year. Potentially, eradication could start just before the fruiting peak when the amount of olive pits available should be at the lowest, unless fruiting is very asynchronous between trees and years.

While summer has also generally lower rat densities (Capizzi et al. 2016), it is the hottest period of the year potentially affecting health and safety of fieldworkers and it is also the season when most tourists visit the island increasing the risk of interaction between visitors and their pets with anticoagulant bait.

Yellow-legged gulls are one of the species known to be affected by poisoning during aerial broadcast eradication projects (Sposimo et al. 2019). To avoid this one should plan any aerial drop of rodenticide for the period, if any, when gulls are not present in breeding colonies which would have to be determined specifically for Sušac. In any case impacts on gulls can largely be avoided by wiring bait blocks into biodegradable containers, even during aerial broadcast since the main impact seems to be with loose blocks (Sposimo et al. 2019).

A proposed timetable of eradication phase activities is given in Table 9 below, assuming an over-winter poisoning phase

Table 9: *Proposed timeline of the eradication operation*

Activity	**Prior to Sept**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Pre-eradication phase: Minimise harbourage and alternative food sources	●	●	●					
Establish base for fieldworkers, including accommodation, storage and workshop space	●	●						
Establish climbing routes, fix anchor bolts and via ferrata	●	●						

Mark out grid of bait stations, trail cutting and put stations in position		●	●					
Intensive poisoning phase				●	●	●		
Intensive monitoring phase					●	●	●	●

Communication

At time of writing this report, the mobile phone signal on Sušac is very poor and the project could not rely on this communication method during the eradication phase, both within the fieldwork team on the island and with the mainland. It is beyond the scope of this report to find the best solution for this but installing a mobile phone signal mast or investing in a satellite phone are two options. Regardless, strong hand held radios (walkie talkies) should be used between crew on the island, with at least one unit per team. The advantage of these are as a back up to any phone service, and one can communicate between all teams set on the same channel simultaneously if necessary.

3.1.3 Non-target species including non-native species

The origins of wood mice on Adriatic islands is unclear, but fossil evidence on western Mediterranean islands indicate introduction by humans in prehistoric times (Traveset et al. 2009). Moreover, there is currently no documented negative impact by this species on shearwaters, Eleonora's falcon and lizards on Sušac or elsewhere. Interactions with native flora is likely (Traveset et al. 2009) but poorly documented. The eradication of wood mice therefore is not under consideration.

There are currently no records of house mice *Mus musculus* on Sušac. Predicting trophic changes as a result of eradications is complicated, but there is evidence that mice and rats have somewhat overlapping diets and that mice can increase substantially after removal of rats as a cause of competitive release (Ruscoe et al. 2011). Although the impacts of house mice on Mediterranean islands is poorly documented and there is some evidence that they can prey on small bird eggs (Traveset et al. 2009), they are not known to cause population level impacts in the Mediterranean region on the species of conservation concern considered in this report.

The relocation or eradication of rabbits which are of feral origin and cats should be strongly considered. Rabbits and livestock damage vegetation and might increase after rat eradication (Thomas et al. 2017). Cats can even predate on adult shearwaters (Oppel et al. 2011). Population density or numbers present are not currently known and feasibility would need to be assessed separately. The presence of livestock may be causing soil erosion and preventing vegetational succession, but these impacts can be reduced by, for example, fencing in animals to reduce their footprint. Local expertise

in botany and island ecosystems would be required to define the best management practice, or indeed find that freely roaming livestock are not causing damage on the island.

The use of anticoagulant rodenticides, especially the more potent second generation products, poses a risk of potential impacts on non-target species present on Sušac. There are two ways by which non-target species could be affected by rodenticide – 'primary' poisoning, where the animals eat the bait directly, and 'secondary' poisoning, where they eat animals which have themselves eaten the bait. There is also the potential for unintended ecological consequences of rat removal, as their removal will affect species which predate upon them, species which are predated upon by them, and species which compete with them for resources. At first consideration, there are no species on the island which would be negatively impacted by the loss of invasive rats. The risks to non-target species will need to be assessed continuously but it appears that the main risks are likely to be to birds of prey and corvids, particularly crows and ravens. A risk assessment and mitigation measures are presented in Table 10.

Lizards can enter bait stations, potentially consume small amounts of bait and also feed on invertebrates that have themselves consumed bait. However, several case studies exist showing that reptiles are not affected negatively at a population level by eradications applying rodenticides, on the contrary, there is evidence for increase post-rat eradication (Capizzi et al. 2016; Jones et al. 2016). On Desecheo Island, Puerto Rico, a capture-mark-recapture study carried prior to, during and after aerial application of brodifacoum did not find an impact on survival within study timeframes (Herrera-Giraldo et al. 2019). In another aerial application of brodifacoum, this time on Pinzon, Galápagos, rodenticide residues remained in lizards for several hundred days but no mortality was observed in this closely studied population (Rueda et al. 2016). The risk of non-target poisoning might have been higher in these examples due to bait being administered outside bait stations. Bromadiolone is known to be less toxic to invertebrates and reptiles than to mammals and birds, and on Surprise Island, New Caledonia, no lizards were observed to feed on the bait blocks deployed during eradication and no lethal effects were observed in the short or long term (Caut et al. 2008). Sub-lethal effects are less well known and close monitoring should be carried out during any eventual eradication attempt.

Table 10: *Potential risks to non-target species of rodenticide use on Sušac (taken from Varnham & Austad 2019)*

Species	**Impact risk (Primary or Secondary poisoning)**	**Description of impacts and possible mitigation measures**
Mammals		
Wood mice	1°: High 2°: Low	Cannot be excluded from bait stations. Likely to take the bait and be killed by it. However, bait station grid size targeting *Rattus rattus* means that many individuals will not encounter bait stations and will survive. Numbers likely to increase, possibly sharply, following rat eradication due to an end to predation and competition. Any dead animals found will be collected and safely disposed of to minimise risks of secondary poisoning of carnivorous or scavenging species.
Dogs and cats, either resident on the island or	1°: Low 2°: Low	Too big to enter bait stations, though may eat wax block bait if they encountered it. May take bait crumbs dropped by operators or dislodged by rats. This can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found

brought by visitors		outside of bait stations. May consume poisoned rodents and thus be at risk of secondary poisoning. This risk can be reduced by diligently collecting and disposing of dead and dying rodents. Antidote (Vitamin K1 injection) can be offered to any individuals known or suspected to have eaten bait. Visitors should also be encouraged to keep dogs on leads.
Sheep/ goats	1°: Low 2°: Low	May kick over any bait stations and eat bait but can be penned away from areas with bait stations. Antidote (Vitamin K1 injection) can be offered to any individuals known or suspected to have eaten bait.
Rabbits	1°: Low 2°: Low	Use of wires to reduce size of entrance holes in bait stations. Only young animals will then be able to enter bait stations and, as herbivores, they are unlikely to consume bait in harmful quantities. If rabbits are free-ranging then their numbers are likely to increase following rat eradication as predation decreases and they may become more widespread.
Birds		
Birds of prey* (Eleonora's falcon, Peregrine, Common kestrel, Common buzzard)	1°: Low 2°: Medium	Birds of prey may take poisoned rats and mice. This can be mitigated by carefully searching for and disposing of dead and dying rodents. Diversionary feeding could be considered as a way of providing an alternative food source (e.g. setting out fresh rabbit carcasses on 'bird tables') but this has not been particularly effective when tried elsewhere.
Game birds: (e.g. Woodpigeon)	1°: Low 2°: Low	Too big to enter bait stations. Granivorous species may take bait crumbs dropped by operators or dislodged by rats. This can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found outside of bait stations.
Domestic chickens	1°: Low 2°: Low	Too big to enter bait stations and in any case should be kept in areas with no bait stations. Granivorous species may take bait crumbs dropped by operators or dislodged by rats. This can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found outside of bait stations. Antidote (Vitamin K1 injection) can be offered to any individuals known or suspected to have eaten bait.
Corvids (Hooded crow and Raven)	1°: Low 2°: Medium	Corvids may try to open bait stations by sliding the doors out of position but can be deterred through the use of 'crow clips' to prevent the doors being moved in this way. They will also eat bait fragments if found outside bait stations. This risk can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found outside of bait stations. They may also eat poisoned rats, mice, other small animals or invertebrates. Collecting and disposing of dead or dying rodents will reduce this risk.
Yellow-legged gull	1°: Low 2°: Medium	Unable to enter bait stations but likely to eat bait fragments if found outside bait stations. This risk can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found outside of bait stations. They may also eat poisoned rats, mice, other small animals or invertebrates. Collecting and disposing of dead or dying rodents will reduce this risk.

Seabirds (e.g. Yelkouan and Scopoli's shearwaters)	1°: Low 2°: Low	Very unlikely to be able to enter bait stations, or to eat wax block bait.
Land birds (passerines, e.g. Chaffinch, Linnet, Greenfinch, Skylark and Woodlark)	1°: Low 2°: Low	Small birds cannot be excluded from bait stations but unlikely to enter. Granivorous species may take bait crumbs dropped by operators or dislodged by rats. This can be mitigated by taking great care not to drop crumbs and to pick up any bait fragments found outside of bait stations. Insectivorous species may be at risk of secondary poisoning by eating invertebrates which have themselves eaten the bait.
Reptiles		
Lizards (Italian wall & Sharp-headed) and Turkish gecko	1°: Low 2°: Low	Cannot be excluded from bait stations. May take bait in very small quantities but unlikely to be harmed by it.
Invertebrates		
Various species, primarily ants, beetles, slugs and snails	1°: Low 2°: Low	Cannot be excluded from bait stations, may take bait in small quantities but will not be harmed by it. Theoretical risk that animals eating these invertebrates may be poisoned, but this is not known to have occurred on any previous eradication project. Slugs and snails found in stations should be removed and safely disposed of. Stations prone to repeated interference from invertebrates should be moved by a few metres.

***** Peregrine falcons may also occasionally take mice and small rats, and Common kestrel and Common buzzard are more likely to do so, meaning there may be a small risk of secondary poisoning there. However, no birds of prey are known to have been killed in any UK rat eradication project in which RSPB has been involved to date (all projects make considerable efforts to find any animals which may have been killed by poisoning, both rats and potential non-target species).

3.1.4 Key issues to resolve before operation proceeds

All the issues required to address the logistical, non-target and other challenges prior to the operational phase are listed here, but the first three are currently the most important factors.

- **Survey the island with a rat eradication expert experienced in aerial baiting, to advise on feasibility of a hybrid project and review relevant legislation**
- **Surveying cliff areas with professional climber/rope access, specialist certified to install anchors and via ferrata**
- **The two crucial points above will lead to addressing the main issue of choice of bait deployment method, whether fully ground-based or a hybrid project including aerial broadcast**

- Repeat trail cutting exercise with power tools and re-estimate total time required to open baiting grids
- Survey the island with a botanical team/expert to identify:

    - the period of the year when natural food (seeds, shoots bulbs etc.) to rats is lowest
    - any rare shrubs that should be avoided during trail cutting of a baiting grid
    - any species that are expected to increase after eradication (or indeed any that may be negatively impacted) and be set as indicators for monitoring successful restoration
- Further sampling of *Rattus rattus* and *Apodemus sylvaticus* for DNA reference & possible resistance to anticoagulant
- Further year-round index trapping of rats for better knowledge of seasonal densities, proportions of juveniles and stomach contents, ultimately informing eradication timing
- Establish density/numbers of freely roaming rabbits, cats, goats and sheep, making decisions on management of these populations. In a ground-based approach measures can be taken to ensure that they are not impacted negatively at population level
- Establish a monitoring baseline of ecological indicators, including but not limited to shearwaters, Eleonara's falcon and lizards
- Choice of timing for eradication start
- Acquisition of vessel
- Identify best solutions for upgrade or building of temporary dwellings on Sušac for ground-based team, including food, water and waste storage
- Drinking water desalination system
- Establish location of a rapid incursion response hub on Lastovo mainland, ideally close to Pasadur harbour

3.2 Sustainability

An assessment must be made as to whether the benefits of the eradication operation can be maintained afterwards and the required biosecurity measures to be maintained in perpetuity.

Sušac is well beyond the maximum known swimming distance of *Rattus spp.* which is currently believed to be around two kilometres for *R. norvegicus*. Therefore, the main risks of incursion are posed by any vessels visiting or sailing close to the island. An assessment of these risks and proposed prevention strategies are presented in Table 11.

In addition to two years of post-eradication monitoring to establish whether the project was successful, routine biosecurity surveillance measures should continue in perpetuity. Firstly, strict quarantine and prevention measures should be in place to reduce as much as possible the chances of new introductions occurring on the islands. The purpose of routine surveillance is to detect any newly arriving rats as soon as possible, in order to launch a rapid and properly resourced incursion response and prevent a new population becoming established. Monitoring stations should be present at the most likely incursion points such as the jetties as well as around the present dwellings and lighthouse. Additionally, monitoring stations can be present at the shearwater colonies which are visited regularly by researchers. Non-toxic flavoured wax blocks, rodent motels, tracking tunnels and trail cameras can all be part of the biosecurity monitoring toolkit. Surveillance visits should be conducted **every four to eight weeks** with some flexibility according to the main incursion pathways identified (Bell & Daltry 2012), also ensuring maintenance and attractiveness of lures to rats. GoodNature Self-resetting traps can also be part of the biosecurity tool assemblage, if they can be set in closed containers to ensure that non-target species such as lizards do not enter.

An eradication project should ensure that expertise is maintained within the organisations involved, so that if an incursion response has to be carried out the necessary trained and motivated personnel are available. This might include climbers and/or rope access certified personnel. Current best practice in responding to probable or definite rat sign is to set out a 50m grid of stations for 500m in all directions from the rat sighting or sign. This means that if the rat is seen in the middle of the island this could be a grid covering 100ha (1000m X 1000m) and consisting of 424 (21 x 21) bait stations. However, in practice it is likely to be over a smaller area as sightings or signs tend to occur near the edges of islands. Nevertheless, an area of rapid incursion response may well involve trail cutting to reopen baiting trials as well as sections with cliffs requiring rope access.

Table 11: *Potential invasion pathways for black and brown rats to reach Sušac*

PATHWAY	RISK	PREVENTION STRATEGY
Boats from mainland/ Lastovo bringing high risk cargoes such as bulk food supplies, animal feed, building supplies or other bulky cargoes in which rats (and other small mammals) could stow away	High	• Careful checks of cargo before loading (visual inspection for rodent damage, entry/ exit holes). • If possible, check cargoes with rodent detection dog before loading • Rodenticide stations on boat • Boat captains know to return to port of origin if signs of rodents are found on board – do not proceed to Sušac, do not throw rodent overboard • Unload cargo straight into a rodent-proof room containing rodenticide stations and snap traps. Leave for at least 24 hrs • Routine surveillance on island should help detect any newly arriving rats
Private recreational boats	Medium	• Signs at ports of origin informing boat users of Sušac's rat-free status • Prevent boats from mooring up against island, particularly overnight • Do not permit boats to leave rubbish on the island • Increase monitoring by park management of private recreational boats anchoring around the island • Routine surveillance on island should help detect any newly arriving rats
Fishing boats	Medium	• Signs at ports of origin informing fishermen of Sušac's rat-free status • Direct outreach with local fishermen
Shipwrecks	Low	• Routine surveillance on island should help detect any newly arriving rats
Storm-enhanced dispersal (i.e. floating on debris)	Low	• Routine surveillance on island should help detect any newly arriving rats
Deliberate introduction	Low	• Routine surveillance on island should help detect any newly arriving rats

Building on the assessment above, a full biosecurity plan should be drawn up for the island to minimise the risks that other species are introduced to the island or moved from the island during all visits that are made.

3.3 Political & legal acceptability

The political and legal considerations that have to be taken into account to ensure the project is feasible are assessed.

Nature Protection Law prescribes management of national categories of protected areas and Natura 2000 sites. The Law prescribes that these areas are managed by the public institution, established by Croatian Government. Public institutions manage protected areas based on the management plan and annual plans. Nature Park Lastovo Islands was established in 2006.

Sušac is part of the Nature Park Lastovo Islands (Lastovsko otočje). Sušac is also part of the Natura 2000 network, designated as a Special Areas of Conservation (SAC) and Site of Community Importance (SCI) with site code HR5000038, and as a Special Protection Area (SPA) with site code HR1000038 and name Lastovsko otočje. The Croatian Government Ministry of Economy and Sustainable Development currently oversee biodiversity conservation.

LIFE Artina is currently carrying out conservation measures including predator management, including the use of rodenticides, on the Lastovo Archipelago and has obtained all the necessary permits from the relevant authorities. The scale of the proposed eradication project of Sušac is considerably larger but presumably is also likely to obtain the necessary permits.

Public institution Nature Park Lastovsko otočje oversees and regulates all activities within the park, including visits to Sušac. The institutions are partners and carry out LIFE Artina conservation actions. An eradication project on Sušac would not be possible without the full support and involvement of the park management.

The Park has a management plan which envisages conservation of seabirds through control/eradication of rats on colonies. In addition to the 10-year management plan, there are annual plans that are approved by the Ministry of Economy and Sustainable Development.

The following aspects of the project are identified as potentially requiring permits from relevant local authorities:

- aerial drop/hand broadcast regulations*
- rodenticide type for use in open areas in relation to local and EU Biocide Regulation 528/2012
- further trapping and sampling of target species and wood mice
- vegetation trail cutting
- working, temporary living and regularly visit on the island part of the N2K network
- erecting temporary dwellings
- installing via ferrata and abseiling anchor bolts
- setting up of signage educating on biosecurity measures
- disposal of used rodenticide

*In the EU, aerial baiting requires a derogation under Article 55 of the EU Biocide Regulation no. 528/2012 (Capizzi et al. 2020).

To the best of our knowledge there are no known archaeological sites on the island which would potentially mean additional permits to ensure no damage to the historical sites is made.

3.4 Social acceptability

The eradication project is assessed for its acceptability to all stakeholders and what support is given to the project by each group in anticipation of stakeholder consultation which needs to be undertaken.

Through LIFE Artina the first major predator management within the Lastovo Archipelago for conservation purposes is being carried out. The park authorities are partners in this project and therefore support these efforts fully. The park management are, and will continue to be, involved in all stages of the proposed Sušac rat eradication project, and are crucial for its execution. Apart from being the management authority of the site, the park personnel are mostly locals from Lastovo, and are an important link to liaise with the local community.

The community on Lastovo is made up of around 700 inhabitants. LIFE Artina is working closely with the community to raise awareness of the seabirds of the archipelago and the threats they face. The community potentially has a lot to gain from ecotourism and an increase in tourists attracted to the islands due to their improved nature protection. In 2020, the community of Zaklopatica village on Lastovo, had a negative reaction to an increased number of Yelkouan shearwaters grounded in the village following successful predator control on the islet of Zaklopatica. The community also claimed that the number of rats had increased in the village because of rat control on the islet, but it is highly unlikely that there is a connection between the two. Zaklopatica is a unique setting due to the proximity of a shearwater colony islet to an inhabited village and it is unlikely that rat control and/or eradication on Sušac would cause a similar reaction. Nevertheless, LIFE Artina is taking this opportunity to work more closely with the Lastovo inhabitants and it is thought that the negative reaction is temporary and caused by misunderstandings.

LIFE Artina staff interact with the inhabitants of Sušac during routine fieldwork. Both the lighthouse keepers and shepherds seem positive about the idea of a reduced or eradicated rat population, though a formal consultation has yet to be carried out. This should specifically include understanding opinions on the following:

- A full restoration of the Sušac ecosystem might want to include the removal of feral rabbits and cats as well as management of freely roaming livestock, how do island residents and stakeholders feel about this?
- The measures in place to manage risks to non-target species to an acceptably low level, especially if it is decided not to remove any domestic and feral animals.
- Inhabitants should be comfortable with fieldworkers living on the island for some time during the execution of the project (likely to be around seven months).

- Bait stations will need to be located inside all buildings. Are island residents happy for project staff to enter dwellings and the lighthouse regularly in order to bait and monitor for rat signs? If not, are they happy to be trained to do it themselves?
- Explanation of biosecurity checklist for each visit to the island and accordance with improved waste management procedures. Rat proof waste containers would be provided by the project.

Management by for example fencing of goats and sheep might cause some opposition from other shepherds from Lastovo due to the common practice to use islets in the archipelago for grazing of freely roaming livestock. Local expertise in botany and island ecosystems would be required to define the best management practice, or indeed find that freely roaming livestock are not causing damage on the island.

Plovput, the company managing the lighthouse, would be a strong partner in a potential eradication project, and could provide assistance in shipping supplies and personnel.

Other local stakeholders who should be consulted are the fishermen, diving centres and any frequent local tourists regularly visiting Sušac. A biosecurity checklist for each visit to the island and onboard measures to prevent stowaway rats should ideally be in place with all stakeholders prior to the proposed eradication project.

In addition to the park management, support from the Croatian government and environmental permitting departments are required for the smooth running of the project and possibly for co-financing.

During subsequent planning of this eradication project all the above identified stakeholders should be consulted, general support gauged and any doubts and issues solved and explained. Until support is ascertained, ideally through written consent, the feasibility of the eradication should be kept as conditional (Thomas et al. 2017). **The written consent, or partnership, of the park management (Public Institution Nature Park Lastovo Islands), Croatian government (as land owners), Plovput, shepherd(s) and Lastovo community represented by the Municipality of Lastovo should be obtained before funding applications.**

Apart from the above stakeholders, one should not neglect the opinion of the general population of Croatia, especially amongst animal welfare and rights groups. Understandable concerns for the target species and for non-target species perceived to be at risk should be addressed by the strong justification for the project and rationale behind the choice of eradication methods to decrease impacts while increasing the likelihood of success at the first and only attempt. Measures to mitigate risks to non-target species should also be clearly explained.

3.5 Environmental acceptability

The eradication project should not have a net negative effect on the island environment including non-target species and an assessment to ensure this is conducted, considering both the short-term and long-term impacts of the eradication.

The species of highest conservation value on Sušac, both shearwater species, the Eleonora's falcon, and the lizard species *Podarcis sicula* and *Dalmatolacerta oxycephala* are the most likely fauna species to benefit from eradication.

Table 10 in section 3.1.3 lists all potential non-target species, both native and non-native, that could be impacted by the use of rodenticide bait through primary or secondary poisoning. No species were identified to be likely to have permanent and population-wide negative repercussions from an eradication project. Therefore, it is likely that all but the black rat population will recover from any potential impacts.

The only species identified which might compete for bait with black rats are wood mice, but while they are expected to consume some bait their presence should not jeopardize the success of the rat eradication. Neither are they expected to be eradicated using the methods described in this study. Home ranges of mice are much smaller than the proposed grid size of 40m by 50m and a sufficient number will survive the eradication and allow the population to rebound or even increase (Thomas et al. 2017). Although there is some doubt whether wood mice are native to Sušac, an eradication attempt would require a grid size of 20m by 20m or smaller and even then, holds a high risk of failure. The fact that mice are present on the island does, however, pose a larger secondary poisoning threat to raptors such as Common kestrels, which, as observed on the Italian island of Pianosa, rarely prey on rats (Sposimo et al. 2019).

Previous rat eradication projects in the UK in which RSPB have been involved have been carried out without any known raptor deaths and, with care, this project can achieve the same outcome. The project team will diligently look for and dispose of any dead or dying rodents found, thus minimising the risks to predatory or scavenging birds. Crows and ravens will be deterred from accessing bait stations in a number of ways, including reducing the size of the entrance hole and using a 'crow clip' to prevent them opening the lids of bait stations. If some bait is dropped aerially or by hand onto ledges then this should also be secured inside biodegradable tubes to reduce risks to non-target species.

While beyond the scope of this feasibility study, other introduced species are also present on Sušac, namely goats, sheep, feral rabbits and cats. If the aim of a project is not only to alleviate predation pressure by rats, but to restore the complete ecosystem then serious consideration should be given to managing all non-native mammals, with the possible exception of wood mice for logistical reasons. Indeed, cats can have a hugely detrimental impact on shearwater colonies by predation of both adult and young birds (Oppel et al. 2011), however no such incidents have so far been documented on Sušac. Rabbits and livestock are likely to be damaging the vegetation and suppressing succession. The numbers of any of these species present on the island is not currently known, but would have to be quantified, and specific feasibility studies drawn up in case their removal is to be carried out. Proper fencing of livestock might be considered as a good management measure compatible with restoration of the island. In any case, if these species are not removed, there have been several successful rat eradications on islands where these species were present without their suffering any negative long-term impact at a population level (Sposimo et al. 2019, Capizzi et al. 2020). Rabbits tend to increase on islands after rat eradication, which could have adverse impacts on vegetation (Thomas et al. 2017).

Rodenticide residues in the soil is another environmental concern from such a project but would be limited by deploying bait inside containers, using bait blocks that can be wired for at least the majority

of the process and operators making sure to avoid spill of bait crumbs. This risk is also likely to be smaller with a one-off eradication campaign rather than multi-year applications of rodenticide in a control setup.

The trails that would be cut to allow for baiting across the islet are likely to regrow on the completion of the eradication project. However, botanical surveys with local expert advice should be carried out prior to trail cutting to make sure no rare or extremely slow growing species are damaged. Only some trails will need to be maintained in order to reach a set of representative monitoring stations across the island. These will be used both for determining the success of eradication two years after its completion and for permanent biosecurity surveillance. In cases where vegetation does not regenerate where trails were cut, or where former damage has been created by, for example, overgrazing, the project may decide to include an element of planting native flora which would require little to no irrigation.

An eradication project would see a larger than usual number of persons on Sušac, which might pose a threat of human disturbance to sensitive fauna such as breeding birds of prey. An eradication over the autumn and winter would overlap with breeding of Eleonora's falcon in the beginning and perhaps peregrine falcon at the end. Care would be taken to avoid nesting areas as much as possible to keep disturbance to a minimum. The installation of temporary accommodation would take place in already open locations with no or little vegetation close to one of the jetties.

3.6 Capacity

The potential project partners and entities to implement it have been identified, but the assessment made below is general to the skills and expertise required to undertake an eradication project on Sušac.

A large well-functioning team is required on the ground for the duration of the eradication project, made up of the personnel described in Table 12. 18-22 personnel will be needed for the duration of the eradication, which is likely to last around seven months. At any one time it is expected that there will be 14 to 18 personnel on the island. The larger total number of personnel is to allow for some rotation and opportunity to take time off the island. Some or all of the general field team members could be volunteers, it is unlikely to be a problem to recruit high-quality volunteers for this kind of work, but the team leaders, GIS technician and specialist climbing staff should be paid.

Four staff will also be needed to carry out the final check, which takes place two years after the rat eradication in order to make sure there are no rats remaining on the island, which will take 3-4 weeks. This would likely involve the operations manager, the GIS technician or one of the field team leaders, and at least two team members (these could possibly be volunteers).

***Table 12**: Key Skills needed to complete the project to eradicate black rats from Sušac*

ROLE (No. people in role)	RESPONSIBILITIES	KEY SKILLS AND EXPERIENCE

Operations Manager (1)	Leads operational phase of project. Day to day project management of poisoning and intensive monitoring phases. Co-ordination and leadership of other project staff. Liaising with other project partners and external organisations (e.g. equipment manufacturers, the media).	Extensive experience of managing complex ground-based rat eradication projects. Likely to be appointed from overseas.
Lead GIS Technician (1)	Leads on all GIS and mapping issues as well as database design and management.	Extensive experience of setting up and managing GIS databases. Experience on eradication projects very useful but not essential. Could be from Croatia or overseas.
Field Team Leaders (2)	These will lead the field teams on Sušac under the direction of the Operations Manager.	Experienced fieldworkers, used to living and working in challenging conditions. Experience on eradication projects very useful but not essential. Could be from Croatia or overseas.
Team Members (could include volunteers) (6-8 persons at any time	General field work duties – mainly checking bait stations and monitoring equipment. Ideally team members would stay for at least 4 weeks, though some may stay for shorter periods.	People with at least some field experience, ideally used to living and working in challenging conditions or at least prepared to live and work in these conditions. Experience on eradication projects useful but not essential. Could be from Croatia or overseas.
Specialist climbers (4-6 at any time)	Lead on any rope access work needed for steep parts of the site, checking bait stations and monitoring equipment here. Rotation to allow for rest of the island should be considered and would require a larger team.	Highly experienced climbers, trained in all necessary techniques used to living and working in challenging conditions. Experience on eradication projects useful but not essential. Could be from Croatia or overseas. 22-30 abseil routes and a via ferrata route have been estimated in the case of a fully ground-based project. If all of these routes need access by personnel every three days during eradication, as opposed to lowering bait stations on permanent cord on some of the ledges, a team of six climbers (3 pairs) are required to be on the island at all times. Each team would carry out 5-6 routes per day which is reasonable if pairs alternate on who abseils.

Skipper	Responsible for transporting goods and people to and from the island, and when the weather permits to drop fieldworkers on points on the island's coast closer to the trails to be baited.	Experienced in driving a small to medium sized boat in adverse sea conditions and to drop off and pick up people without the presence of a jetty.

All staff and volunteers will need to be trained in safe rodenticide use, either by senior project staff (e.g. operations manager and team leaders) or more formally, depending on legal requirements. It would also be necessary for most if not all project staff to have Expedition First Aid training as, in the event of an accident, it could take several hours to get casualties to hospital.

3.6.1 Project management

LIFE Artina is led by the main beneficiary BIOM, which besides this multi-partner project has experience in managing or participating in several other large projects. BIOM would therefore be an excellent candidate for managing the restoration project of Sušac. However, an eradication at this scale will be the first of its kind for the organisation and indeed for Croatia. Therefore, it would be essential for its success to bring in as partners, contracted parties or expert employees, persons with prior experience specific to large scale eradications. The project management team should have the capacity to take responsibility and have the necessary skills for the following (derived from Thomas et al. 2017):

- The overall success of the project
- Managing the project through all Project Stages to completion
- Finding the people and equipment needed
- Ensuring the health and safety of the team/stakeholders
- Regulatory compliance
- Setting appropriate and measurable goals, objectives and outcomes to enable project evaluation
- Managing the project team, giving it direction and keeping it focused, motivated and determined to succeed
- Delegating tasks
- External communication and stakeholder engagement
- Making operational decisions and changes as necessary in the field
- Deciding on priorities
- Budgeting
- Evaluating and reporting on the project
- An 'eradication mind-set': a 'can-do' attitude, motivated and dedicated to achieve the project's goals and objectives, and an understanding that nothing less than 100% kill rate is acceptable for eradication purposes
- Broad experience in the conservation field, and specific experience in leading ground-based eradication operations using bait stations
- Ecological knowledge of the target species and its prey species
- Appropriate boat handling /helicopter flying /rock climbing skills to enable access to the entirety of the project area

- Good people skills, able to build and maintain positive and productive working relationships with key stakeholders and staff
- Good verbal and written communication
- Problem identification and resolution skills
- Good negotiation skills, ability to prepare cases thoroughly and also listen, consult and accept negative or alternative viewpoints constructively
- Ability to plan, prioritise, delegate appropriately, set timelines and work to deadlines
- Understanding of local environmental regulations
- Sensitive to, and appreciative of, local cultural perspectives
- Knowledge of the project and its intended outcomes

3.6.2 Specialist input

Apart from the four to six specialist rope access personnel in Table 12, certified experts are needed to drill in anchor bolts and via ferrata rungs.

Alternatively, to a via ferrata on the steep north slope, aerial broadcast from a helicopter could be utilised. This would require a helicopter pilot with prior experience in eradications and a support team. An appropriate helicopter, GPS-guided navigation system and specialist bait-spreading bucket will also be needed.

A vessel and captain should be available at all times during the duration of the seven month eradication process. Additionally, supplies might be shipped by Plovput. Irrespective of both these two options it would be ideal that several of the ground-based field team have a valid boat license.

Construction workers to set up temporary lodging for the field team are required for this task as well specialist technicians to set up an off-grid desalination facility sufficient to provide daily potable water for up to 18 persons during the eradication process. Water storage from rain, and water transported by Plovput boat can supplement this but would require additional water storage next to accommodation dwellings.

3.6.3 Staffing

At least a proportion of the staff should be Croatian, or even better from Lastovo, to make sure that appropriate interaction with visitors, locals and so forth is maintained during the project. The management team, especially, should be highly experienced with eradication projects of this scale using similar methods. Indeed, a world class Operations Manager will need to be recruited internationally to oversee the actual eradication phase. All persons involved in the project should be experienced fieldworkers, with experience of working and living on islands or in other remote areas.

3.7 Financial viability

An assessment of the financial viability of the project is made by estimating operational costs of eradicating black rats from Sušac.

When costing the project, we recommend including funding to cover the preparation phase, eradication, 2 years of post-eradication monitoring (this will also form the basis of the ongoing biosecurity checks which will be needed in perpetuity to maximise the chances of the island remaining rat free) and a final check after two years to confirm whether the project has succeeded. The estimated cost of these essential project stages is currently calculated as €950636 (€1140763.64 when

including the recommended 20% contingency buffer). Many of the costs, especially for equipment and training were based on UK prices, and thus may differ from their Croatian equivalents. A detailed spreadsheet of estimated costs accompanies this report ("Susac_eradication_budget_estimation.xlsx"). This has been designed so that Croatian project partners with a better idea of local costs can update the budget themselves as information becomes available.

Ideally, the project would also include a programme of pre- and post-eradication ecological monitoring, as well as community engagement activities on Lastovo. Resources will also need to be found to fund the staff, equipment and transport costs associated with ongoing biosecurity. To ensure that the project is financially viable it will be necessary to have the whole amount of the funding for the operational phase in place before starting work as the entire project would be compromised if the money ran out part way through. It may be possible to secure all the necessary funding from one source, though it is perhaps more likely that multiple sources will be required, perhaps a mixture of grants from government, EU and NGO conservation funding streams as well as donations from individuals and companies.

With financing options such as EU LIFE, equipment and assets purchased under the project remain the property of the partner organisation on termination of the project. It follows that good planning will ensure the sustainability and viability of the project after the project funding terminates. For example, if a desalination plant is purchased this would save Plovput future water transport costs to Sušac and the lighthouse. Likewise, if a powerful vessel is purchased by the park management this will increase their surveillance capacity and frequency of visits to the island, in turn benefiting from collected park entry fees from private yachts. Parts of the restored or constructed accommodation and base for the fieldwork team during the eradication phase could be converted into an interpretation centre for visitors to the island. This could play a key role in encouraging biosecurity and educating the public on the important island ecosystem and species.

4. Next steps forward after this feasibility study report

- Recognising that this current feasibility project does not complete all answers that arise from such an exercise, the next step would be to address all key issues listed in section 3.1.4. Table 13 in section 5 recommends concluding solutions for the main issues. It is important that additional expert persons to the current authors are brought in for further assessment. These include:
    - An expert in rat eradications involving aerial rodenticide broadcast in hybrid aerial and ground-based projects
    - A certified rope access expert to assess whether all ledges and slopes can be accessed safely
    - A botanical expert to determine when the least food is available to rats
    - A local rat eradication expert with local knowledge and ability to speak Croatian to conduct stakeholder consultations

- Identify other restoration objectives as part of a potentially larger project such as soil restoration, promotion of vegetational succession and attraction of breeding birds to suitable areas so far not colonised on the island.
    - If it is decided to include removal or eradication of other non-native species additional feasibility studies for these species are written up.

- If all outstanding issues have been resolved and depending on the final outcome of the assessments made, the next stage would be to create a strong partnership of entities willing and capable to undertake the project. Together these would seek the necessary funding for the project. One potential scheme which typically funds full eradication & restoration projects is the EU LIFE fund.

- In parallel to securing funding, a peer-reviewed operational plan for the project is drawn up while working alongside relevant authorities to ensure the required permits and agreements are obtained.

- A biosecurity plan for the island should also be drawn up at this stage.

- A further objective would be to obtain more complete knowledge of the biodiversity of Sušac. Monitoring of shearwater breeding size is currently ongoing but should be repeated annually and with a focus on exploring new areas to better establish breeding population size and range. Additionally, further baseline data should be collected on the other island fauna and flora. Key groups and species can be identified to facilitate the process. All parameters chosen for monitoring should be easily identifiable and allow monitoring and comparison post-eradication.

- Once funding is secured, in the first year of the project one would ensure that all necessary senior staff are hired, and the facilities for the execution of eradication are set in place. Living accommodation should be established on the island in the second year, with a view to start the operational phase of the eradication in autumn (though note project timing may change depending on the results of rat diet, breeding activity and food availability studies). Additionally, all the abseiling anchors and via ferrata on cliffs would be set up. Trail cutting starts two months before the projected start of the poisoning stage of the project.

- The poisoning stage of the eradication would be carried out over a period of approximately six months, most likely starting in late autumn of the second year.

- Two years after eradication is completed an intensive search (three-four weeks) is carried out to establish whether Sušac has achieved rat-free status. During these two years strict biosecurity measures will be in place and biosecurity surveillance will continue afterwards. Both the intensive search and ongoing routine surveillance will be carried out on a selected representative sample of monitoring stations but will not require the full original baiting grid.

- Biosecurity measures, trialled and established prior to eradication commencement would be in place and enforced continually. Every visit to the island by all (regular) visitors will follow a biosecurity checklist, not only for black rats but for any potential species accidentally brought to or taken from the island. Biosecurity will continue throughout the future.

- Setup of a rapid response hub and have a trained team and necessary supplies ready in case of a rapid incursion response is needed - this should aim to have people on the island to start an incursion response within 48hrs of rat sign being found.

5. CONCLUSION

The ground-based eradication of black rats from Sušac is feasible based on the seven criteria in the feasibility section, on the condition that all outstanding issues are resolved. The key ones are:

- All abseiling routes and steep slopes are determined safe to access and the necessary anchor bolts and via ferrata can be set up
- All the necessary permits for rodenticide use, trail cutting, and accommodation set up on the island can be acquired.
- All local stakeholders identified confirm full support to the project.
- The necessary funding to reach the estimated operational budget of €1188764 can be acquired

All issues, logistical or otherwise, considered and the respective recommendations are presented in Table 13.

The total estimated budget of the project is high but the net benefit for the ecosystem of Sušac, the community of Lastovo and contribution to Adriatic island biodiversity outweigh these financial costs. More importantly, environmental costs, such as risks of impacts on non-target species have been considered and properly addressed. The current report has drawn up several measures which should be put in place to reduce the impact, and these will continue to be refined prior to the eradication phase. The cost effectiveness of the eradication project might be higher if it simultaneously tackles other non-native species and restoration goals.

This report reviewed the feasibility of a completely ground-based operation using fixed bait stations, but identified the possibility of a hybrid project including aerial drop of bait on the steeper slopes to be another possible approach. Assessment of such an approach would require a separate feasibility study by eradication experts experienced with hybrid operations.

Table 13: *The issues considered during the feasibility study for eradication of black rats on Sušac and recommendations to resolve these.*

ISSUE	**RECOMMENDATION**
Number of staff required of varied skill sets	Recruitment of highly motivated and skilled staff including a world class Operational Manager.
Length of trail cutting required and time needed - 74 279m of trails with 40 by 50m grid; 806 hours to cut trails estimated for 2 personnel working simultaneously from experience on Petrovac and by categorising habitat by density. This is estimated for a fully ground-based project. The tool used on Petrovac was a pair of long-handled garden loppers and it might be faster with for example petrol-powered brush cutters.	Trail cutting starts a clear two months before the projected start of the poisoning stage of the project. E.g. for a winter project, where baiting is planned to start at the beginning of November, this would mean starting trail cutting at the beginning of September. Working 4 hour days (just focussing on trail cutting & not including preparation and walking around the island); it is estimated that a team of twelve (six pairs) would take 34 days to complete this work if not using power tools.
Cliff access - the cliffs were surveyed by boat and photographs of the coastline analysed by the authors. Areas which could be accessed by scrambling, and those which could only be accessed by abseiling or fixed access routes were identified	22 to 30 abseil routes identified, as well as a section cliff which should have a via ferrata installed. These should be surveyed on the ground by specialist climber(s) or rope access experts who would set up anchor bolts if routes are determined as safe. Abseiling on some routes might be avoided by lowering down bait on permanent lines.
Timing - when to start the eradication process	Eradication will last around seven months with a ground-based approach and should be in the period when the natural food supply of rats is at its lowest. Surveying the island with a botanical expert, combined with rat stomach content analysis should help establish this. Index trapping in winter, with records of age-class of each rat trapped would further inform this decision.

Rodenticide deployment method – fully, ground-based or a combination of aerial and ground-based.	Use of helicopters is likely to increase costs significantly (especially in a combined aerial and ground-based project). Appropriately experienced staff will be needed, including at least one helicopter pilot with experience of following a set grid fly path and support staff, all with eradication experience, as well as an appropriate helicopter and bait distribution bucket. There might also need to be a helipad on the island, which is likely to incur further construction costs. The closest heliport with refuelling facility is Split which might mean considerable flight time costs.
Accommodation for staff on the island. There are currently no suitable buildings which could be used to house the project team and store food, drinking water and equipment.	Options are to a) build new living quarters and other buildings or b) adapt existing structures. Both options will require considerable financial investment and it will be logistically complex to transport all necessary building materials and other resources to the island.
Drinking water. The large number of staff working on the project will need considerable supplies of freshwater. Fresh water supplies on the island appear to be very limited.	If there is no drinking water on the island then it will be necessary to either set up a desalination facility, harvest rainwater and/or to bring fresh water in from Lastovo or mainland Croatia. Transporting large quantities of water is likely to be costly and the necessary infrastructure will need to be in place to safely store water on Sušac.
Other introduced species; namely rabbits and cats. These might be having a detrimental impact on the Sušac ecosystem and it might not be possible to reach the full objectives without their removal.	Quantify numbers present of each species and gauge public opinion on potential removal. If determined as feasible, eradicate or relocate with most humane methods within the same project.
Unknown or uncertain permitting requirements by Croatian Authorities. General eradication at such a scale, but specifically including aerial drop, rodenticide use, trail cutting, accommodation on the island	Recommendations by persons familiar with Croatian law and environmental permits, as well as possibility of sharing feasibility study with permitting bodies for initial feedback

Unknown or uncertain public opinion. Most if not all stakeholders have not yet been formally consulted.	Consult with all stakeholders identified over a period of time and solve any issues that might be identified.

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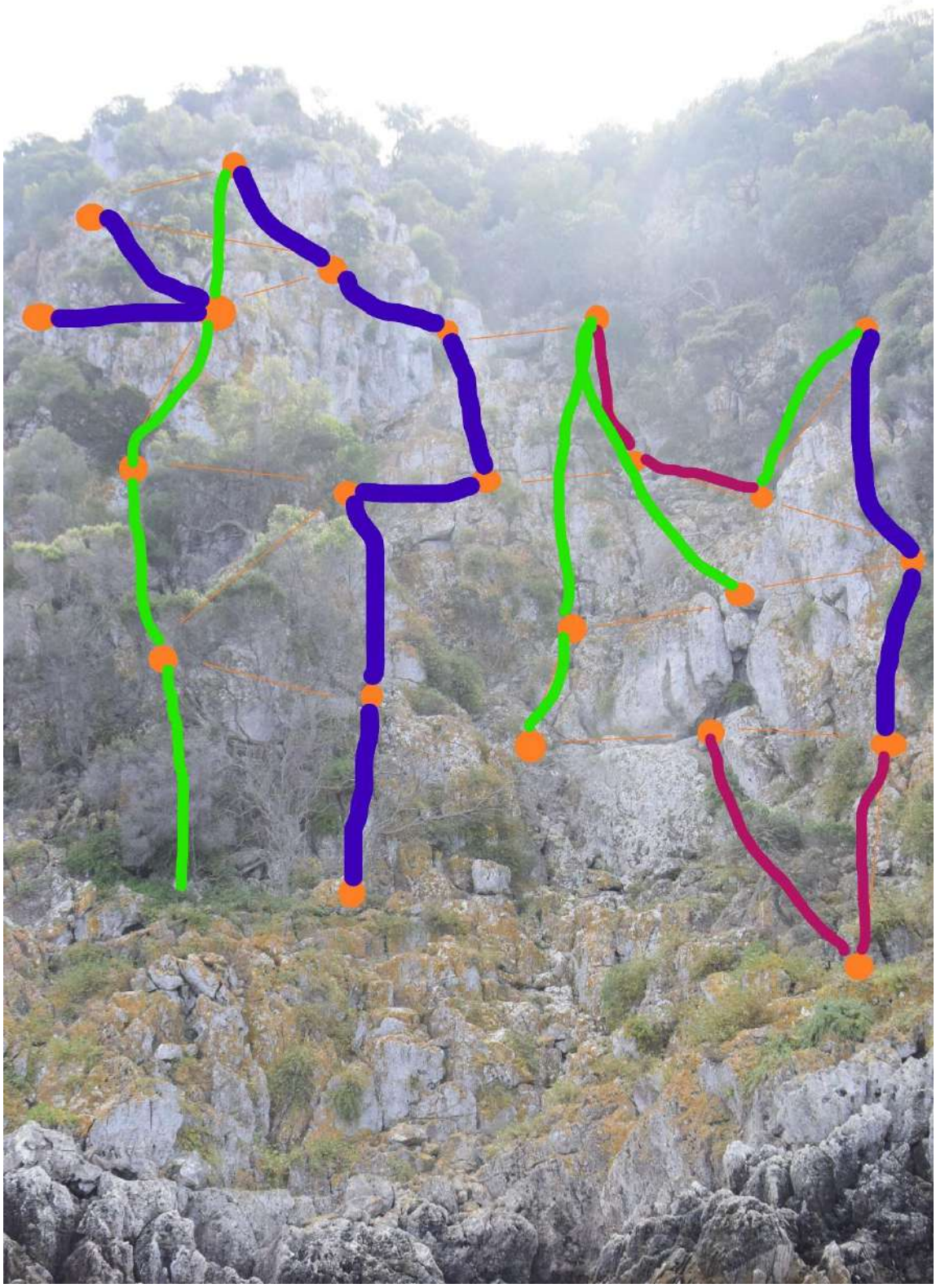
8. APPENDICES

Appendix 1. Examples of images taken during photomapping of the Sušac coast, with overlaid suggested abseiling routes in Figure 1. All vegetated ledges requiring rope access to reach in order to conduct the necessary baiting in a fully ground-based eradication project have been identified from images and suggested routes have been marked. However, it is paramount to assess these on the ground. While some of these might be accessed without rope access by highly skilled persons, it is not

a one-off operation but rather that during an eradication each ledge would have to be reached in an intense rotation of baiting every three days. Therefore, all measures to make access safe have to be in place. The area in Figure 2 is a steep vegetated area making single pitch abseiling complicated and potentially dangerous. Therefore, a via ferrata, with rungs and cable that fieldworkers can be attached to at all times, is recommended instead.

Appendix 1: Figure 1: *Example of marked potential abseiling routes to vegetated ledges on cliffs identified through photomapping. These ledges would require regular baiting in a ground-based eradication set up. Additionally, the three caves without routes to them should be checked for size and whether they have rats in case they would require regular baiting as well.*

Appendix 1: Figure 2: *Area of cliff and steep vegetated slope on the north part of Sušac, where a combination of abseiling and via ferrata might be required to reach all the ledges where baiting should be carried out in a ground-based operation*



Appendix 1 Figure 2: *Potential set up of a via-ferrata drawn up by professional climber Andrew Warrington (MC Adventure, Malta) based on photographic survey only. Colour code: orange dots are possible locations of bait stations, via ferrata sections in electric blue; abseiling routes in lime green; walking paths in purple.*

Appendix 2.

Workings and results from estimation of vegetation coverage on Sušac, the length of baiting grid trails required and ultimately the time required to cut these trails to dense scrub. Moreover, images from Sušac are presented to give examples of the vegetation that is present and which were used to ground-truth the mapping done in QGIS desktop application using satellite imagery. Figure 1 shows both Category 1 vegetation, which is low and sparse, but also category 2 vegetation which is higher and denser. Figure 2 shows an example of vegetation in category 3 which is higher and denser. Category 4 vegetation is shown in Figure 3 where, although the vegetation is the highest, it is possible to walk under the trees and therefore less vegetation cutting is required.

Total baiting area: 3.725km^2 (372.5ha)

Minimum number of bait stations with 40x50m grid (5 per hectare): 1860

Approximate Area of habitat category 1: 1.124km^2 (112.4ha)

Approximate Area of habitat category 2 & 3: 2.236km^2 (223.6ha)

Approximate Area of habitat category 4: 0.365km^2 (36.5ha)

Approximate Total length of horizontal trails for bait station deployment: 74 279m

Approximate Total length of horizontal trails for bait station deployment within habitat category 2 & 3: 44 859m

Approximate hourly rate for trail cutting habitat category 1 & 4: 120m/hr*

Approximate hourly rate for trail cutting habitat category 2 & 3: 80m/hr*

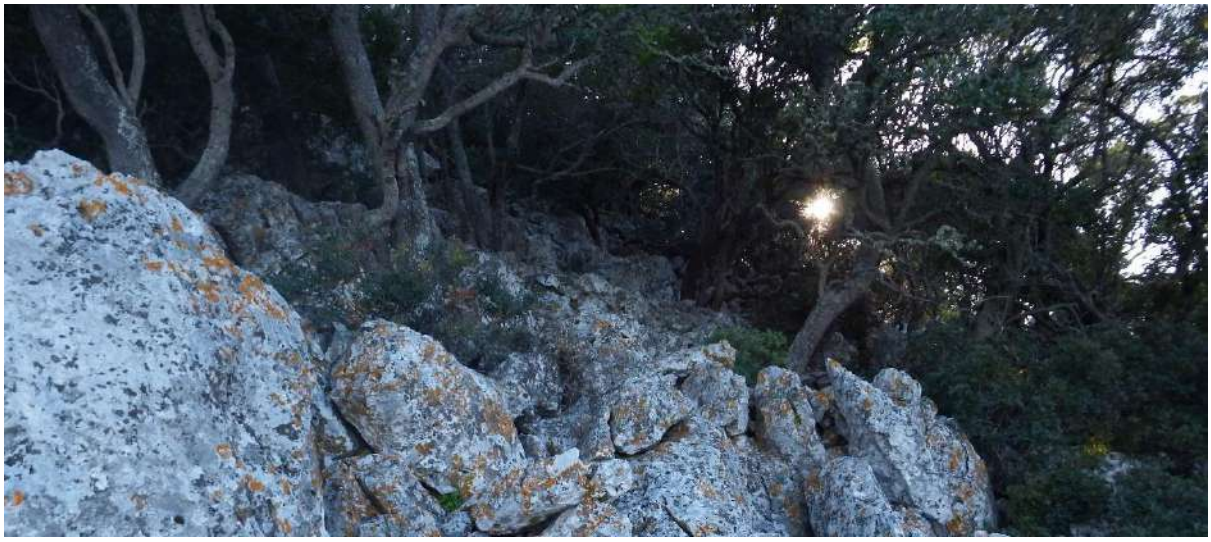
Approximate total time cutting trails in habitat category 1 & 4: 245 hours*

Approximate total time cutting trails in habitat category 2 & 3: 561 hours *

*2 persons needed for trail cutting working together simultaneously

Appendix 2: Figure 1: *Vegetation of category 1 to the left in the image, requiring minimal trail cutting due to low and sparse shrub. Vegetation of category 2 on the right in the image, which due to high density would require trail cutting in a ground-based eradication operation.*

Appendix 2: Figure 2. *Vegetation of category 3, which due to high density would require trail cutting in a ground-based eradication operation.*



Appendix 2: Figure 3: *Woodland of category 4, which for the most part is high enough to walk underneath but might require some trail cutting in case of a ground-based eradication operation*

Appendix 2: Figure 4: *Depiction of long-handled garden loppers, similar to the ones used on Petrovac to clear vegetation for baiting grids and on which estimates of time needed for trail cutting on Sušac have been made*