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“Conservation measures to assist the adaptation of *Falco eleonorae* to climate change”

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Assessment of refueling pattern of migratory passerines on Antikythira ACTION A.3

Final Report - December 2017

SUMMARY

Based on preliminary results of a diet study on the Eleonora's Falcon (*Falco eleonorae*) in southern Greek colonies, the main prey items of the species are Phylloscopus warblers (mainly Willow warbler *Phylloscopus trochilus*, but also Wood Warbler *Phylloscopus sibilatrix* and Common Chiffchaff *Phylloscopus collybita*), Thrushes (mainly Whinchat *Saxicola rubetra* but also Common Redstart, *Phoenicurus phoenicurus* and the Common Nightingale *Luscinia megarhynchos*), Shrikes (mainly Red-backed shrikes *Lanius collurio* but also Woodchat shrike *Lanius senator*), Flycatchers (mainly the Spotted Flycatcher *Muscicapa striata* but also the Pied Flycatcher *Ficedula hypoleuca* and the Collared Flycatcher *Ficedula albicollis*) and Sylvia warblers like the common Whitethroat *Sylvia communis*.

The assessment of refueling pattern of migratory passerines on Antikythira focused on the above species (target species). Additionally, the Golden Oriole *Oriolus oriolus*, Garden Warbler *Sylvia borin*, Blackcap *Sylvia atricapilla* and Red-breasted Flycatcher *Ficedula parva* were also used in this assessment, as they were expected to reveal interesting information regarding the refuelling rates achieved by passerines on the island.

In conclusion, during the spring migration season, even though birds are expected to be in a hurry to reach their breeding grounds, passerines that arrive to Antikythira, stopover at the island for a short period during which they are refueling to a small but significant amount. Regarding the autumn season, even though Antikythira's location just before the Mediterranean and the Sahara, is strategic for birds to prepare for the barrier crossing, there are no indications the target species are doing so.

Even though the abundance of birds was clearly higher in agricultural land, there were no clear patterns regarding the overall habitat use as different species seemed to use different habitats.

Climate Change and Bird Migration from the perspective of the Eleonora's Falcon

It has been shown that long-distance migrants have generally advanced their autumn peak passage through Western Europe during the past decades. In contrast, the short-distance migrants, winter in the Mediterranean area, generally show a delay in their autumn passage.

Capture data were used for six species of long-distance migrants. These species were selected because they comprise the main pray of the Eleonora's Falcon and enough data were available.

The available data show there is a general trend that late birds tend to pass through our study site earlier with the advancement of years, thus shortening the total migration period. This is possible to affect negatively the food availability of the Eleonora's falcons, especially towards the end of the breeding season. Juveniles are known to depart the breeding grounds later than the adults and as a result are expected to be more affected.

The improvement of the habitat for migratory birds at the island is aiming to prolong the stopover of the birds on the site and might even increase the number of birds wintering at the area.

ΠΕΡΙΛΗΨΗ

Βάσει των προκαταρκτικών αποτελεσμάτων της μελέτης της δίαιτας του Μαυροπετρίτη σε αποικίας της νότιας Ελλάδας, τα κύρια είδη λείας είναι στρουθιόμορφα και συγκεκριμένα οι φυλλοσκόποι (κυρίως ο Δενδροφυλλοσκόπος και ο Θαμνοφυλλοσκόπος), οι κιχλίδες (κυρίως ο Καστανολαίμης , το Αηδόνι και ο Φοινίκουρος), οι λανιίδες (κυρίως τα είδη Αετομάχος και Κοκκινοκεφαλάς), οι μυγοχάφτες (Σταχτομυγοχάφτης και Κρικομυγοχάφτης και Μαυρομυγοχάφτης) και οι τσιροβάκοι όπως ο Θαμνοτσιροβάκος.

Η εκτίμηση των μεταναστευτικών προτύπων των στρουθιόμορφων στα Αντικύθηρα, επικεντρώθηκε στα παραπάνω είδη με την προσθήκη των ειδών Συκοφάγος, Κηποτσιροβάκος, Μαυροσκούφης και Νανομυγοχάφτης, για τα οποία υπήρχε σημαντικός αριθμός δεδομένων και αναμενόταν να δώσουν σημαντικές πληροφορίες για το ρυθμό αναπλήρωσης των ρυθμών ανεφοδιασμού των στρουθιόμορφων στην περιοχή.

Συμπερασματικά, κατά τη διάρκεια της εαρινής μετανάστευσης, παρότι θεωρητικά τα πτηνά προσπαθούν να φτάσουν το συντομότερο δυνατό στις περιοχές αναπαραγωγής τους, τα στρουθιόμορφα που σταθμεύουν στα Αντικύθηρα , παραμένουν για ένα μικρό χρονικό διάστημα κατά το οποίο ανεφοδιάζονται σε σημαντικό βαθμό.

Όσον αφορά στην φθινοπωρινή μεταναστευτική περίοδο, αν και τα Αντικύθηρα βρίσκονται σε στρατηγικό σημείο για τον ανεφοδιασμό των πουλιών, ακριβώς πριν τη διάσχιση της Μεσογείου και της Σαχάρας, δεν υπάρχουν ενδείξεις ότι τα είδη-στόχοι χρησιμοποιούν την περιοχή για τροφοληψία παρότι κάποια είδη σταθμεύουν στο νησί.

Αν και η αφθονία των πουλιών στα Αντικύθηρα ήταν εμφανώς υψηλότερη σε αγροτικά ενδιαιτήματα, δεν βρέθηκαν απόλυτα πρότυπα όσον αφορά στην γενικότερη χρήση των ενδιαιτημάτων, καθώς διαφορετικά είδη φαίνεται πως χρησιμοποιούν και διαφορετικά ενδιαιτήματα.

<u>*Κλιματική αλλαγή και μετανάστευση, υπό την προοπτική του Μαυροπετρίτη.*</u>

Έχει δειχθεί από μελέτες ότι τα μεταναστευτικά είδη μεγάλων αποστάσεων στη δυτική Ευρώπη, έχουν γενικώς επισπεύσει την κορύφωση της φθινοπωρινής τους μετανάστευσης , κατά τις τελευταίες δεκαετίες. Σε αντίθεση, τα είδη τα οποία μεταναστεύουν σε κοντινές αποστάσεις και διαχειμάζουν στη Μεσόγειο, δείχνουν καθυστέρηση στο φθινοπωρινό τους πέρασμα.

Χρησιμοποιήθηκαν δεδομένα σύλληψης για έξι είδη μεταναστευτικών ειδών μεγάλων αποστάσεων. Τα συγκεκριμένα είδη επελέγησαν επειδή αποτελούν συχνή λεία του Μαυροπετρίτη και γιατί υπήρχε για αυτά ικανός όγκος δεδομένων.

Τα αποτελέσματα δείχνουν πως υπάρχει μια γενική τάση σύμφωνα με την οποία τα πουλιά τα οποία περνούσαν από τα Αντικύθηρα κατά το τέλος της μεταναστευτικής περιόδου έχουν επισπεύσει τις ημερομηνίες μετανάστευσής τους. Αυτό έχει ως αποτέλεσμα τη συντόμευση της λήξης της μεταναστευτικής περιόδου. Αυτό πιθανώς να επιδράσει αρνητικά την τροφική διαθεσιμότητα για τον Μαυροπετρίτη , ιδιαιτέρως προς το τέλος της αναπαραγωγικής του περιόδου. Τα ανήλικά άτομα αναμένεται να επηρεαστούν περισσότερο καθώς, κατά κανόνα, η ημερομηνία αναχώρησής τους έπεται αυτής των ενήλικων ατόμων.

Η βελτίωση των διαθέσιμων ενδιαιτημάτων τροφοληψίας στοχεύει στην επιμήκυνση της στάθμευσης των πουλιών στην περιοχή και ενδέχεται επίσης να συνεισφέρει στην αύξηση του αριθμού των διαχειμαζόντων ατόμων..

INTRODUCTION

Based on preliminary results of a diet study on the Eleonora's Falcon *Falco eleonorae* in southern Greek colonies, the main prey items of the species are *Phylloscopus* warblers (mainly Willow warbler *Phylloscopus trochilus*, but also Wood Warbler *Phylloscopus sibilatrix* and Common Chiffchaff *Phylloscopus collybita*), Thrushes (mainly Whinchat *Saxicola rubetra* but also Common Redstart, *Phoenicurus phoenicurus* and the Common Nightingale *Luscinia megarhynchos*), Shrikes (mainly Red-backed shrikes *Lanius collurio* but also Woodchat shrike *Lanius senator*), Flycatchers (mainly the Spotted Flycatcher *Muscicapa striata* but also the Pied Flycatcher *Ficedula hypoleuca* and the Collared Flycatcher *Ficedula albicollis) and* Sylvia warblers like the common Whitethroat *Sylvia communis*. The assessment of refueling pattern of migratory passerines on Antikythira focused on the above species (target species). Additionally, the Golden Oriole *Oriolus oriolus,* even though not being so abundant in the prey remnants of the Eleonora's Falcon, has been observed to be hunted several times during spring season by the falcons on Antikythira and thus was also included in the related fieldwork activities. Additionally the Garden Warbler *Sylvia borin*, the Blackcap *Sylvia atricapilla* and Red-breasted Flycatcher *Ficedula parva* are abundant migrants during spring and/or autumn and thus were also used in this assessment, as they were expected to reveal interesting information regarding the refuelling rates achieved by passerines on the island.

METHODS

Mist net trapping, bird ringing

Mist netting and bird ringing took place for the estimation of the passerine species composition, the estimation of relative abundance and the minimum stopover duration of passerines on the island of Antikythira for a total period of 178 days. The fieldwork was implemented during the autumn seasons of 2014-2016 and the spring seasons of 2015-2016 (Table1).

Table 1. Mist netting dates

Field season	Starting date	Ending date	Duration (days)
Autumn 2014	06 September	05 October	29
Spring 2015	07 April	23 May	46
Autumn 2015	2 September	27 September	25
Spring 2016	28 March	20 May	53
Autumn 2016	05 September	30 September	25

Mist netting took place at a location at the centre of the island (35°51'N, 23°18'E; Fig. 1) every day from dawn and thereafter for eight hours, except for days with adverse weather conditions.

Eleven and twelve mist nets of a total length of 144 and 154 m were used during the spring and autumn season respectively (Fig. 1). These mist nets were considered to be the constant effort mist netting site, while the same positions and total length will be used during the whole duration of the project in order to obtain comparable data throughout the progression of the project (i.e., in the framework of Action D1). Additional mist nets (total length of 45m) were used opportunistically and sporadically outside the constant effort site in order to increase the number of species trapped and increase the recapture rate of ringed birds

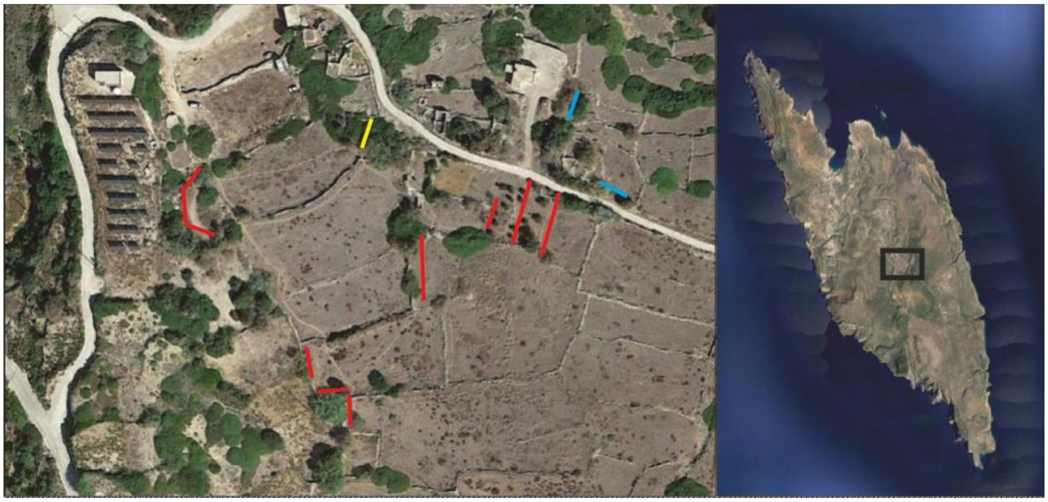


Figure 1. The mist netting location and the position of the mist nets. Red lines represent the positions of mist nets used during both spring and autumn season. Yellow colour highlights mist nets used only during spring, while blue colour those used only during autumn.

Trapped birds were identified according to Svensson (1992) and weighed to the nearest 0.1 g. Maximum wing length (Svensson 1992) was recorded as a measurement of size. Visible subcutaneous fat stores were estimated according to Kaiser (1993).

Colour ringing

In order to increase the resighting rate of trapped birds, colour rings (Fig. 2) were deployed along with the metal rings to a selected number of species. The combination of the colours and positions of the rings (including the metal ring) was unique for each individual (per species).

The selection of the species on which colour tagging was deployed was based on *(a)* the abundance of the migratory species on the island, (b) whether they were known to be (or potentially could be) a preferred prey item by the Eleonora's Falcon (target species) and (c) on their behaviour (cryptic species which could make the reading of the colour rings difficult were excluded). During 2015 and 2016 field seasons, colour rings were deployed on a wide range of species and the effectiveness of colour ringing in increasing of the resightings will be evaluated per species before the beginning the new field season in the frame of the monitoring action D1.

Figure 2. Deployment of colour rings and coloured tagged birds before releasing.

All colour ringing combinations used were registered and licensed by the European colour-ring Birding platform (http://www.cr-birding.org/) and the Hellenic Bird Ringing Centre. In total, 1,035 birds of 19 species were colour tagged during the spring and autumn field seasons of 2015 and 2016 on Antikythira (Table 2).

Table 2. Species and birds per species on which colour rings were deployed during 2015 -2016.

	n of tags	
Species	Spring	Autumn
Ficedula albicollis	107	4
Ficedula hypoleuca	146	1
Ficedula parva	0	23
Ficedula semitorquata	11	0
Hippolais icterina	40	9
Iduna pallida	11	0
Lanius collurio	0	16
Lanius senator	76	0
Luscinia megarhynchos	48	3
Muscicapa striata	121	69
Passer hispaniolensis	38	0
Phoenicurus phoenicurus	50	19
Phylloscopus collybita	1	0
Phylloscopus orientalis	3	0
Phylloscopus sibilatrix	118	0
Phylloscopus trochilus	47	35
Saxicola rubetra	24	2
Sylvia melanocephala	4	5
Turdus merula	4	0

Radio tagging and radio tracking

In order to obtain more detailed information regarding the stopover duration of some selected passerine species, as well as to evaluate the habitat selection of those species, two types of transmitters were used. More specifically, between the 7th and the 8th of September 2014, light weight transmitters (Model: PicoPip Ag379; Biotrack Ltd, UK) were deployed on 2 Spotted Flycatchers, 2 Willow Warblers and 2 Whinchats. Likewise between the 14th of September and the 17th of May 2015, light-weight radio transmitters were deployed (encoded Nanotags; model:NTQB-1; Lotek wireless Inc, Canada), on 5 Woodchat Shrikes, and 3 Spotted Flycatchers. Likewise, the following year (2016) between the 15th of April and the 17th of May 2016, light-weight radio transmitters were deployed (encoded Nanotags; model:NTQB-1; Lotek wireless Inc, Canada), on 4 Woodchat Shrikes, and 1 Spotted Flycatcher. Finally, during the autumn season of 2016 an additional transmitter was deployed at a Spotted Flycatcher. Three more transmitters were planned to be deployed during the autumn season of 2016 but the bad weather and the low number of Spotted Flycatcher hindered our capturing attempts. The transmitters will be used for the implementation of D1 Action, (monitoring action) which uses the same methodology, means and practices as A3 Action.

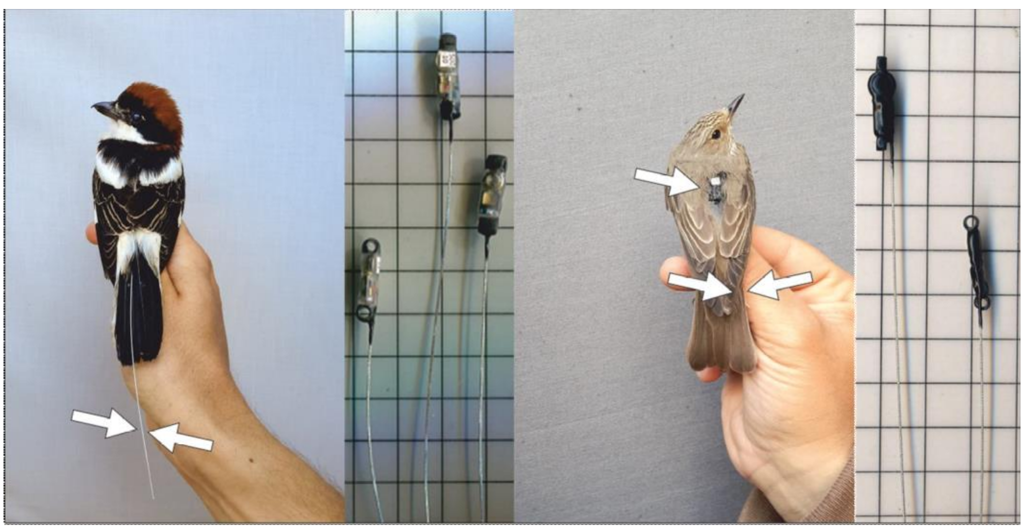


Figure 3. A radio tagged Woodchat Shrike (left), Spotted Flycatcher and the type of radio tags that were deployed on them.

Radio transmitters were attached by leg-loop harness (Rappole & Tipton, 1991) and had a minimum life-span ranging from 14 to 21 days. The radio transmitters were activated (with the use of an infrared activator, Fig. 4) just before the deployment at the birds. A hand held receiver (Model: SRX800 m-2; Lotek wireless inc, Canada, used for NTQB-1 transmitters and Sirtrack; Biotrack Ltd, UK used for the PicoPip transmitters) and a three element Yagi antenna (Model: Flexible Yagi; Biotrack Ltd, UK) were used for radio tracking. All the birds equipped with radio transmitters were trapped at the constant effort ringing site and released at the same site immediately after the deployment (average time from trapping to release was 20 min).

Bird positions were determined by homing (White & Garrott, 1990) and birds were approached to no less than an estimated 10 m to avoid disturbance from the observer. It was determined that a tagged bird was on a specific position, mainly by visual confirmations (radio tagged birds were also colour ringed) and when that was not possible (e.g. due to dense vegetation) from the signal strength. Bird locations were recorded with an Android hand-held PC (tablet) using the Locus Maps Free application. The minimum interval between successive locations of a single bird was 30 minutes. This sampling rate was chosen, in order to allow birds ample time to move from one end of their home range to another and increase the independence of observations (White & Garrott, 1990; Chernetsov & Mukhin, 2006).

Figure 4. The Infrared transmitter activator and a transmitter with leg harness, activating a transmitter and radio tracking activities.

When a signal from a given transmitter could not be detected from a bird’s last known position, observers expanded outward on foot or by car until either the bird was found or it could be concluded the bird was no longer present anywhere in the island.

Birds were assumed to have resumed migration if they remained undetected for at least three consecutive days after last contact.

Furthermore, 6 additional light weight transmitters (Model: PicoPip Ag379; Biotrack Ltd, UK), were purchased with independent funds and used on Golden Orioles. A hand held receiver (Model: Sirtrack; Biotrack Ltd, UK) and a three element Yagi antenna (Model: Flexible Yagi; Biotrack Ltd, UK) were used for radio tracking. The same radio tracking protocols were followed.

Bird surveys and counts

In order to estimate abundance of migrating birds stopping over on Antikythira, during both spring and autumn, bird counts were conducted. More in details, bird counts were conducted during autumn seasons of 2014-2016 and during spring season of 2015-2016 (Table 3).

Table 3. Summary of bird counts conducted

Season	Period of surveys	N of surveys
Autumn 2014	19 Aug - 9 Sep	39
Spring 2015	20 Apr - 04 May	90
Autumn 2015	08 Sep- 23 Sep	34
Spring 2016	18 Apr - 24 Apr	25
Autumn 2016	18 Sep - 30 Sep	36

Table 4. Main habitat type of each transect.

Id	Type	Habitat	Id	Type	Habitat
ALT01	Point	Agricultural	ALT18	Point	Maquis
ALT02	Point	Phrygana	ALT19	Point	Maquis
ALT03	Point	Maquis	ALT20	Point	Agricultural
ALT04	Point	Phrygana	ALT21	Point	Agricultural
ALT05	Point	Phrygana	OPT01	Point	Maquis
ALT06	Point	Phrygana	OPT02	Point	Maquis
ALT07	Point	Phrygana	OPT03	Point	Phrygana
ALT08	Point	Maquis	OPT04	Point	Maquis
ALT09	Point	Phrygana	OPT05	Point	Phrygana
ALT10	Point	Maquis	OPT06	Point	Maquis
ALT11	Point	Phrygana	OPT07	Point	Maquis
ALT12	Line	Phrygana	OPT08	Point	Maquis
ALT13	Line	Maquis	OPT09	Point	Maquis

Id	Type	Habitat	Id	Type	Habitat
ALT14	Line	Phrygana	OPT10	Point	Phrygana
ALT15	Line	Phrygana	OPT11	Point	Phrygana
ALT16	Point	Maquis	OPT12	Point	Phrygana
ALT17	Point	Maquis	OPT13	Point	Maquis

*Transects without a shade were surveyed repeatedly and transects with a shade were surveyed just once.

Both point and line transects were used (Fig.5, Table 4). Count units were spread in such a way that all the main habitat types of interest on the islands (phrygana, maquis & agricultural land; Table 4) would be covered. The four line transects used were of 665 m, 205 m, 617 m and 551 m in length, respectively (Fig. 5). Some transects were surveyed repeatedly every second or third day, while some others were surveyed only once. Transects surveys were conducted from 7:15 up to 12:30 and from 18:00 to 19:15.

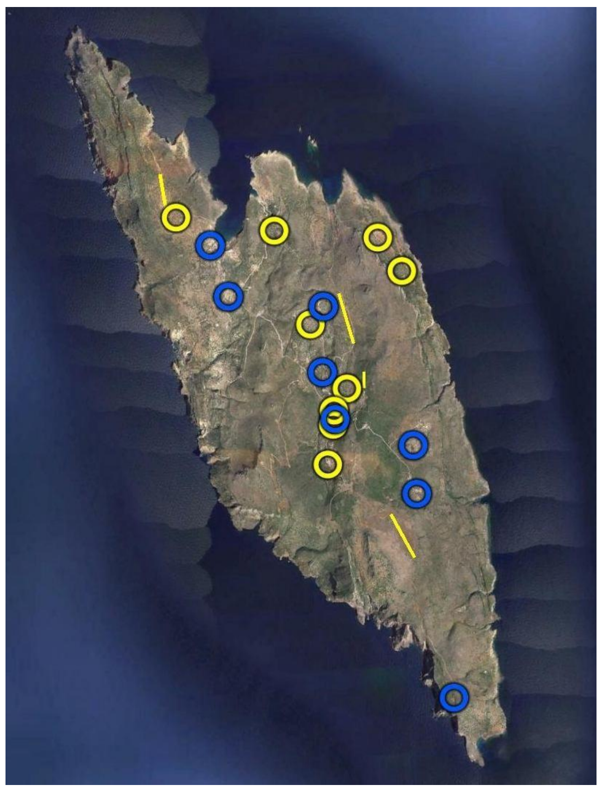


Figure 5. Point and line transect surveyed on Antikythira. Transects in yellow were surveyed repeatedly while those in blue were surveyed just once.

During autumn season of 2014 the "Plot sampling method" was used, which assumes that all birds are detected on the sampled area. In order to estimate true abundance, the Distance Sampling method was used during the field season of 2015. Distance sampling (Buckland et al. 2001) is a density estimation sampling method, in which birds are counted within a sample of defined areas (in our case, plots). The plots are long, narrow strips (line transect sampling) or circles (point transect sampling). The distance sampling extension allows for the possibility that some of the birds present in the plot are not detected. However, it is useful to begin by considering the case of perfect detection (i.e, Plot sampling method). The assumptions of the methods are (a) birds on the line or point are certain to be detected, (b) birds are detected at their initial location, (c) distance measurements are exact, (d) for birds that occur in clusters (groups), cluster sizes are recorded without error and (e) the sampled plots (circles or strips) are representative of the entire survey region. In order to be able to apply distance sampling methods, the distance of each bird observed from the line or point transect needs to be measured or estimated.

The general habitat (phrygana, maquis & agricultural land) were registered for every surveyed transect. Additionally, the microhabitats used by each bird observed in the field were registered. More specifically, the habitat characteristics (percentage of coverage by each habitat type) within a $4m^2$ square, the center of which was the observed bird, were recorded. The habitat coverage of the squares was recorded with an accuracy of 5%. Habitat types used were:

1. Bare Ground (BG): no vegetation cover.
2. Herbal vegetation (including grass)
3. Phrygana (Ph): Low woody vegetation cover, dominated by spaced, spiny and aromatic cushion-shaped shrubs.
4. Low Maquis (LMa): evergreen, sclerophyllous shrubs and trees of mean height of <1m
5. High Maquis (HMa): evergreen, sclerophyllous shrubs and trees of mean height of> 1m.

Climate Change and Bird Migration from the perspective of the Eleonora's Falcon

Numerous effects of climate change on the spring phenology of temperate animals and plants are well documented (Wolkovich et al. 2012, Parmesan et al. 2013). Warmer temperatures have been shown to initiate earlier arrivals of migratory songbirds (Lehikoinen et al. 2013). Autumn, by contrast, has received less attention: in the publication database Scopus there are only about one-half to one-third as many climate change studies set in autumn as compared to spring (Gallinat et al. 2015). It has been shown that long-distance migrants have generally advanced their autumn peak passage through Western Europe during the past decades, implying that there is a selection pressure to cross the Sahel as early as possible before the onset of the dry season (e.g. Jenni & Kéry 2003). In contrast, the short-distance migrants, winter in the Mediterranean area, generally delayed their autumn passage (e.g. Jenni & Kéry 2003). Additionally phenological changes in key life-history traits can cause temporal mismatches between interacting species (Miller-Rushing et al. 2010).

In order to look into the possible impact of climate change in bird migration across the study areas we used data of the constant effort, autumn, ringing campaign run by the Hellenic Ornithological Society at Antikythira, from 2018 up to 2017. Capture data were used for six species of long-distance migrant (Table 5). These species were selected because they comprise the main pray of the Eleonora's Falcon and enough data were available. Additionally the whole data set of trapped birds (expect raptors and owls that are not ray items for the species) were used to look into the impact of climate change to migration phenology as a whole. All the studied species are long –distance migrants, apart from the Eurasian blackcap which can include individuals which are short distance migrants.

Table 5. Species used in the analysis.

Species	Number of Individual
Whinchat Saxicola rubetra	159
Red-backed shrike Lanius collurio	190
Willow warbler Phylloscopus trochilus	980
Spotted flycatcher Muscicapa striata	745
Common whitethroat Sylvia communis	227
Eurasian blackcap Sylvia atricapilla	976
All trapped species	9189

RESULTS

Species composition

In total 4,463 birds of 62 species were trapped during the spring mist netting trapping seasons. Of all the birds ringed, 3,729 birds of 59 species were trapped at the constant effort site (Table 6). The composition of the species did not differ significantly between the constant effort trapping site and the opportunistic netting sites. The only species that were trapped at the opportunistic mist nets and not at the constant effort site was the Common buzzard *Buteo buteo*, Bluethroat *Luscinia svecica* and the Black-crowned Night Heron *Nycticorax nycticorax* which are not a target species (Table 7). Likewise during the autumn season of 2014 -2016 a total of 1,366 birds of 45 species were trapped (Tables 8 & 9).

Table 6. Composition of species trapped during spring at the constant effort site.

Species	2015	2016	Total	Species	2015	2016	Total
Accipiter nisus	0	2	2	*Lanius senator*	36	37	73
Acrocephalus arundinaceus	36	37	73	*Locustella luscinioides*	1	0	1
A. palustris	1	0	1	*Luscinia megarhynchos*	37	59	96
A. schoenobaenus	32	66	98	*Merops apiaster*	53	7	60
Acrocephalus scirpaceus	8	5	13	*Motacilla flava*	2	0	2
Anthus trivialis	63	39	102	*Muscicapa striata*	77	177	254
Caprimulgus europaeus	8	8	16	*Oenanthe hispanica*	2	1	3
Carduelis spinus	0	1	1	*Oriolus oriolus*	149	60	209
Circus macrourus	2	0	2	*Otus scops*	3	3	6
Coc. coccothraustes	0	1	1	*Passer hispaniolensis*	4	42	46
Cuculus canorus	2	0	2	*Phoenicurus ochruros*	0	1	1
Delichon urbicum	49	76	125	*P. phoenicurus*	37	74	111
Emberiza calandra	1	2	3	*Phylloscopus collybita*	14	51	65
Emberiza hortulana	1	0	1	*P. orientalis*	3	5	8
Emberiza melanocephala	0	2	2	*P. sibilatrix*	102	124	226
Erithacus rubecula	2	10	12	*P. trochilus*	20	76	96
Falco tinnunculus	2	2	4	*Prunella modularis*	0	1	1
Falco vespertinus	0	1	1	*Riparia riparia*	34	161	195
Ficedula albicollis	76	124	200	*Saxicola rubetra*	35	28	63
Ficedula hypoleuca	191	163	354	*Serinus serinus*	0	3	3
Ficedula semitorquata	9	8	17	*Streptopelia decaocto*	1	2	3
Fringilla coelebs	0	1	1	*Streptopelia turtur*	29	44	73
Hippolais icterina	17	51	68	*Sturnus vulgaris*	0	1	1
Hippolais polyglotta	0	1	1	*Sylvia atricapilla*	78	76	154
Hirundo rustica	30	30	60	*Sylvia borin*	244	337	581
Iduna pallida	11	27	38	*Sylvia cantillans*	4	43	47
Jynx torquilla	12	18	30	*Sylvia communis*	32	53	85
Sylvia curruca	1	1	2	*Turdus philomelos*	1	12	13
Sylvia melanocephala	1	0	1	*Upupa epops*	7	12	19
Turdus merula	1	2	3	**Total**	**1561**	**2168**	**3729**

Table 7. Composition of species trapped opportunistically during spring season

Species	2015	2016	Total	Species	2015	2016	Total
Accipiter nisus	0	2	2	*Merops apiaster*	25	21	46
Acrocephalus arundinaceus	0	10	10	*Muscicapa striata*	15	62	77
A. schoenobaenus	3	11	14	*Nycticorax nycticorax*	1	0	1
A. scirpaceus	2	3	5	*Oriolus oriolus*	16	17	33
Anthus trivialis	5	3	8	*Phoenicurus ochruros*	1	0	1
Buteo buteo	0	4	4	*P. phoenicurus*	2	32	34
Caprimulgus europaeus	2	4	6	*Phylloscopus collybita*	3	9	12
Cuculus canorus	0	1	1	*P. orientalis*	1	3	4

Species	2015	2016	Total	Species	2015	2016	Total
Delichon urbicum	1	0	1	*P. sibilatrix*	2	16	18
Emberiza melanocephala	0	1	1	*P. trochilus*	1	11	12
Erithacus rubecula	0	6	6	*Riparia riparia*	2	2	4
Ficedula albicollis	6	36	42	*Saxicola rubetra*	1	4	5
Ficedula hypoleuca	4	48	52	*Streptopelia turtur*	1	10	11
Ficedula semitorquata	0	1	1	*Sylvia atricapilla*	16	27	43
Fringilla coelebs	0	1	1	*Sylvia borin*	18	114	132
Hippolais icterina	10	31	41	*Sylvia cantillans*	3	19	22
Hirundo rustica	0	3	3	*Sylvia communis*	2	14	16
Iduna pallida	3	5	8	*Sylvia curruca*	0	1	1
Jynx torquilla	0	7	7	*Sylvia melanocephala*	0	3	3
Lanius senator	1	6	7	*Turdus merula*	0	1	1
Luscinia megarhynchos	4	18	22	*Turdus philomelos*	1	4	5
Luscinia svecica	0	1	1	**Total**	**152**	**572**	**724**

Table 8. Composition of species trapped during autumn at the constant effort site.

Species	2014	2015	2016	Total
Accipiter nisus	1	0	0	1
Acrocephalus arundinaceus	2	1	0	3
Acrocephalus palustris	1	1	1	3
Acrocephalus schoenobaenus	1	1	0	2
Acrocephalus scirpaceus	3	3	1	7
Anthus campestris	0	0	2	2
Anthus trivialis	2	2	1	5
Buteo buteo	1	0	0	1
Caprimulgus europaeus	1	2	0	3
Carpodacus erythrinus	0	0	1	1
Cuculus canorus	0	0	2	2
Emberiza calandra	0	0	1	1
Erithacus rubecula	49	0	11	60
Falco tinnunculus	1	0	0	1
Ficedula albicollis	7	4	5	16
Ficedula hypoleuca	2	4	2	8
Ficedula parva	38	22	14	74
Hippolais icterina	57	29	11	97
Hirundo rustica	7	0	3	10
Iduna pallida	0	0	1	1
Jynx torquilla	1	2	2	5
Lanius collurio	8	14	10	32
Lanius senator	2	0	3	3
Luscinia luscinia	0	1	0	5
Luscinia megarhynchos	11	6	4	21
Motacilla flava	0	1	11	12

Species	2014	2015	2016	Total
Muscicapa striata	40	50	37	127
Oenanthe oenanthe	0	1	7	8
Oriolus oriolus	8	13	3	24
Otus scops	10	4	2	16
Passer hispaniolensis	2	0	0	2
Phoenicurus phoenicurus	25	18	43	86
Phylloscopus sibilatrix	10	12	9	31
Phylloscopus trochilus	71	82	56	209
Riparia riparia	1	0	0	1
Saxicola rubetra	16	9	8	33
Streptopelia turtur	2	6	2	10
Sylvia atricapilla	34	24	47	105
Sylvia borin	73	31	26	130
Sylvia cantillans	23	10	4	37
Sylvia communis	40	12	18	70
Sylvia curruca	1	0	4	5
Sylvia melanocephala	1	0	1	2
Turdus philomelos	2	0	0	2
Upupa epops	0	1	2	3
Total	**554**	**366**	**355**	**1277**

Table 9. Composition of species trapped opportunistically during autumn season.

Species	2014	2015	2016	Total
Accipiter brevipes	0	0	3	3
Acrocephalus palustris	0	0	2	2
Acrocephalus scirpaceus	0	0	2	2
Anthus trivialis	0	1	2	3
Caprimulgus europaeus	0	1	1	2
Cettia cetti	0	1	0	1
Erithacus rubecula	0	0	8	8
Ficedula albicollis	0	2	0	2
Ficedula parva	0	6	5	11
Hippolais icterina	0	2	12	14
Hirundo rustica	0	0	1	1
Iduna pallida	0	0	1	1
Ixobrychus minutus	0	0	1	1
Jynx torquilla	0	0	4	4
Lanius collurio	0	1	2	3
Lanius senator	0	0	1	1
Luscinia megarhynchos	0	0	5	5
Motacilla flava	0	0	1	1
Muscicapa striata	0	6	14	20
Oriolus oriolus	0	1	3	3

Species	2014	2015	2016	Total
Otus scops	0	0	1	2
Phoenicurus phoenicurus	0	8	19	27
Phylloscopus sibilatrix	0	1	2	3
Phylloscopus trochilus	0	17	42	59
Saxicola rubetra	0	0	2	2
Streptopelia turtur	0	0	4	4
Sylvia atricapilla	0	8	84	92
Sylvia borin	4	4	16	24
Sylvia cantillans	0	3	5	8
Sylvia communis	0	1	12	13
Sylvia melanocephala	0	0	5	5
Turdus philomelos	0	0	2	2
Upupa epops	1	0	0	1
Total	**5**	**63**	**262**	**330**

As evident form Tables 6-9 and Fig. 6 the relative abundance of the target species is much higher during the autumn season. On the other hand, the number of species and birds in general is higher during the spring season.

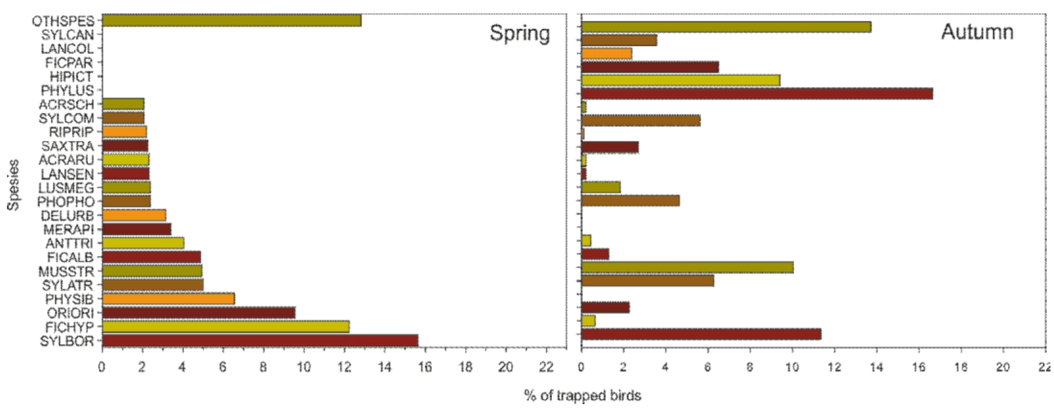


Figure 6. Relative abundance of species composition during spring and autumn. Were SYLBOR: *Sylvia borin*, FICHYP: *Ficedula hypoleuca*, MUSSTR: *Muscicapa striata*, PHYSIB: *Phylloscopus sibilatrix*, ORIORI: *Oriolus oriolus*, FICALB: *Ficedula albicollis*, RIPRIP: *Riparia riparia*, SYLATR: *Sylvia atricapilla*, DELURB: *Delichon urbicum*, PHOPHO: *Phoenicurus phoenicurus*, ANTTRI: *Anthus trivialis*, ACRSCH: *Acrocephalus schoenobaenus*, LUSMEG: *Luscinia megarhynchos*, PHYLUS: *Phylloscopus trochilus,* SYLCOM: *Sylvia communis*, ACRARU: *Acrocephalus arundinaceus*, LANSEN: *Lanius senator*, HIPICT: *Hippolais icterina*, SYLCAN: Sylvia cantillans, ERIRUB: *Erithacus rubecula*, FICPAR: *Ficedula parva*, RESSPES: the rest of the species pooled.

Phenology of passerine migration

When assessing the refueling pattern of migratory passerines it is essential to look into the phenology of migration, as the abundance of birds will most likely vary within and between seasons. During the spring seasons of 2015-2016 a high daily variation of the migration flow was evident (Fig 7), with the peak of the migration flow taking place around 25th April and with a clear fade down after the second half of May. On the contrary, during the autumn fieldwork seasons the migration flow was much more moderate (Fig7).

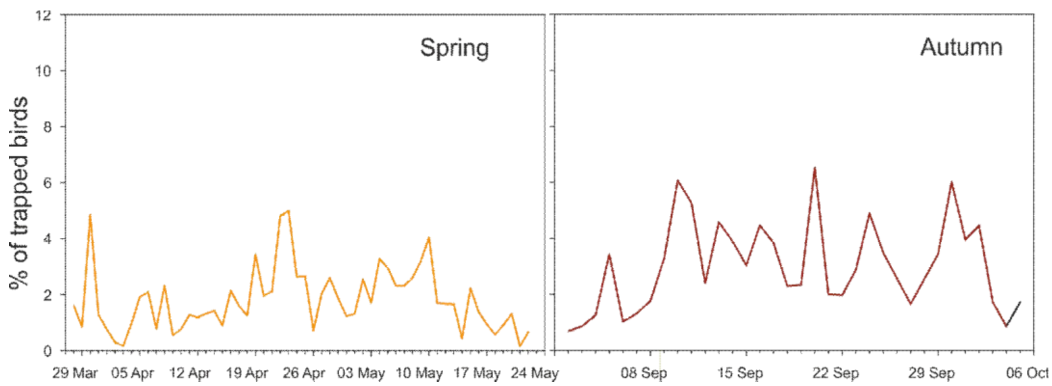


Figure 7. Migration phenology of passerines during spring and autumn season on Antikythira as expressed through bird ringing data.

As can been seen from the phenology of the eight most abundant species during the spring season (Fig. 8), most of them were still present on Antikythira after the beginning of May when the majority of Eleonora's Falcons return to Antikythira. Even though the Eleonora's Falcon is considered to feed on migratory birds mainly during the breeding season, it has been observed several times to hunt migrating passerines on Antikythira during spring and thus, high abundances of migratory birds during spring is beneficiary for the species.

During autumn, as it can be seen from the migration phenology of the eight most abundant species (Fig. 9), the peaks of passage are spread all across the season with some species peaking early and other later on. The target species that are considered to be the main prey of the Eleonora's Falcon seem to appear in waves as is evident from the phenology of the Willow Warbler *Phylloscopus trochilus,* the Spotted Flycatcher *Muscicapa striata* and the Common redstart *Phoenicurus phoenicurus*. This pattern ensures a steady prey availability for the Eleonora's Falcon during autumn on the island, as shown in Fig. 9.

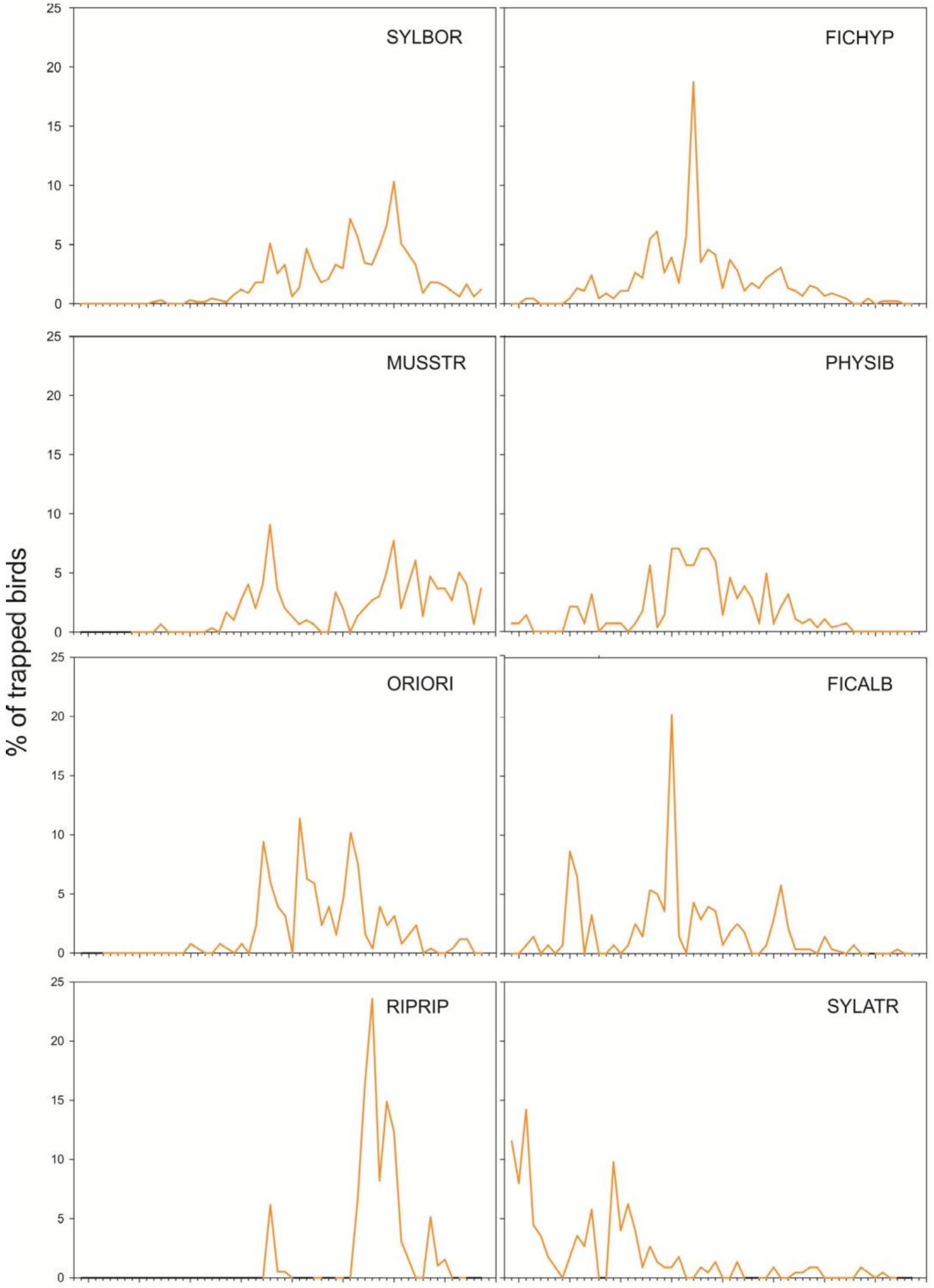


Figure 8. Phenology of the eight most abundant species during the spring season. (SYLBOR: *Sylvia borin*, FICHYP: *Ficedula hypoleuca*, MUSSTR: *Muscicapa striata*, PHYSIB: *Phylloscopus sibilatrix*, ORIORI: *Oriolus oriolus*, FICALB: *Ficedula albicollis*, RIPRIP: *Riparia riparia*, SYLATR: *Sylvia atricapilla)*

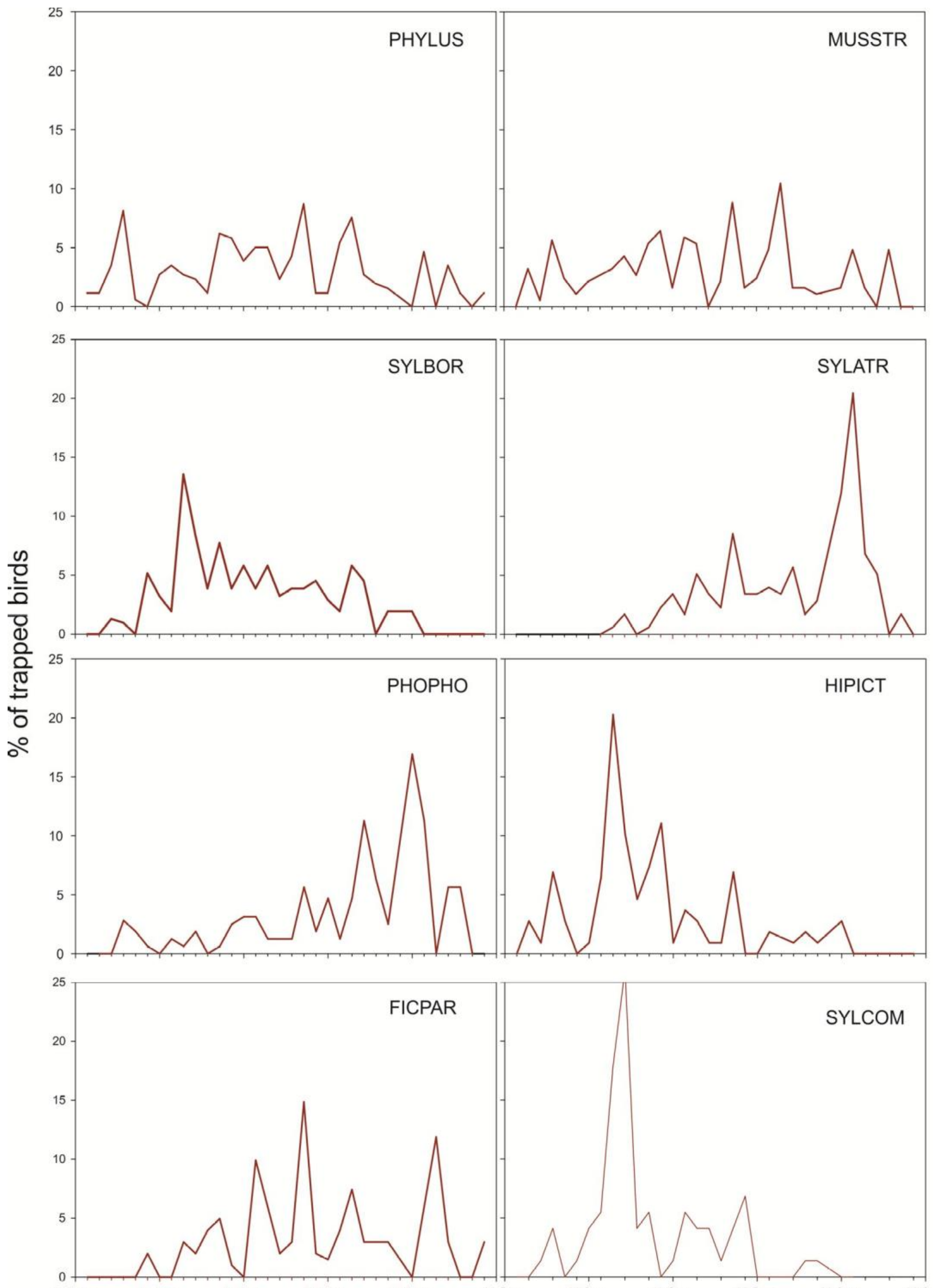


Figure 9. Phenology of the eight most abundant species during the autumn season. (PHYLUS: *Phylloscopus trochilus* , MUSSTR: *Muscicapa striata*, SYLBOR: *Sylvia borin*, SYLATR: *Sylvia atricapilla*, PHOPHO: *Phoenicurus phoenicurus*, FICPAR: *Ficedula parva*, SYLCOM: *Sylvia communis*)

Stopover duration

In order to evaluate the stopover duration of passerines on Antikythira, three distinct approaches were used. Namely, the minimum stopover duration was estimated from the retraps of birds ringed (Table 10), the stopover duration based on resightings of colour tagged birds (Table 11) and the exact stopover duration estimated from radio tagged birds (Table 12).

The minimum stopover duration estimated from the retrapping data is an estimate of the true stopover duration of birds. That it because 1) there is no way to ensure that when a bird is trapped and ringed for the first time, it is newly arrived to the locality (in this case to Antikythira) and 2) there is no way to tell how much more a bird will remain at the site after it has been retrapped. Nowadays, there are new statistical and mathematical tools available that could improve the estimate of stopover duration, but these methods need much larger data sets and thus are not applicable in the present project. The advantage though of the method used is that it can be applied to a wide variety of species (as wide as the diversity for species being trapped during bird ringing). Even though it is an underestimation, the estimate is valuable when comparing between and within seasons and before and after specific conservation actions.

As presented in Table 10, a significant percentage (varying from of 0% to 55% for spring and 0% to 10% for autumn) of the birds trapped, made a stopover on Antikythira that varied for just one day for the Common Whitethroat *Sylvia communis* and Common Nightingale during autumn, up to five days on average for the Common Redstart *Phoenicurus phoenicurus*, again during autumn.

Estimating stopover duration from resightings of colour tagged birds, which is the second approach we applied, is a method that gives a more precise estimate of the actual stopover duration. Still, the study team cannot be sure if a bird that is being tagged has been around before tagging, but that is a common issue related to all the methods that can be applied. The method increases the accuracy of estimation as the bird can be tracked even if it has moved away from the trapping area. The main disadvantage of the method is that it is extremely time demanding and can be applied to a limited number of species as its success relies mainly on the ecology and behavior of the species.

Estimating the stopover duration with the use of radio transmitter is by far the most accurate method. That is because, even though one cannot estimate if the birds tagged with a transmitter have been on the island before, nor and for how long, we can be sure (under normal circumstances) when a radio tracked bird has resumed its migration and left the island. In both methods using retrapping and resighting data, the date of departure is not sure and thus the stopover duration can be underestimated.

Table 10. Number, percentage and mean minimum stopover duration of birds that were retrapped after at least one day on Antikythira during spring and autumn season.

	Spring			Autumn		
Species	Retraps	%Retraps	mean stopover (± sd)	Retraps	%Retraps	mean stopover (± sd)
LUGMEG	16	13.56%	4.3±4.03	1	3.85%	1.00
SYLCOM	3	2.97%	3.0±2.00	1	1.20%	1.00
SYLBOR	41	5.75%	2.8±1.94	13	8.44%	2.7±2.56
SYLATR	24	12.18%	3.6±2.45	4	2.03%	1.5±1.00
PHYSIB	30	12.30%	3.3±2.07			
MUSSTR	20	6.04%	4.3±4.72	5	3.40%	4.0±2.45
FICHYP	17	4.19%	2.9±1.87			
FICALB	11	4.53%	4.0±4.34			
ORIORI	5	2.07%	4.0±2.00	1	3.70%	1.00
LANSEN	4	4.44%	2.8±1.50			
ACRARU	17	20.48%	3.4±2.62			
ACRSCH	9	8.04%	1.8±1.39			
ANTTRI	11	10.00%	2.9±1.81			
JYNTOR	5	22.73%	1.6±0.89			
HIPICT	8	7.41%	1.8±1.16			
CAPEUR	1	0.95%	3.0			
MERAPI	1	1.19%	1.0			
STRTUR	3	3.90%	2.3±1.15			
PHYCOL	10	55.56%	4.2±3.12			
ERIRUB	5	4.63%	2.8±2.17			
PHOPHO	18	12.41%	4.6±4.09	11	9.73%	5.0±4.82
PHYLUS	3	3.13%	4.3±2.31	2	0.75%	2.0±1.41

sd:standard deviation. When only one bird was resighted, the actual value is given.

LUSMEG: *Luscinia megarhynchos*, SYLCOM: *Sylvia communis*, SYLBOR: *Sylvia borin*, SYLATR: *Sylvia atricapilla*, PHYSIB: *Phylloscopus sibilatrix*, ORIORI: *Oriolus oriolus*, FICALB: *Ficedula albicollis*, RIPRIP: *Riparia riparia*, SYLATR: *Sylvia atricapilla*, FICHYP: *Ficedula hypoleuca*, FICALB: *Ficedula albicollis*, ORIORI: *Oriolus oriolus*, LANSEN: *Lanius senator*, ACRARU: *Acrocephalus arundinaceus*, ACRSCH: *Acrocephalus schoenobaenus*, ANTTRI: *Anthus trivialis*, JYNTOR: *Jynx torquilla,* , HIPICT: *Hippolais icterina*, CAPEUR: *Caprimulgus europaeus*, MERAPI: *Merops apiaster*, STRTUR: *Streptopelia turtur*, PHYCOL: *Phylloscopus collybita*, PHOPHO: *Phoenicurus phoenicurus*, PHYLUS: *Phylloscopus trochilus*

Table 11. Number and percentage of birds that colour ringed and resighted after one day on Antikythira and mean minimum stopover duration base on resightings during spring and autumn season.

Species	Spring			Autumn		
	n of tags	Resightings (%)	stopover (mean ± sd)	n of tags	Resightings (%)	stopover (mean ± sd)
Ficedula albicollis	107	0%		4	0%	
Ficedula hypoleuca	146	3.42%	3.0±1.41	1	0%	
Ficedula parva	0	0%		23	4.35%	1
Ficedula semitorquata	11	0%		0	0%	
Hippolais icterina	40	0%		9	0%	
Iduna pallida	11	0%		0	0%	
Lanius collurio	0	0%		16	0%	
Lanius senator	76	18.42%	3.9±1.30	0	0%	
Luscinia megarhynchos	48	0%		3	0%	
Muscicapa striata	121	2.48%	5.3±5.86	69	11.59%	7.3±4.46
Passer hispaniolensis	38	0%		0	0%	
Phoenicurus phoenicurus	50	0%		19	0%	
Phylloscopus collybita	1	100.00%	10	0	0%	
Phylloscopus orientalis	3	0%		0	0%	
Phylloscopus sibilatrix	118	5.08%	2.7±0.82	0	0%	
Phylloscopus trochilus	47	0%		35	0%	
Saxicola rubetra	24	0%		2	0%	
Sylvia melanocephala	4	0%		5	0%	
Turdus merula	4	0%		0	0%	

sd:standard deviation. When only one bird was resighted, the actual value is given.

The stopover duration of five species was estimated by means of radio-tracking (Table 12). The stopover duration of the Woodchat Shrike and Spotted Flycatcher were similar to the values estimated with the resightings of the colour ringed birds (Table 10) during spring. In the case of the Golden Oriole, in which colour ringing cannot be used as it is a cryptic species, the stopover duration seemed to be approximately 2 days longer than estimated from the retrapping data and a much higher percentage of this species seems to stopover on Antikythira (1% estimated from retrapping data vs ¾ of the birds based on radio tracking). Spotted Flycatcher during autumn gave a much smaller value of stopover duration comparing to the retrap and resighting data which indicates that there is a significant individual variation on the stopover duration with the species.

Table 12. Stopover duration of selected species based on radio tracking.

Species	Mean stopover	SD	N	Season
Woodchat Shrike	2.9	3.32	8	Spring
Golden Oriole	5.7	0.50	6	Spring
Spotted Flycatcher	1	0	2	Spring
Spotted Flycatcher	1	0	2	Autumn
Willow Warbler	1	0	2	Autumn
Whinchat	1	0	2	Autumn

In conclusion, a significant portion of the birds that land on Antikythira during both spring and autumn seasons seems to conduct a stopover on the island. The stopover duration varies from one day up to 10 days and depends on the species and the season.

Species abundance

Our main goal was to estimate true densities per basic habitat type for the island of Antikythira by applying Distance Sampling methods. The data gathered though were not enough to apply the statistical tests and models necessary for the estimation of the detection probability, which is used for the calculation of the true abundance. Therefore, a density index, defined as number of birds observed per area was estimated instead. For the density index all the observations of passerines and near passerines detected within a radius of 100 m from the observation point or line transect were used. The true abundance will be conclusively estimated right after the following fieldwork seasons when more data will have been gathered in the framework of the monitoring action D1.

During spring season 1,597 birds belonging to 52 species (including migratory and resident raptors and other non passerines) were recorded. Likewise, during autumn 482 birds belonging to 44 species were recorded.

Both during spring and autumn, agricultural land seems to have the highest overall bird abundance with the difference between the habitats being significant only for some species (Tables 13 & 14). Regarding the target species, the Spotted Flycatcher showed significant difference in abundance between habitat types during spring and autumn.

Table 13. Species abundance during spring.

	Habitat type			
Species	Agricultural	Maquis	Phrygana	Differences
ANTPRA	9.1 ± 15.31	0.0 ± 0.00	0.9 ± 2.03	Agr vs Maq *
ANTTRI	8.6 ± 5.25	5.7 ± 6.24	8.7 ± 5.67	n.s.
EMBCAL	28.3 ± 45.57	1.8 ± 2.67	4.2 ± 4.62	n.s.
FICALB	5.3 ± 6.77	6.2 ± 9.41	3.6 ± 6.13	n.s.
FICHYP	37.2 ± 39.99	12.7 ± 10.22	17.4 ± 12.97	n.s.
LANSEN	17.1 ± 19.99	12.3 ± 10.07	13.3 ± 13.05	n.s.
LUSMEG	23.1 ± 37.92	15.4 ± 17.34	11.9 ± 13.04	n.s.
MOTFLA	9.4 ± 13.97	9.9 ± 12.47	25.9 ± 49.40	n.s.
MUSSTR	34.3 ± 13.60	21.0 ± 15.41	9.3 ± 13.01	Agr vs Phr *
ORIORI	22.9 ± 16.62	13.9 ± 20.56	14.0 ± 18.80	n.s.
PHOPHO	14.8 ± 22.62	5.5 ± 11.08	2.5 ± 3.37	n.s.
PHYLUS	0.0 ± 0.00	1.6 ± 2.33	1.8 ± 3.47	n.s.
SAXTRA	29.9 ± 20.69	11.4 ± 14.71	9.0 ± 10.94	n.s.
STRTUR	102.4 ± 88.49	26.8 ± 21.73	11.3 ± 12.79	Agr vs Phr, Maq *
SYLCOM	12.5 ± 13.00	3.9 ± 5.64	15.2 ± 18.43	n.s.
ALL	406.0 ± 153.70	198.6 ± 66.38	170.1 ± 60.80	Agr vs Phr, Maq *

Codes of species as in Table 5. n.s: not significant, *: p<0.05, **:p<0.01, ***: p<0.001, Agr: Agricultural land, Phr: Phrygana, Maq: Maquis.

Table 14. Species abundance during autumn.

	Habitat type			
Species	Agricultural	Maquis	Phrygana	Differences
EMBCAL	15.9 ± 27.57	0 ± 0	0.0 ± 0.00	n.s
FICALB	1.3 ± 2.30	0.7 ± 1.62	0.0 ± 0.00	n.s
FICHYP	1.3 ± 2.30	6.7 ± 12.48	0.3 ± 0.56	n.s
LANCOL	17.0 ± 16.02	1.5 ± 3.71	0.3 ± 0.56	n.s
LUSMEG	2.1 ± 3.68	14.1 ± 13.16	1.4 ± 1.25	n.s
MOTFLA	5.6 ± 6.51	12.5 ± 13.76	11.9 ± 12.10	n.s
MUSSTR	19.6 ± 4.01	23.2 ± 23.12	3.4 ± 7.00	Phr vs Maq *
ORIORI	12.7 ± 5.51	5.8 ± 8.90	0.0 ± 0.00	Agr vs Phr *
PHOPHO	2.1 ± 3.68	3.4 ± 4.75	0.0 ± 0.00	n.s
PHYLUS	7.7 ± 10.08	4.7 ± 9.55	0.7 ± 1.03	n.s
SAXTRA	22.3 ± 8.42	10.7 ± 14.44	12.9 ± 11.73	n.s
STRTUR	12.5 ± 12.74	4.0 ± 9.75	4.6 ± 6.61	n.s
SYLCOM	6.9 ± 6.43	8.0 ± 12.60	2.5± 2.27	n.s
ALL	170.6 ± 29.31	129.3 ± 34.99	70.9 ± 27.58	Phr vs Maq *, Agr vs Phr **

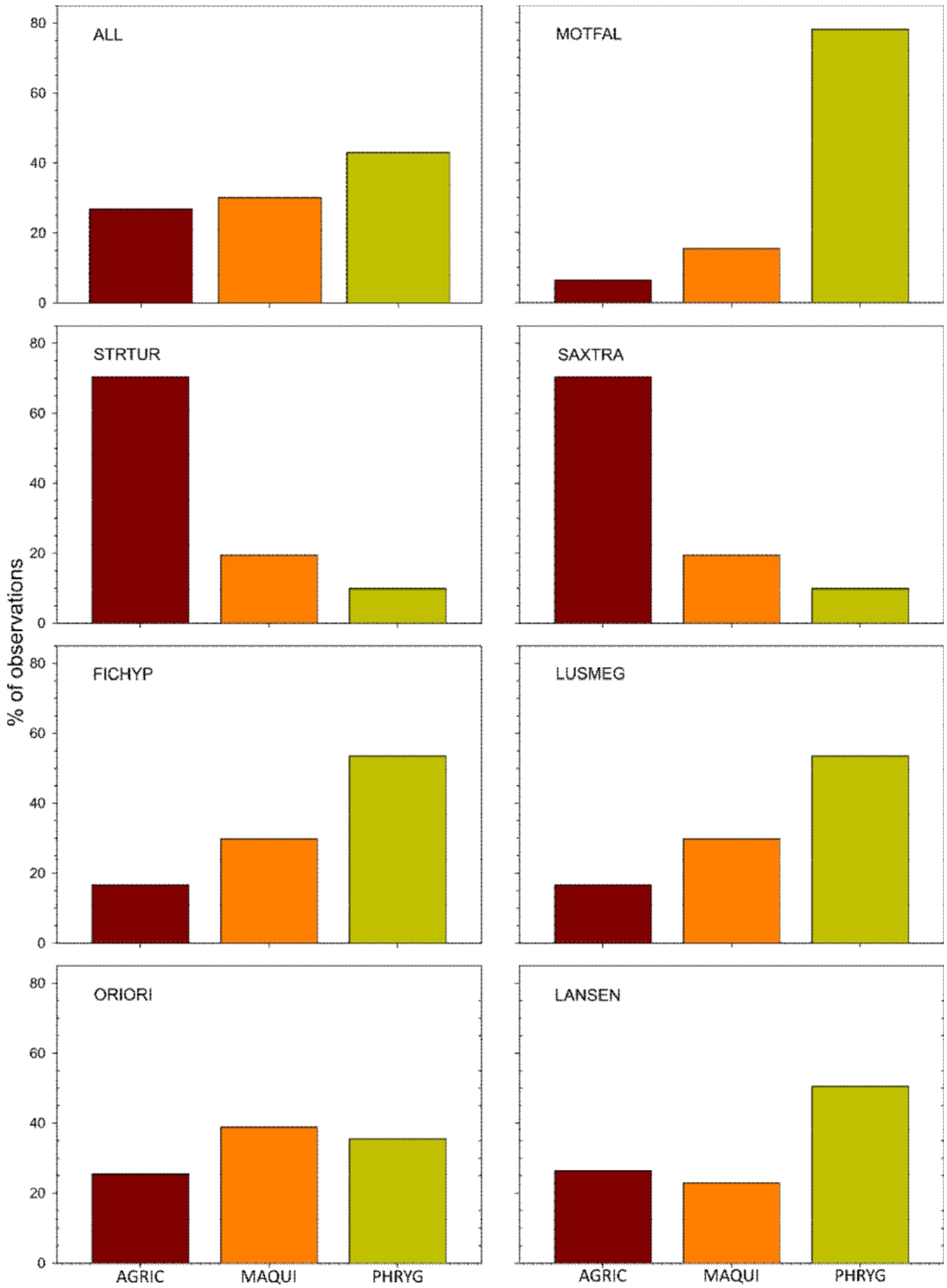
Codes of species as in Table 5. n.s: not significant, *: p<0.05, **:p<0.01, ***: p<0.001, Agr: Agricultural land, Phr: Phrygana, Maq: Maquis.

As shown from the above, and from the mist netting results too, both the species composition and the number of birds that use Antikythira as stopover during spring are much larger compared to autumn. On the other hand, during autumn even if bird abundance is lower, the target species are among the most common species present on the island.

Habitat use

In order to evaluate the habitat use of bird stopping over on Antikythira, the general habitat type of the transects used for the estimation of bird abundance was evaluated.

Even though the abundance of birds was clearly higher in agricultural land, there were no clear patterns regarding the overall habitat use as different species seemed to use different habitats (Fig. 11). Overall, 26.9% of the recorded birds used Agricultural land, 30.1% used Maquis and 43.0% used Phrygana. Habitat use though does not necessary reflect habitat preference as the most suitable habitat might be scarce (which is the case on Antikythira), and thus the birds are forced to use suboptimal habitat during their stopover.



% of observations
ALL
MOTFAL
STRTUR
SAXTRA
FICHYP
LUSMEG
ORIORI
LANSEN
0
20
40
60
80
AGRIC
MAQUI
PHRYG

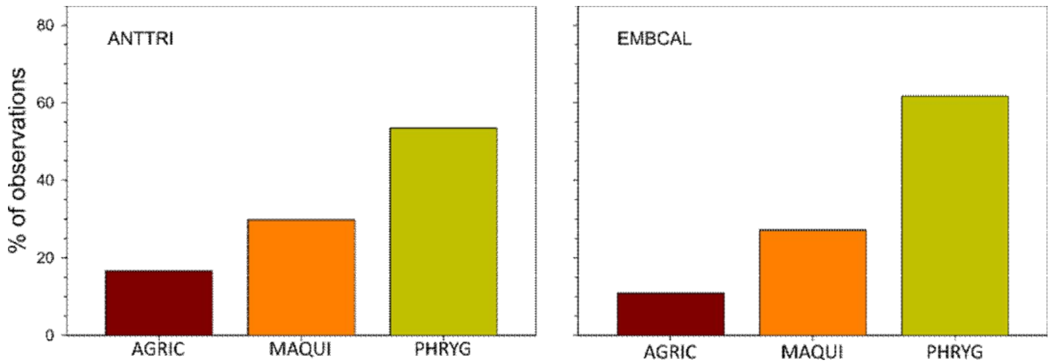


Figure 11. Habitat use by the observed birds. AGRIC: agricultural land, MAQUI: maquis, PHRYG: Phrygana. Codes of species as in Table 5.

Habitat selection

Microhabitat selection was estimated by using the tracking data available for birds with more than 10 localizations during their stopover. For each tracked bird with 10 or more localizations, the individual home ranges were estimated as 100% minimum convex polygons. In total, we used 481 positions belonging to 18 Woodchat Shrikes, 91 positions belonging to 6 Spotted Flycatcher and 163 belonging to 6 Golden Orioles. Micro-habitat selection was investigated by comparing habitat characteristics mapped within $4m^2$ squares centered around the localizations to an equal number of $4m^2$ squared centered around non-visited locations. Non-visited locations were selected within the 100% MCP of each bird, located at least 2 m from each other and at least 5 m from the localizations. The habitat coverage of the squares was mapped with an accuracy of 5%. Slightly different approaches regarding the habitat categories for each studies species were used in order to fit each species' ecological requirements and characteristics.

The habitat categories used for the habitat mapping of the Woodchat Shrike were:

1. Bare Ground (BG): No vegetation coverage
2. Low Grass and Herbal vegetation (LGr): Grass and herbal vegetation of mean height > 30 cm
3. High Grass and Herbal vegetation (HGr): Grass and herbal vegetation of mean height < 30 cm

4. Low Phrygana (LPh): Low woody vegetation cover, dominated by spaced, spiny and aromatic cushion-shaped shrubs. Mean height <0.4 m.
5. High Phrygana (HPh): Woody vegetation cover, dominated by spaced, spiny and aromatic cushion-shaped shrubs. Mean height 0.4 m – 0.8 m
6. Medium Maquis (MMa): Evergreen, sclerophyllous shrubs and trees of mean height 0.8 m – 1.5 m
7. Low Maquis (LMa): Evergreen, sclerophyllous shrubs and trees of mean height of < 0.8 m
8. High Maquis (HMa): Evergreen, sclerophyllous shrubs and trees of mean height of > 1.5 m

The habitat categories used for the habitat mapping of the Spotted Flycatcher and the Golden Oriole were the following:

1. Bare Ground (BG): no vegetation cover
2. Herbal vegetation (HV; Including grass)
3. Phrygana (Phr): Low woody vegetation cover, dominated by spaced, spinyand aromatic cushion-shaped shrubs
4. Cultivated land (Cult)
5. Low Maquis (LMa): evergreen, sclerophyllous shrubs and trees of mean height of <1 m
6. High Maquis (HMa): evergreen, sclerophyllous shrubs and trees of mean height of> 1 m

In the case of the Spotted Flycatcher an extra variable, the presence or absence of artificial poles was additionally used.

A generalized linear mixed model (GLMM) with a binomial error distribution (0=absence, 1= presence) was used (for each species separately) to analyze the occurrence of the three study species, with respect to the aforementioned habitat variables. GLMMs were built using a stepwise process after a modification for variable inclusion developed by Engler et al. (2004). More specifically, this process consists of adding sequentially variables (i.e. the habitat categories) to a null model based on how much reduction in residual deviance they cause (i.e. the variable with the largest residual deviance enters the model first). The process is repeated until all statistically significant variables enter the model. All models built during each step of the process were then compared according to the Akaike Information Criterion (AIC; Akaike 1974) and Akaike weight (Burnham and Anderson 2002), corrected for the sample size. Given the lack of multicollinearity (i.e., Spearman's correlation coefficient r <0.7), all habitat categories were initially considered in the model-building process.

Among all candidate models, the final model that best described habitat selection by three study species is presented in Tables 15-17.

Table 15. Estimated coefficients, weight and standard error (s.e.) for the variables of the most parsimonious model for the Woodchat Shrike.

Variable	Variable weight (descending order)	Coefficient (conditional average)	s.e. (conditional average)
BG	0.918	-3.797	0.841
HGr	0.918	-7.040	2.646
HMa	2.372	0.828	2.081
LGr	0.819	-1.338	0.695
LPh	0.918	-2.752	0.885
LMa	0.385	1.430	0.690
MMa	0.385	0.809	0.660
HPh	0.170	0.463	0.493

255 models in total of which 65 candidate ones (i.e. with statistical significant parameters). Model averaging based on 5 models (95% confidence model set, i.e. sum of AICc >=0.95)

Table 16. Estimated coefficients, weight and standard error for the variables of the most parsimonious model for the Spotted Flycatcher.

Variable	Variable weight (descending order)	Coefficient (conditional average)	s.e. (conditional average)
HV	0.916	-3.300	1.433
HMa	0.588	2.608	0.449
LMa	0.457	1.977	0.446
BG	0.412	-2.690	0.249
Cult	0.412	-2.663	0.449
Phr	0.366	-2.336	0.353

127 models in total of which 11 candidate ones (i.e. with statistical significant parameters). Model averaging based on 5 models (95% confidence model set, i.e. sum of AICc >=0.95)

Table 17. Estimated coefficients, and standard errors for the variables of the most parsimonious model for Golden Oriole

Variable	Coefficient	s.e.
HMa	12.594	2.723
LMa	11.086	2.761

31 models in total of which 15 candidate ones (i.e. with statistical significant parameters). Results based on one model (single best model, since its weight>0.95, thus no model averaging)

Regarding the Woodchat Shrike all candidate variables were included in the model. As it can be interpreted from Table 14, while the existing percentage of bare ground, grass (low and high) and low phrygana increases, the probability of occurrence decreases. Thus, the species is most likely to be observed in squares with high or medium-high vegetation with some openings of either low vegetation or bare ground.

Concerning the Spotted Flycatcher, probability of occurrence decreases with the increase in herbal vegetation, bare ground, cultivations and phrygana (low vegetation in general), while increases with an increase in maquis (high and low). The presence of artificial perches as fences and poles did not seem to influence the species' occurrence, as it was the only variable that was not included in the final (average) model.

Lastly, Golden Oriole seems to occur exclusively in squares with maquis vegetation, both low and high. Lower vegetation apparently is avoided by the species as the corresponding candidate variables (bare ground, herbal vegetation and phrygana) were not included in the final model.

Fuel deposition rate during migration

Fuel deposition rate was estimated as the percentage of body mass change between two capture events. As it can be seen form Fig. 12, the body mass gain during stopover in average was low during both spring and autumn migration seasons. During the spring season, most of the species showed a positive body mass gain, with only some individuals of Blackcaps loosing body mass during their stopover.

The situation is somehow different regarding the autumn season, as three out of six species, namely the Common Nightingale and the Willow Warbler and the Spotted Flycatcher, experienced body mass loss during their stopover on the island. Furthermore some individuals of the Garden Warbler lost body mass as well, but as an average the body mass gain for the species was positive.

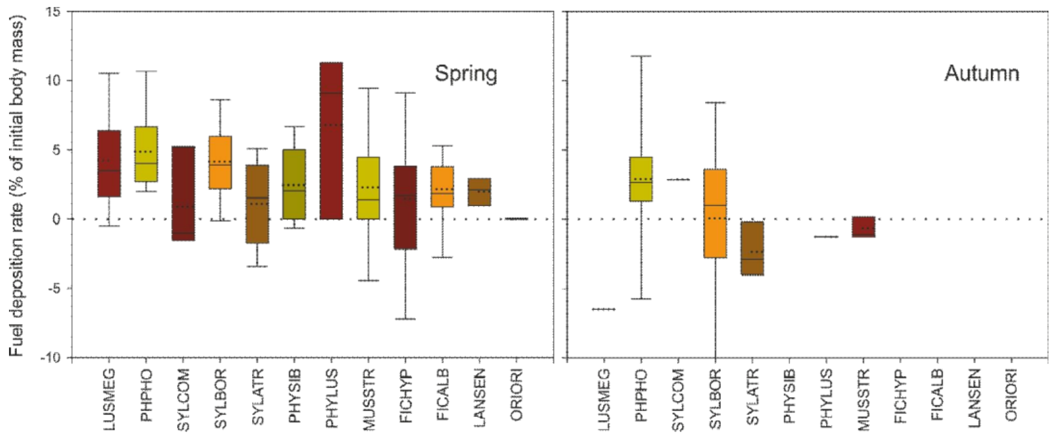


Figure 12. Fuel deposition rate of selected species expressed as percentage of body mass change during stopover on Antikythira during spring and autumn season. Were LUSMEG: Common Nightingale, PHOPHO: Common Redstart, SYLCOM: Common Whitethroat, SYLBOR: Gerden Warbler, SYLATR: Blackcup, PHYSIB: Wood Warbler, PHYLUS: Willow Warbler, MUSSTR: Spotted Flycatcher, FICHYP: Pied Flycatch

Climate Change and Bird Migration from the perspective of the Eleonora's Falcon

Three metrics were computed to quantify the full distributions of autumn migration phenologies for each species in each year, the 5th, 50th (median) and 95th 222 percentile dates. The Least squares linear regression models were fitted to quantify overall changes in early, median and late passage.

As can be seen from Fig.13, there is a general trend that late birds tend to pass through our study site earlier with the advancement of years. That means that the passage for all species of interest seems to be shorter. In the case of the common whitethroat and of all the birds pooled together this is more evident as the median date is also advancing.

These results indicate that there could be significant impact for the Eleonora's Falcon, as less and less prey will be available toward the end of their stay at the breeding site. This impact could be more sever for the first year birds, which in general leave the breeding colonies later than the adults and are less successful in hunting due to their lack of experience.

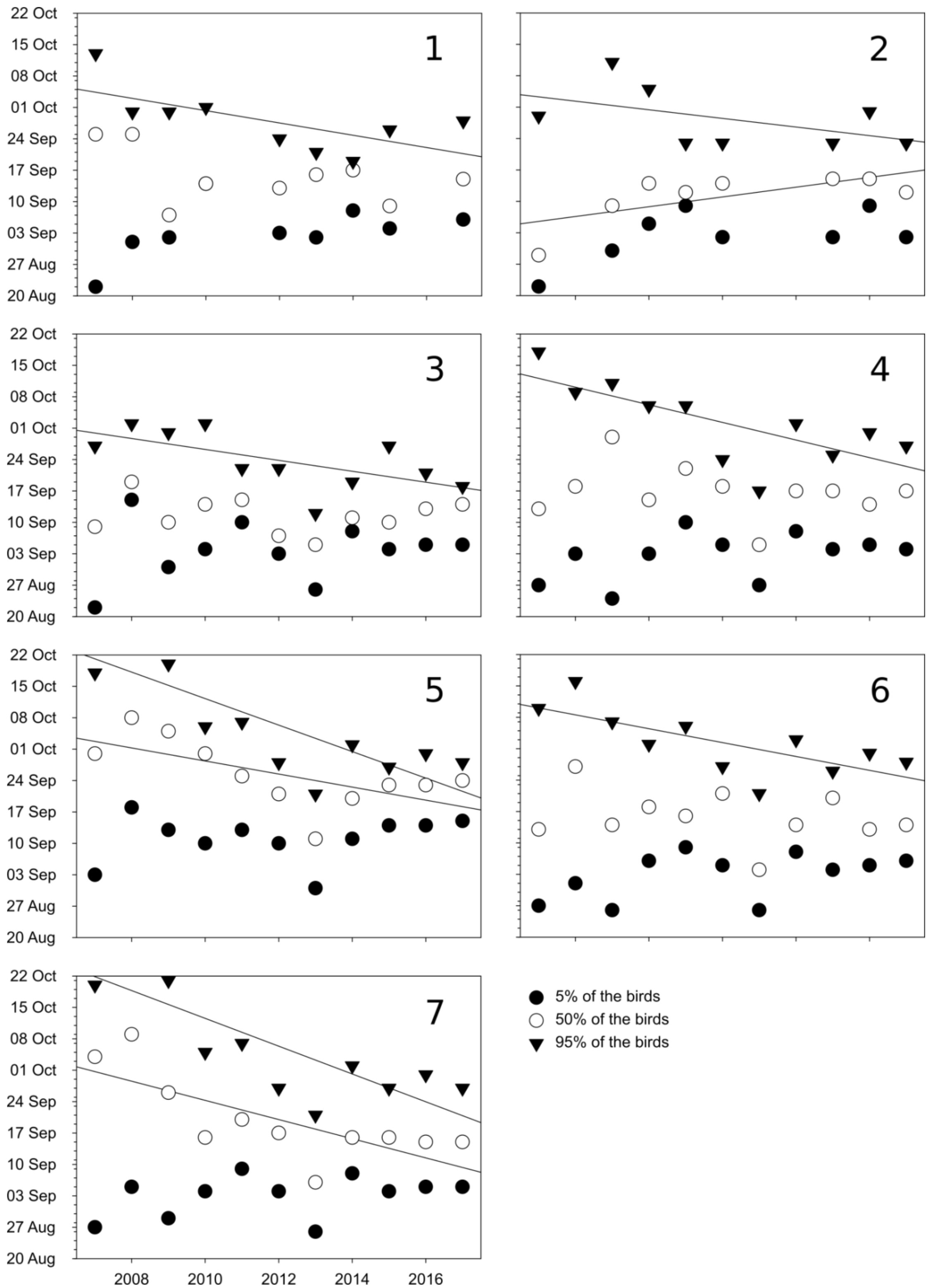


Figure 13. Changes of passage dates of migratory birds over the years. The regression lines indicate statistically significant results of the Least squares linear regression models. 1: Whinchat, 2: Red-backed shrike, 3: Willow warbler, 4: Spotted flycatcher 5: Common

whitethroat 6: Eurasian blackcap and 7: All trapped species pooled together.

GENERAL CONCLUSIONS

Due to its geographical position, in-between the African and the continental Greek coast, Antikythira is considered an exceptional stopover site for a wide variety of birds during both autumn and spring migration. The bird surveys conducted during both migratory seasons revealed that the island is used as a stopover site from an ample variety of species and a big number of birds during spring. During autumn, both the number of birds and species are fewer in comparison to spring. On the other hand, the most abundant species stopping over on Antikythira during autumn are the species that the existing information indicates as the main prey items for the Eleonora's Falcon. Furthermore, from the identification of the migration phenology through Antikythira the target species have a steady migration flow during autumn, providing constant prey availability for the Eleonora's Falcon. Likewise, during spring season the majority of known prey species are still migrating in high numbers when the Eleonora's Falcons have arrived to the island.

Stopover duration of birds on Antikythira depends on the season and the species under consideration. Stopover duration during spring is anticipated to be short as birds are expected to be in a time restrain to rapidly return to their breeding sites. There is no evidence indicating that stopover duration is shorter in spring comparing to autumn, even though the small sample size does not allow proper comparisons between the seasons.

Once birds have landed on the island, it seems that the most used and selected habitats from almost all the studied species are agricultural land and maquis vegetation (both high and low). Lower vegetation habitat types seem to play a secondary importance as they are either not selected or are not used as often by the observed birds. Whether the existing habitat preferences showed by the target species are a result of food availability, hunting strategies or anti predation behavior, cannot be told by the existing data.

Fuel deposition rates are in general low during both migratory seasons. It is expected that body mass gain will be restricted on Antikythira during spring as birds that stopover there have just crossed the Sahara desert and the Meditereann Sea. The migratory trip alone most often leads to major protein break downs that involve the digesting track, which could lead to depressed body mass change. Therefore, the low body mass rates recorded in the present study are not exclusively triggered by the lack of suitable habitat and food availability during spring.

During autumn, birds heading to their wintering grounds in sub-Saharan Africa are expected to prepare for the challenging barrier crossing (Mediterranean and Sahara desert), in advance. Except for some few species adapted to very dry environments, as those that can be found at the northern coast of Africa, all others should prepare in Europe before resuming their migration. However, there is no evidence that a significant refueling is taking place on Antikythira during autumn, not even for species like the Spotted Flycatcher that seems to stopover for several days; whether this is due to lack of prey availability or just a migration strategy cannot be explained by the data in hand.

To sum up, during the spring migration season, even though birds are expected to be in a hurry to reach their breeding grounds, passerines that arrive to Antikythira, stopover at the island for a short period during which they are refueling to a small but significant amount. Regarding the autumn season, even though Antikythira's location, just before the Mediterranean and the Sahara, is strategic for birds to prepare for the barrier crossing, there are no indications the target species are doing so. **The improvement of the available habitat for passerines will be therefore beneficiary for birds stopping over during both spring and autumn on the Island**. Regarding climate change effects, the negative consequences of the advancement of migration passage could be compensated in a small degree with the delay of arrival of the short distance migrant that arrive to the general area to winter. **Furthermore, the improvement of the habitat for migratory birds at the island (" Action C3 - oases for the migratory birds") will possibly prolong the stopover of the birds on the site and might even increase the number of birds wintering at the area.**

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