

Wintering monitoring of Woodcock (*Scolopax rusticola*) on the hunting area in Italy

Tuti M.¹, Rodrigues T.M.², Bongi P.^{3*}, Pennacchini P.⁴, Mazzarone V.⁵ and Sargentini C.¹

- ¹ TUTI Marco, University of Florence, Department of Agri-food Production and Environmental Sciences (DISPAA) – Anima Science, University of Florence, Via delle Cascine, 5, I-50144 Firenze, Italy; e-mail: marcotuti@outlook.it
- ² RODRIGUES Tiago M., Divisão de Caça Pesca e Parques Direção Regional dos Recursos Florestais Rua do Contador 23 9500-050 Ponta Delgada Açores Portugal; e-mail: tmgrodrigues@gmail.com
- ³ BONGI Paolo Hunting office ATC MS13, L.go Bonfigli 3/5, I-54011 Aulla (Massa-Carrara), Italy; ORCID ID: <https://orcid.org/0000-0002-6069-4265>; e-mail: paolo.bongi@atcms13.it
- ⁴ PENNACCHINI Paolo, FANBPO, "Fédération des Associations Nationales des Bécassiersdu Paléarctique Occidental" (president) and FIBec, "Federazione Italiana Beccacciai" (president), via Fausto Vagnetti 12, I-52031 Anghiari (Aezzo), Italy; e-mail: p.pennacchini@fanbpo.com
- ⁵ MAZZARONE Vito, Tuscany Region, Administral regional hunting office, via di Novoli 26, I-50127 Firenze; e-mail: vito.mazzarone@regione.toscana.it
- ⁶ SARGENTINI Clara, University of Florence, Department of Agri-food Production and Environmental Sciences (DISPAA) – Animal Science, University of Florence, Via delle Cascine, 5, I-50144 Firenze, Italy; e-mail: clara.sargentini@unifi.it

Abstract: There is a lot of discussion on the phenology of migration in both management and scientific literatures. Using abundance indices, several monitoring programs have looked into the existence of Western European bird species in various Palearctic regions. Our goal was to describe the Woodcock's presence in Italy both during the wintering phase and pre-nuptial migratory phase. We examined the information gathered between September and March between 2016 and 2021. The presence of woodcock in Italy and other regions of the Mediterranean basin might be compared thanks to the use of the "Indice Cynégétique d'Abondance" (ICA). Temperature and altitude have opposite effects on the abundance index. The monitoring data allowed for the identification of the Woodcock's preferred habitat in the Italian areas, which is a deciduous woodland. Woodcock presence increased from the end of September to late November, and it decreased in late January. The ICA, however, had a considerable increase at the end of February and the beginning of March, attesting to the presence as determined by the pre-nuptial migration period. These findings add significantly to our understanding of the phenology of woodcock migration, particularly for the Italian regions, and provide fresh perspectives for potential management strategies in the future.

Keywords: autumn migration; wintering; pre-nuptial migration; Mediterranean area; abundance indices; monitoring

Citation: To be added by editorial staff during production.

Academic Editor: Firstname
Lastname

Received: date
Accepted: date
Published: date

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Many birds are considered game species and their management choices require knowledge of population abundance to produce adequate hunting plan or hunting quotas, as requested by art. 7 of European Birds Directive n° 09/147. Regarding migratory species, the debate also concerns the area where populations' abundance should be monitored. Often, when the breeding areas are in remote places, the monitoring plans are very scarce [1].

The Eurasian Woodcock *Scolopax rusticola* (hereafter Woodcock) is a mostly migratory wader, widely distributed in the Palearctic [1, 2] whose breeding areas range from Fennoscandia to Eastern Russia [3, 4, 5, 6]. In Western Europe the distribution of

Woodcock is more fragmented and involves United Kingdom, Germany, France, Alps and Pyrenees Regions; some sedentary populations inhabit in northern Spain, the Azores, Madeira and Canary Islands [7].

The Mediterranean basin is an important wintering area for the Woodcock but, until now, monitoring programs addressing its' abundance during that period were developed in the UK [3], Spain [8, 9], France [10, 11, 12], or Portugal [13]. In Italy, some studies analysed age and sex ratio [14, 13, 15, 16].

On this species, population abundance is investigated with both methods, directly and indirectly (Bibby et al. 2000), even if in wintering areas are more common indirect evaluations, based on abundance indices [8, 13].

Abundances estimates could be obtained from an index derived by hunting trip [10] or another obtained from nocturnal banding trips [10, 17].

The abundance indices are widely used in ecology and into a monitoring program, because they are simple to calculate, easy to understand, and have a long history of application. Furthermore, abundance indices are better than species occurrence indices [18].

Several studies investigated the abundances of bird communities using abundance indices and highlighted spatial distribution, habitat preferences [19, 20, 21], richness biodiversity and effect of local environmental changes [i.e. 22, 23].

In this context, Woodcock monitoring programs are even more important, since they allow researchers to determine population abundance and correlate species richness with climatic, environmental, and anthropogenic changes.

Currently, the conservation status of Woodcock is evaluated as "Least Concern" in the red list of the International Union for the Conservation of Nature [24]. In Europe, the breeding trend appears stable [25]; the specie is classified as "hunnable" in the second annex of the EU directive 09/147 and, according to the most recent data, the European population is estimated between 15 and 20 million individuals [26, 27].

We analysed systematic data collected in Italy, by Woodcock hunters, between September 2016 and March 2021, in areas where Woodcock hunting was permitted.

The main goals were to investigate the Woodcock's wintering, and the pre-nuptial migration phenology, by examining the trend of its abundance from the beginning of the wintering season (first decade of September) till the end of March that could represent the last period of stay in the Mediterranean region.

This study, which was carried out with the same methodology and sample effort in the Italian regions, constitutes the first step in the creation of species monitoring programs that may cover the entire national territory.

2.Methods

Survey

We developed a monitoring program with the collaboration of Woodcock hunters, from September to March, 2016-2017 to 2020-2021, in Italy. The hunters were previously trained through qualification courses, whose contents were recognized and validated at ministerial level.

Each season we considered two periods: hunting period (September to January) and post-hunting period (February and March). In Italy, the Woodcock hunting is allowed from the third Sunday of September to the 31st of January. During these periods, the collaborators reported the following information for each hunting or monitoring trip: date, place (at Municipality scale), time (hours and minutes) spent hunting (in the post-hunting period), number of Woodcock flushed (their estimate of different birds), number of participants, number of pointing dogs used, temperature (recorded with personal smartphone), altitude (recorded with personal smartphone, for altitude bands of 500 meters), and vegetation type using three categories: deciduous wood, coniferous wood, brushland.

These data were submitted to an online database, named Beccapp (<http://www.beccapp.it>), where each hunter registers himself using personal username and password.

The information collected allows to estimate the abundance of Woodcock in the form of a hunting index of abundance (ICA - "Indice Cynégétique d'Abondance"; Fadat 1979), which corresponds to the number of different Woodcock flushed during a hunting trip, considering a standard duration of 3.5 hours, divided for the effective duration of the trip. Other two parameters have been used as divider in the calculation of ICA: the number of hunters and the number of pointing dogs involved in monitoring session [13].

Specifically, ICA is calculated as:

ICA: (number of different Woodcocks contacted / trip duration / number of participants / number of pointing dogs used) * 3.5

During the hunting period, according to Italian national law n° 157/92, the hunting trips can be carried out on the five weekly days (excluding Tuesdays and Fridays). In post-hunting period (from 1th February, or from the day of the closing of Woodcock hunting, to the 31st of March), the trips can take place on four fixed days per week (Tuesday, Friday, Saturday and Sunday).

Statistical analysis

We conducted an ANOVA test, using the habitat type as a covariate and the latitude of the monitoring municipality, recorded in decimal degrees, as the fixed factor, to examine the variation in the abundance index with respect to latitude.

We evaluated the variation in Woodcock abundance according to temperature, altitude and vegetation type in three independent zero-inflated negative binomial (ZINB) regression models, each including the number of Woodcock flushed as dependent variable, and the log of the duration of the trip as an offset. Because these data were not available across the entire dataset, we were not able to include these variables in further analyses.

The variation in Woodcock abundance was evaluated during and between seasons, with generalized additive mixed models (GAMM), with negative binomial error family, including the season, the day of the season as a "cycling" variable, the coordinates of the centroid of the commune where the hunting trip took place, the random effect of the hunter, and the log of the duration of the trip divided by the number of dogs and by the number of hunters participating in that trip, was included as an offset (to accommodate differences in sampling effort). We developed three models, full season (hunting period + post-hunting period), hunting period and post-hunting period.

All statistical analyses were performed in R 4.0.5 [28] and the significance of the test was considered at $p < 0.05$.

3. Results

A total of 36,443 trips registered in the Beccapp, were usable for the analyses, corresponding to 29,368 Woodcock hunting trips, with pointing dogs, during the hunting period from 2016-2017 to 2020-2021 (September-January of each hunting season), and 7,075 Woodcock monitoring trips, with pointing dogs (no shooting), during post-hunting period (in February and March) (Table 1).

Table 1. Number of hunting/monitoring trips registered per decade, per season.

Sampling	Month	decade	Season				
			2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Hunting period	September	-					
		2	2	7	1	5	1
	October	3	20	16	17	13	14
		4	71	81	109	150	141
		5	117	144	272	448	342

		6	278	436	438	729	766
November		7	291	555	746	983	932
		8	416	635	947	773	595
		9	312	416	831	926	571
		10	339	489	1016	964	580
December		11	272	321	676	770	1093
		12	281	381	833	894	399
		13	166	220	482	665	478
January		14	169	261	386	608	574
		15	209	205	251	371	466
		16	33	38	170	205	174
Post-hunting period	February	17	142	128	269	296	466
		18	96	164	271	468	582
		19	110	245	546	439	476
	March	20	170	243	230	13	433
		21	89	176	225	4	174

During these trips, over 131,590 hours were spent searching for Woodcock, in 1,588 of the 7,998 Italian communes (Figure 1), resulting in 55,467 contacts with individual birds.

The ANOVA model in which habitat type was a covariate and latitude a factor, did not explained significantly the ICA variation ($df = 1421$; $F = 2.953$; $p = 0.0.86$), and ICA showed similar values throughout the Italian peninsula (Fig. 1).

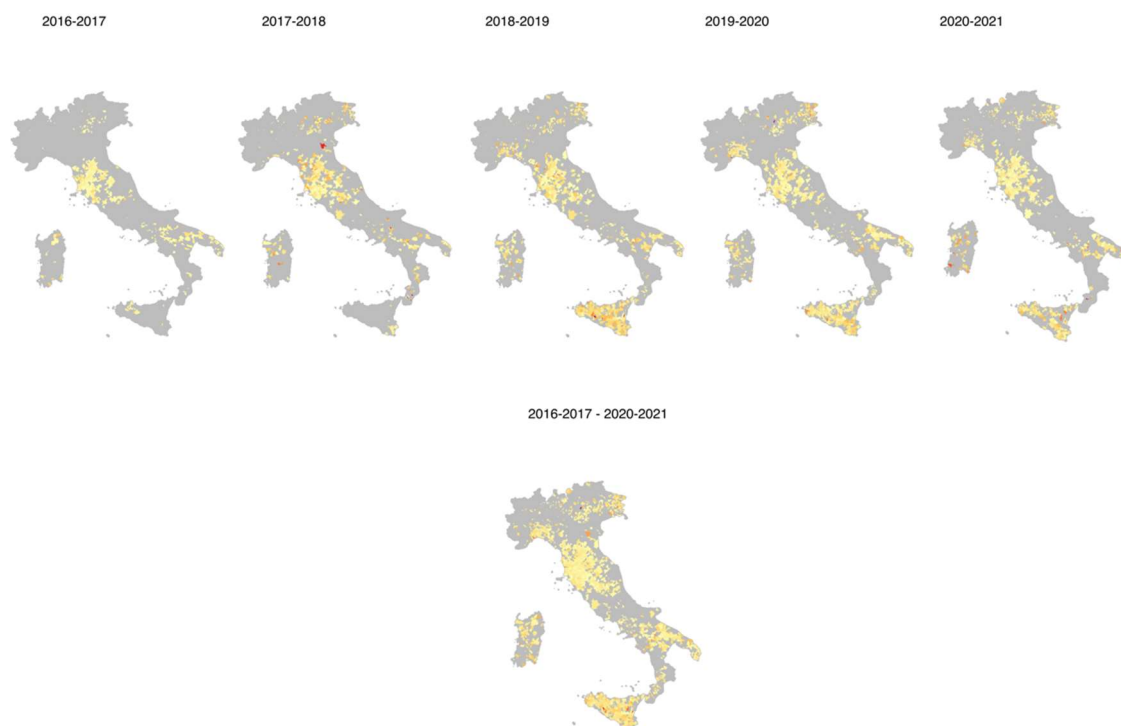


Figure 1. Spatial distribution of Woodcock abundance (Woodcock flushed/hour/hunter/dog) by Italian commune, by season (top row) and in average (2016-2017 to 2020-2021; bottom row). The warmer colours indicate higher abundance. Grey corresponds to non-available data.

The abundance of Woodcock increased with temperature (ZINB, $p < 0.001$; Fig. 2a), and decreased with altitude (ZINB, $p < 0.001$; Fig. 2b), and varied by habitat type (ZINB, $p < 0.001$; Fig. 2c), with coniferous wood having the lowest presence of Woodcock and deciduous wood having the highest ones.

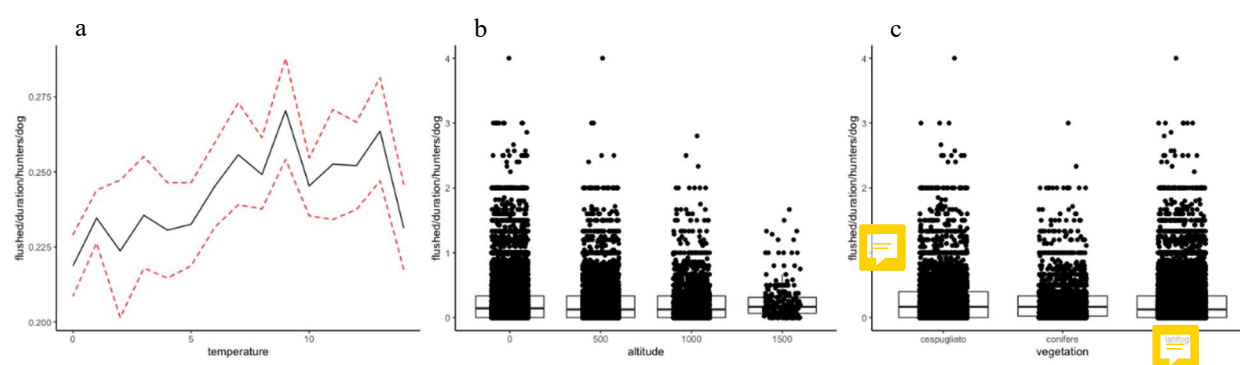


Figure 2. Variation of mean Woodcock abundance (Woodcock flushed per hour per hunter per hunting dog, solid line) by temperature (a, dashed lines correspond to CI 95%), altitude (b) and habitat type (c).

The results of the full season model (hunting period + post-hunting period) were nearly identical to those obtained with data limited to the hunting period (Table 2). The model exhibited some over-dispersion and explained 37.3% of the variance (1.36). The amount of Woodcock flushed was significantly affected by the hunter, the location, and the day of the hunting period (Table 2). Furthermore, these impacts appeared to be more relevant than seasonal variation, which was equally significant (Table 2).

Table 2. Result of the generalized additive mixed model (GAMM) of the number of Woodcock flushed.

	Edf	Ref.df	Chi square	p-value
Season	3.921	3.994	240.6	<0.001
Day	7.920	8.000	6593.7	<0.001
x,y	16.805	18.284	496.5	<0.001
Hunter	938.483	1263.000	13217.0	<0.001

The abundance of Woodcock decreased between 2016-2017 and 2017-2018 seasons, but after a significant recover, in 2018-2019, remained stable until 2020-2021 (Figure 3). For instance, the decrease from 1.0 in 2016-2017 to ~0.8 in 2017-2018 roughly corresponds to a decrease of 20%.

Finally, we considered Woodcock flushed during monitoring trips, in relationship to decades, to evaluate the trend of Woodcock abundance in both, hunting and post-hunting, periods.

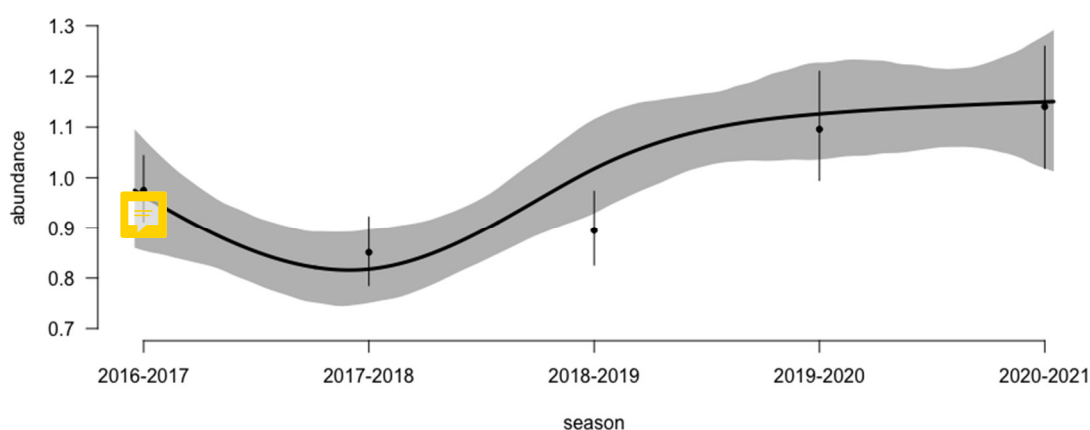


Figure 3. Variation of Woodcock abundance between seasons (2016-2017 to 2020-2021), fitted with a generalized additive mixed model. The grey area corresponds to the confidence interval 95%. The points show the random effect of the seasons and the vertical lines the respective confidence intervals 95%.

The abundance of Woodcock increases 4.75-fold from late September until around the decades nine and ten of the hunting period, which correspond to late November and the beginning of December, and it suffers a 0.84-fold decrease until the end of the hunting period, in late January. During the post-hunting period, the abundance suffers a slight increase; in late March, the Woodcock is still present in Italy, in a level of abundance 1.17-fold higher than in early February, right after the end of the hunting period (Tab. 3; Fig. 4).

Table 3. Result of generalized additive mixed models (GAMM) of the number of Woodcock flushed in Italy, between 2016 and 2021, during hunting (from September to January), and post-hunting (February and March) trips with pointing dogs. The deviance explained by each model is shown in brackets.

	Hunting period (37.7%)				Post-hunting period (31.1%)			
	Edf	Ref.df	Chi sq.	p-value	Edf	Ref.df	Chi sq.	p-value
Season	3.97	3.99	554.8	< 0.001	3.54	3.86	14.3	< 0.001
Decade	2.99	3.00	598.4	< 0.001	1.58	1.82	63.1	< 0.001
Commune	401.62	1,542.0	29,742.9	< 0.001	100.80	644.00	711.9	0.001
Hunter	769.51	1,058.0	52,924.6	< 0.001	417.60	742.00	2,749.9	< 0.001

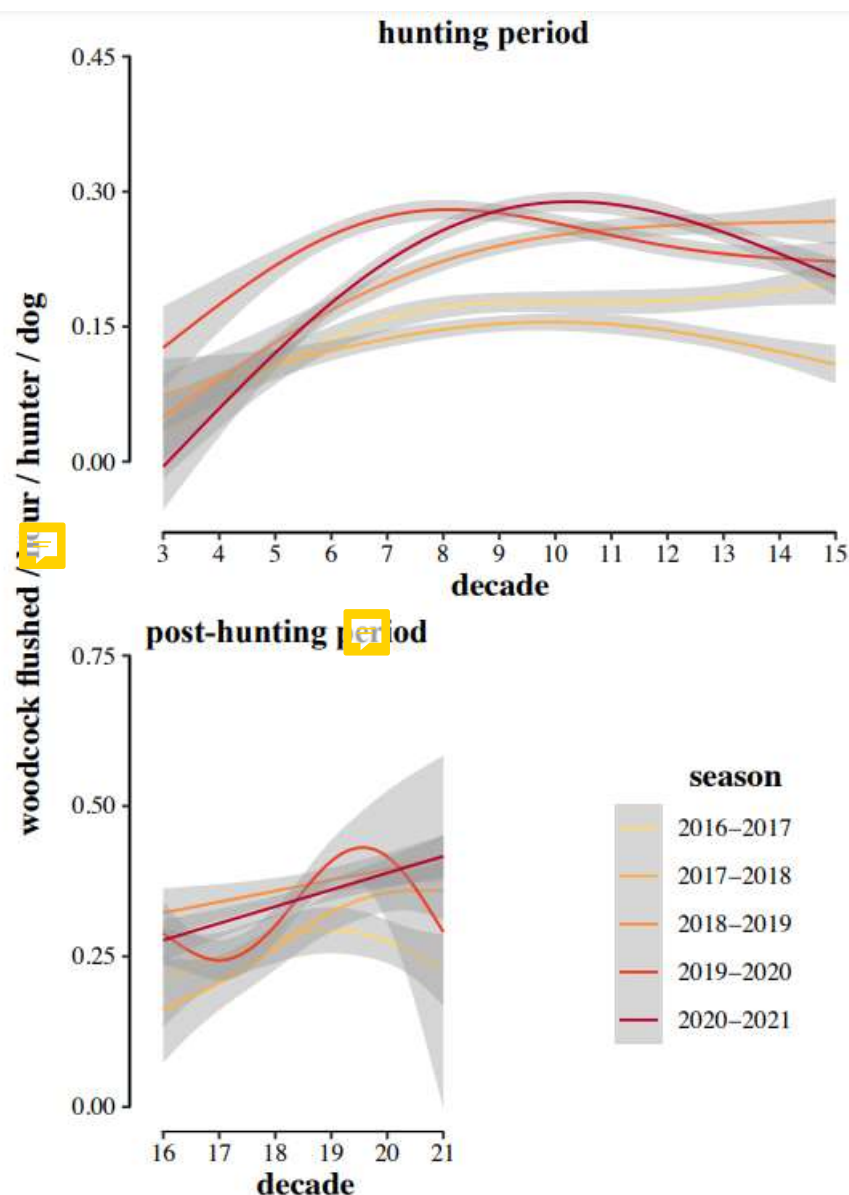


Figure 4. Variation of Woodcock abundance (Woodcock flushed per hour per hunter per hunting dog) along each decade, in both hunting and post-hunting periods, for different seasons (2016-2017 to 2020-2021). The grey areas correspond to confidence intervals 95%.

4. Discussion

The abundance indices have already been used in other studies relating to the migration phases of the Woodcock, and particularly in the wintering areas [29, 8]. We have investigated the presence of Woodcock in Italy considering the abundance and comparing the presence of the species in two sub-periods, the first between 31st January of September till 31st January, and the second one between 1st February to 31st March, for each year. The information gathered on an entire country (in our case Italy) provided crucial information for the understanding of the species and the management options to be implemented, even though these tracking programs may contain biases based on non-stratified and/or random sampling choices, or derived from collaborations with non-technical personnel, i.e. hunters [10].

Our results showed the lack of a latitudinal gradient linked to the presence of the Woodcock. Latitude is a good surrogate for representing factors that have biological importance to organisms [30], and positively affects the densities of many resident bird species [31]. However, it does not always have a major impact on the presence of

migratory species, as Woodcock is. As matter of fact, northern regions had abundance index values similar to southern and central regions, and different from those in other northern regions. This confirmed that migratory pathways run north-east/south-west, with the Italian peninsula positioned obliquely in relation to these patterns [32, 33]. On the other hand the Carpathian Mountains could represent a barrier for the migration of distinct populations. Woodcocks belonging to a Fennoscandian meta-population would migrate north of the Carpathians, while Woodcocks belonging to a Mediterranean meta-population would migrate south of the Carpathians [7]. This variability is also confirmed by the morphological difference that emerged between Woodcocks collected in the north areas and Woodcocks collected in the south areas during the hunting period [14]: the northern Woodcocks looked to have lighter plumage and greater body measurements, as pointed out also by Boidot [34].

The abundance variation suggest that temperature has an impact on the presence of Woodcocks, as it increased in direct proportion to the presence of milder winter temperatures, confirming the results obtained in France during 14 consecutive winters, from 1984/85 to 1997/98 [35].

A species that makes extensive use of wet and muddy areas may have different opportunities to find trophic supplies as a result of how the winter temperatures affected the soil's properties. The Woodcock selects habitats according on trophic availability, which is influenced by rain and other meteorological variables [36, 37, 35].

In Italy the trend of annual and seasonal average cumulative rainfall has not changed significantly over the past 60 years (1961-2020), but if we only consider the last 35 years (1985-2020), the annual and seasonal averages have increased steadily [38], primarily as a result of exceptional and sporadic meteorological events. According to this trend, rainfall is more in the winter and autumn, especially in the peninsular regions [39]. This could increase the availability of trophic resources.

This scenario might have enhanced the trophic resources available to Woodcock, which would have increased population abundance and length of stay in the Mediterranean basin. At the same time, the milder winters have made the alpine and pre-alpine areas favourable to wintering of the species, where in the past it was temporally present only during migration periods.

In addition to climate factors, between 1985 and 2015, Italy's forests grew by 28%, going from 8,675,100 hectares to 11,110,315 hectares. The forest gradually and consistently expanding until the percentage of land covered by woods has reached 38% [40], increasing the habitat available for Woodcock. Wooded hedges and coniferous wood represent an important habitat for wintering, especially during the daytime, because this habitat type showed high availability of refuge areas [41, 42, 37]. Even though during the night Woodcock preferred meadows for higher presence of earthworms, an important component of Woodcock's diet [43, 41, 44, 37].

The number of Woodcocks seen during the post-hunting period has steadily increased, and in the last three years, they have been comparable to those seen during the hunting period.

As concern the trend of abundance per decade, the positive values in the second decade of September could testify the presence of breeding contingents, especially in the Alps.

The first significant increase in abundance value occurs from the third decade of October to the second of November, the period of maximum post-nuptial migratory flux; the curve, however, even if a lesser extent, maintains an increasing trend until the second decade of December, defining the autumn migration period from mid-October to mid-December. Subsequently, even if the mean trend shows a continuous decrease till the end of January, the single seasonal curves show fluctuations which vary from season to season and are likely related to the meteorological trend. It was observed that some contingents move to south-southwest later and only if forced by waves of frost in the countries of origin, for example Balcan countries [45]. A similar behaviour was observed

during winter between France and Spain, where some Woodcocks change wintering site even in late season, like they resumed the migration [46]. Furthermore, in some particular conditions, Woodcocks concentrate in certain biotopes, making altitudinal shifts, changing exposure or reaching riparian or coastal areas. These movements can affect the value of the ICA if the hunting effort is also concentrated in these places.

The pre-nuptial migration period, on the other hand, is better delineated and described by a "bell" which starts from the second decade of February and reaches a peak in the second decade of March, maintaining high values even in the third decade. The higher average value of abundance in the monitoring period compared to the hunting season, it is due, as mentioned above, to a lower monitoring effort. However, it could depend by a higher concentration of Woodcocks too. The pre-nuptial migration, in fact, compared to the autumn, takes place in a shorter period of time (on average 40 days compared to 70 days of the post-nuptial migration), as evidenced by recent studies with satellite transmitters [33].

5. Conclusion

The migratory periods are showed by the peaks of the curves of abundance per decade, and they are included from the first decade of October to the second of December (post-nuptial migration) and from the second decade of February to the third of March (pre-nuptial migration).

A milder climate and an increase of precipitation especially in autumn and winter season, together to an expansion of forest surface, could be the explanation of the increase of the annual abundance of Woodcock in Italy, during the five years of study. A longer period will be necessary to outline a more realistic trend, even if our results gave a basis to investigate deeply the phenology of migration in Woodcock.

Some opportunistic movements are still possible during the wintering period, depending by the meteorological conditions changing, and this could be generate a variation in Woodcock presence in different part of Italy, consequently in Mediterranean areas.

The Woodcock has maintained a consistent presence in Italy throughout the winter, which is encouraging from the perspective of conservation. The stay until the beginning of spring has been confirmed in virtually every region of Italy, adding to worries regarding the precise timing of this species' pre-nuptial transit in the Mediterranean area.

Author Contributions: Conceptualization, T.M., P.P. and M.V.; methodology, T.M., B.P., and S.C.; validation, B.P. and R.T.M.; formal analysis, B.P. and R.T.M.; investigation, T.M., P.P. and M.V.; resources, P.P., M.V. and S.C.; data curation, R.T.M.; writing-original draft preparation, T.M., R.T.M., B.P., and S.C.; writing-review and editing, all authors; visualization, T.M., B.P., P.P., M.V., and S.C.; supervision, R.T.M.; project administration, P.P. and M.V. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We are grateful to the woodcock hunters who participated in this monitoring project. We also want to express our gratitude to their pointing dogs, who spent a lot of time searching for the woodcocks; without them, many of the woodcocks would not have been identified. Also acknowledged is FIBEC – Federazione Italiana Beccacciai – (the Italian Woodcock Hunters Federation), for its assistance in fostering respect for this species and advancing knowledge of woodcock.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ferrand, Y.; Gossmann, F. Elements for a Woodcock (*Scolopax rusticola*) management plan. *Game Wildl. Sci.* **2001**, *18*(1), 115-139.
2. Van Gils, J.; Wiersma, P.; Kirwan, G.M. Eurasian Woodcock (*Scolopax rusticola*), version 1.0. In *Birds of the World* del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A., de Juana, E., Eds; Cornell Lab of Ornithology, Ithaca, NY, USA. **2020** doi.org/10.2173/bow.eurwoo.01.
3. Hoodless, A.N.; Coulson, J.C. Survival rates and movements of British and continental Woodcock *Scolopax rusticola* in the British-Isles. *Bird Study* **1994**, *41*, 48-60.
4. Hagemeijer, W.; Blair, M. The EBBC atlas of European breeding birds. Their distribution and abundance. EBCC and AD Poyser, London, **1997**, pp 1-903.
5. Gossmann, F.; Fokin, S.; Iljinski, I. (2000) Ringing of Woodcock in Russia from 1991 to 1997. In *Fifth European Woodcock and Snipe Workshop*, Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group. Wetlands International Global Series No. 4, and International Wader Studies 11, Wageningen, Netherlands; Kalchreuter H. Eds. pp. 10-14
6. Bauthian, I.; Grossmann, F.; Ferrand, Y.; Julliard, R. Quantifying the origin of Woodcock wintering in France. *J. Wildl. Manage.* **2007**, *71*, 701 – 705
7. Ferrand, Y.; Gossmann, F. *La Bécasse des bois, Histoire naturelle*. Effet de lisière, Saint-Lucien, **2009**, pp. 1-224.
8. Guzmán, J.L.; Arroyo, B. Predicting winter abundance of Woodcock *Scolopax rusticola* using weather data: implications for hunting management. *Eur. J. Wildl. Res.* **2015**, *61*, 467-474 doi10.1007/s10344-015-0918-4.
9. Guzmán, J.L. Factores que modulan la abundancia invernal de la becada (*Scolopax rusticola*): implicaciones para su gestión y conservación. Universidad de Calatilla-La Mancha, IREC, PhD Thesis, **2013**.
10. Ferrand, Y.; Gossmann, F.; Bastat, C.; Guénézan, M. (2008) Monitoring of the wintering and breeding Woodcock populations in France. *Rev. Catalana. Ornitol.* **2008**, *24*, 44-52
11. Cau, J.F.; Boidot, J.P. (2003) Assessment of the abundance of Woodcock over the last ten hunting seasons in France. In *Sixth European Woodcock and Snipe Workshop*, Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group; Nantes, France, 25-27 November; Ferrand Y. Eds; Wageningen, Wetlands International, 2003, pp. 23-25.
12. Fadat, C. Estimation des variations relatives de densités de bécasses (*Scolopax rusticola*) par la méthode des indices cynégétiques d'abondance (I.C.A.). *Bull. Mens. Off. Nat. Chasse. N° Sp. Scine. Tech. Déc.*, **1979**, 71-110.
13. Gonçalves, D.; Rodrigues, T.; Pennacchini, P.; Lepetiti, J.P.; Taaffe, L.; Tuti, M.; Meunier, B.; Campana, J.P.; Gregori, G.; Pellegrini, A. Survey of Wintering Eurasian Woodcock in Europe. In *Proceedings of the Eleventh American Woodcock Symposium*, Kremenz D.G., Andersen D.E., Cooper T.R. Eds; **2019**, pp. 240-251.
14. Tuti, M.; Pennacchini, P.; Giannini, N.; Sargentini, C. Demographic structure of Woodcock (*Scolopax rusticola*) in Italy, ten years of observations 2010-2019 (In Italian). *Atti Soc. Tosc. Sci. Nat. Mem. Serie B*, **2021**, *128*, 29-37.
15. Aradis, A.; Landucci, G.; Tagliavia, M.; Bultrini, M. Sex Determination of Eurasian Woodcock *Scolopax rusticola*: a molecular and morphological approach. *Avocetta*, **2015**, *39*, 83-89.
16. Spanò, S.; Ghelini, A. Some results of a five years study on woodcock in Italy. Pages 127-131. In *Second European Woodcock and Snipe Workshop*, Proceedings of International Waterfowl Research Bureau, Slimbridge, Glos, England H. Kalchreuter H. Eds; **1983**, pp. 127-131.
17. Ferrand, Y.; Aubry, P.; Gossmann, F.; Bastat, C.; Guénézan, M. (2010) Monitoring of the European woodcock populations, with special reference to France. In *Proceedings of the Tenth American Woodcock Symposium*, Michigan Department of Natural Resources and Environment, Stewart C.A., Frawley V.R. Eds; Roscommon, Michigan, USA, **2010**, pp. 37-44.
18. Lamb, E.G.; Bayne, E.; Holloway, G.; Schieck, J.; Boutin, S.; Herbers, J.; Haughland, D.L. Indices for monitoring biodiversity change: Are some more effective than others? *Ecol. Indic.* **2009**, *9*, 432-444.
19. Canterbury, E.G.; Martin, T.E.; Petit, D.R.; Petit, L.J.; Bradford, D.F. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conserv. Biol.* **2000**, *14*(2), 544-558.
20. Guetté, A.; Gaüzère, P.; Devictor, V.; Jiguet, F.; Godet, L. Measuring the synanthropy of species and communities to monitor the effects of urbanization on biodiversity. *Ecol. Indic.* **2017**, *79*, 139-154.
21. Padhye, A.D.; Pingankar, M.; Dahanukar, N.; Pande, S. Season and landscape element wise changes in the community structure of avifauna of Tamhini, Northern Western Ghats, India. *Zoos'*, **2007**, *22*(9), 2807-2815.
22. Madden, H.; Van Zanten, A. Monitoring of terrestrial avifauna in six habitats on St. Eustatius, Caribbean Netherlands, 2009-2017. *Caribb. J. Sci.* **2020**, *50*, 23-36.
23. Chambers, L.E.; Hughes, L.; Weston, M.A. Climate change and its impact on Australia's avifauna. *Emu* **2005**, *105*, 1-20.
24. IUCN International Union for Conservation of Nature: annual report 2019. IUCN, **2019**, Eds; Gland, Switzerland pp. 1-52.
25. Wetlands International. *Annual reports and accounts*. **2011**, pp. 1-67. www.wetlands.org.

26. Wetlands International (2020)  *Waterbird Population Estimates*, Fifth Edition. Summary Report. Wetlands International, Wageningen, Netherlands, 2012, pp. 1-28. www.wetlands.org
27. BirdLife International. 2020. Species factsheet: *Ardea insignis*. Downloaded from: <http://datazone.birdlife.org/species/factsheet/White-bellied-Heron-Ardea-insignis>
28. R Core Team. 2021 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. <https://www.R-project.org/>
29. Birtsas, P.; Sokos, C.; Papaspyropoulos, K.G.; Batselas, T.; Valiakos, G.; Billini, C. Abiotic factors and autumn migration phenology of Woodcock (*Scolopax rusticola* Linnaeus, 1758, Charadriiformes: Scolopacidae) in a Mediterranean area. *Ital. J. Zool.* **2013**, *80*, 392-401.
30. Newton, I.; Dale, L. Relationship between migration and latitude among west European birds. *J. Anim. Ecol.* **1996**, *65*, 137-146.
31. Forsman, J.T.; Mönkkönen, M. The role of climate in limiting European resident bird populations. *J. Biogeog.* **2003**, *30*, 55-70.
32. Spina, F.; Volponi, S. *Atlas of bird migration in Italy. Vol. 1. Non-Passerines* (In Italian). Eds; Ministero dell'Ambiente, ISPRA, Tipografia SCR, Roma, **2008**, pp. 1-32.
33. Tedeschi, A.; Sorrenti, M.; Bottazzo, M.; Spagnesi, M.; Telletxea, I.; Ibáñez, R.; Tormen, N.; De Pascalis, F.; Guidolin, L.; Rubolini, D. Interindividual variation and consistency of migratory behavior in the Eurasian Woodcock. *Curr. Zool.* **2020**, *66*(2), 155-163 doi: 10.1093/cz/zoz038.
34. Boidot, J.P. *Mystérieuse et Fascinante Bécasse des bois*. Naves Editions Imprimerie du Corrèzien, Tome III, **2012**, pp. 40-45.
35. Tavecchia, G.; Pradel, R.; Gossman, F.; Bastat, C.; Ferrand, Y.; Lebreton, J.D. Temporal variation in annual survival probability of the Eurasian Woodcock *Scolopax rusticola* wintering in France. *Wildl. Biol.* **2002**, *8*, 21-30
36. Doherty, K.E.; Andersen, D.E.; Meunier, J.; Oppelt, E.; Lutz, R.S.; Brug, J.C. Foraging location quality as a predictor of fidelity to a diurnal site for adult female American Woodcock *Scolopax minor*. *Wildl. Biol.* **2010**, *16*, 379-388. doi:10.2981/09-100
37. Duriéz, O.; Ferrand, Y.; Binet, F.; Corda, E.; Gossmann, F.; Fritz, H. Habitat selection of the Eurasian woodcock in winter in relation to earthworms availability. *Biological. Conservation.* **2005**, *122*, 479-490.
38. Fioravanti, G.; Frascchetti, P.; Lena, F.; Perconti, W.; Piervitali, E.; Pavan, V. *Climate indicators in Italy in 2020*. (In Italian) ISPRA Eds; **2021**, pp. 1-76.
39. Colombo, T.; Pelino, V.; Vergari, S.; Cristofanelli, P.; Bonasoni, P. Study of temperature and precipitation variations in Italy based on surface instrumental observations. *Global Planet Change* **2007**, *57*(3-4), 308-318. doi:10.1016/j.gloplacha.2006.12.003.
40. Gasparini, P.; Floris, A.; Rizzo, M.; Patrone, A.; Credentino, L.; Papitto, G.; Di Martino, D. (2021) The third Italian national forest inventory INFC 2015: procedures, tools and applications (In Italian). *GEOmedia* **2021**, anno XXIV n. 6/2020= 6-16. ISSN 1128-8132.
41. Wilson, J. Wintering site fidelity of woodcock in Ireland. In *Second European Woodcock and Snipe Workshop* International Waterfowl Research Bureau, Slimbridge UK, Kalchreuter H. Eds; **1983**, pp. 18-27.
42. Imbert, G. Distribution spatio-temporelle des Bécasses (*Scolopax rusticola*) dans leur habitat diurne, en forêt domaniale de Boulogne-sur-mer (Pas-de-Calais) France. In 3ème Symposium Européen sur la Bécasse et la Bécassine Paris, 14-16 Octobre, Havet P., Hirons G. Eds; **1988**, pp. 53-59.
43. Hirons, G.; Bickford-Smith, P. The diet and behaviour of Eurasian woodcock wintering in Cornwall. In *Second European Woodcock and Snipe Workshop*, International Waterfowl Research Bureau, Slimbridge, UK, Kalchreuter H. Eds; **1983**, pp 11-17.
44. Binet, F. *Dynamique des peuplements et fonctions des lombriciens en sols cultivés tempérés*. Thèse de doctorat, Université de Rennes 1, Rennes, France, **1993**.
45. Tuti, M.; Gambogi, R.; Galardini, A. The Eurasian Woodcock (*Scolopax rusticola*) At San Rossore Estate (Migliarino San Rossore Massaciuccoli Regional Park, Tuscany, Italy): A Four Years Study (In Italian). *Atti Soc Tosc Sci Nat, Mem, Serie B* **2017**, *124*, 109-119.
46. Péron, G.; Ferrand, Y.; Gossmann, F.; Bastat, C.; Guénézan, M.; Gimenez, O. (2020)  Escape migration decisions in Eurasian Woodcocks: insights from survival analyses using large-scale recovery data. *Behav. Ecol. Sociobiol.* **2011**, *65*, 1949-1955 doi: 10.1007/s00265-011-1204-4.