Wildlife Biology

WLB-00806

Godin, S., Reitz, F., Bacon, L. and Bro, E. 2021. Recent changes in the reproductive success of farmland birds: conservation and management implications. The declining grey partridge *Perdix perdix* as a case study. – Wildlife Biology 2021: wlb.00806.

Appendix 1-2

Appendix 1. Script of the model (Unified Life-cycle Model software)
https://www.biologie.ens.fr/~legendre/ulm/ulm.html

```
{ the model simulates a population of grey partridges in a close hunting estate
{ we assume that all females pair

defmod perdix(1)
rel : rn

defrel rn
n = adspring
{n is the number of females at time t in early spring


{ the initial population size is 150 females on the whole area: n = initialdensity * area)
{ area of the hunting estate (in km²)
defvar area = 30

{ initial density / population size
defvar initialdensity = 5

defvar n =150

{ density at time t
defvar density = n / area


{ ***** SURVIVAL RATES *****
{ survival of adult females over spring and summer: Sss
defvar Sss= max(min(gaussf(0.47, 0.134),0.933),0.352)

{ survival of adult females over autumn and winter: Saw
defvar Saw= 0.6


{ ***** REPRODUCTIVE SUCCESS *****
{ probability of each category 'high', 'medium' and 'low' mean reproductive success (mRS): ph, pm, pl
defvar ph= 0.23

defvar pm= 0.54

defvar pl= 0.23

{ random draw of the category of reproductive success of year t
{ high mRS: x=0; medium mRS: x=1; low mRS: x=2
defvar x= tabf(ph,pm,pl)

{ number of surviving females in late summer:  adsummer
defvar adsummer = binomf(n, Sss)

{ number of females at the time of the "birth-pulse" (late July, i.e. when coveys are monitored): adjuly
defvar adjuly = round(1.134*adsummer)

{ all females pair but only a part of them have offspring in summer -> number of females with offspring, depending upon
the category of the mean reproductive success
{ high mRS: bh; medium mRS: bm; low mRS: bl
defvar bh = round(adjuly - (0.25*adjuly))

defvar bm = round(adjuly - (0.40*adjuly))

defvar bl = round(adjuly - (0.50*adjuly))


{ NUMBER OF OFFSPRING (OF BOTH SEXES) YEAR t

{ number of offspring (produced for each category of mean reproductive success before any density-dependent process
{ high mRS: juvh; medium mRS: juvm; low mRS: juvl
{ the mean brood size depends on the category of the mean reproductive success
defvar juvh = poissonf(bh, 8.8)

defvar juvm = poissonf(bm, 7.6)
```

```
72
73  defvar juvl = poissonf(bl, 6.5)
74
75
76  { ***** DENSITY-DEPENDENCE *****
77  { density-dependence is assumed to occur when spring density is higher than a density threshold (pairs/km²)
78  defvar thresholdDD = 30
79
80  { number of offspring if density-dependence
81  { high mRS: juvhDD; medium mRS: juvmDD; low mRS: juvlDD
82  defvar juvhDD = if((density)>thresholdDD, max(round(juvh-(45*(n/area))), 0), juvh)
83
84  defvar juvmDD = if((density)>thresholdDD, max(round(juvm-(45*(n/area))),0), juvm)
85
86  defvar juvlDD = if((density)>thresholdDD, max(round(juvl-(45*(n/ area))), 0), juvl)
87
88  defvar juveniles = if (x, if(x-1,juvlDD,juvmDD),juvhDD)
89
90
91  { mean reproductive success
92  defvar mRS = juveniles/adsummer
93
94
95  { FEMALE POPULATION SIZE BEFORE THE HUNTING SEASON
96  defvar SexRatio = 0.5
97
98  defvar offspring = round(juveniles * SexRatio)
99
100 defvar nPreHunting = offspring + adsummer
101
102
103 { ***** HUNTING MODULE *****
104 { hunting bag management scenarios: max number of birds that can be shot, depending upon both the mRS and the
105 density of the local population
106
107 { indexes to code the grid of hunting quotas
108 { index for mSR: 0, 1, 2, 3, 4
109 defvar nindr = if(mRS<2.5, 0, if(mRS<3, 1, if(mRS<3.5, 2, if(mRS<4, 3, 4))))
110
111 { index for density: 10, 20, 30,40, 50
112 defvar nbpairs = if(density<5, 10, if(density<10, 20, if(density<20, 30, if(density<40,40,50))))
113
114 {index compiling the 2 previous indexes: 10-14, 20-24, 30-34, 40-44, 50-54
115 defvar ird = nindr + nbpairs
116
117 { weighting grid
```

	no hunting	scenario 1 (hunting plan, Eure-et-Loir)	scenario 2 (hunting plan, modified)	scenario 3[1] (hunting plan, modified)		scenario 4 (MB/H-S, example)
				mSR(t-1) ≥3.5	mSR(t-1) <3.5	
defvar nc0 =	0	0	0; 2*area for ird=14	0	0	0; 1 for ird=14, 41 and 50
defvar nc1 =	0	2*area	2*area	2*area	0	1
defvar nc2 =	0	0.1*n	0.1*n	0.1*n	0	1
defvar nc3 =	0	0.2*n	0.2*n	0.2*n	0	1; 4 for ird=51
defvar nc4 =	0	0.3*n	0.3*n	0.3*n	0	2; 3 for ird=42
defvar nc5 =	0	0.4*n	0.4*n	0.4*n	0	2
defvar nc6 =	0	0.5*n	0.5*n	0.5*n	0	5
defvar nc7 =	0	0.75*n	0.75*n	0.75*n	0	5
defvar nc8 =	0	1*n	1*n	1*n	0	5 * number of hunters (60)

```
118
```

[1] For this scenario, make the following changes into the script:
Line 8: add ', rHuntingYearYES'
Line 13: insert 'defrel rHuntingYearYES'
Line 14: insert 'HuntingYearYES= max(Next-1, 0)'
Line 126: insert
'defvar HuntingYearYES= 1
defvar HuntingYearNO = 2
defvar Next = if(x>1, HuntingYearNO, HuntingYearYES)
defvar quotaBIS = if(HuntingYearYES<1, quota, 0)'
Line 219: change quota into quotaBIS

```
{ hunting bag
defvar quota = if(ird<11, nc0, if(ird<12, nc0, if(ird<13, nc0, if(ird<14, nc0, if(ird<15, nc0, if(ird<21, nc0,if(ird<22, nc0,
if(ird<23, nc1, if(ird<24, nc1, if(ird<25, nc1, if(ird<31, nc0, if(ird<32, nc0, if(ird<33, nc3, if(ird<34, nc4, if(ird<35, nc5,
if(ird<41, nc0, if(ird<42, nc2, if(ird<43, nc4, if(ird<44, nc6, if(ird<45, nc7, if(ird<51, nc0, if(ird<52, nc3, if(ird<53, nc6,
if(ird<54, nc7, nc8)))))))))))))))))))))))) * SexRatio


defvar CompletionRate = 0.30

defvar nPostHunting = round(nPreHunting - (quota*CompletionRate))

defvar adspring = binomf(max((nPostHunting), 0), Saw)
```

Appendix 2

Period	CategoryOfRS	mBS	proportion
Present	high	0	0,259075908
Present	medium	0	0,444423077
Present	low	0	0,582450832
Present	high	1-3	0,068481848
Present	medium	1-3	0,101153846
Present	low	1-3	0,123550177
Present	high	4-6	0,145214521
Present	medium	4-6	0,148653846
Present	low	4-6	0,15279879
Present	high	7-9	0,211221122
Present	medium	7-9	0,142692308
Present	low	7-9	0,091275845
Present	high	10-12	0,184818482
Present	medium	10-12	0,103076923
Present	low	10-12	0,037317196
Present	high	13+	0,131188119
Present	medium	13+	0,06
Present	low	13+	0,012607161
Past	high	0	0,25216763
Past	medium	0	0,397366471
Past	low	0	0,504944868
Past	high	1-3	0,085500963
Past	medium	1-3	0,097474776
Past	low	1-3	0,121405024
Past	high	4-6	0,148121387
Past	medium	4-6	0,147010203
Past	low	4-6	0,145163124
Past	high	7-9	0,201950867
Past	medium	7-9	0,159721826
Past	low	7-9	0,123223826
Past	high	10-12	0,17015896
Past	medium	10-12	0,11999088
Past	low	10-12	0,071615323
	high	13+	0,142100193
	medium	13+	0,078435843
	low	13+	0,033647834