Ptarmigan Stock Assessment for 2024

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Executive Summary

This document provides the most recent results of integrated population models (IPMs) for rock ptarmigan in the six hunting regions of Iceland. It also provides optimal harvest strategies and the optimal length of the hunting season in each of the regions for 2024. Populations sizes in spring 2024 were somewhat larger than in 2023, except in the South and West regions where small declines were observed (Fig. S1). Productivity in 2023 was near to below average in all regions. Fall population sizes in 2023 were higher than those in 2022 except in the West (Fig. S-2). All fall population sizes in 2023 were higher than average. Hunter effort and harvest rates during the 2023 season were much lower than average in all regions, and harvest rates have generally been declining since 2005. The low harvest rates in 2023 help explain why spring populations mostly did not decline in spite of only average to below-average production. Based on a harvest management objective that seeks to balance hunting opportunity and ptarmigan abundance, the optimal season lengths for the 2024 hunting season are: East – 45 days; Northeast – 20 days; Northwest – 20 days; South – 20 days; West – 20 days; and Westfjords – 25 days. The optimal harvest strategies and the season lengths they prescribe are adaptive, in the sense that they will "evolve" over time as experience with varying season lengths is accumulated.

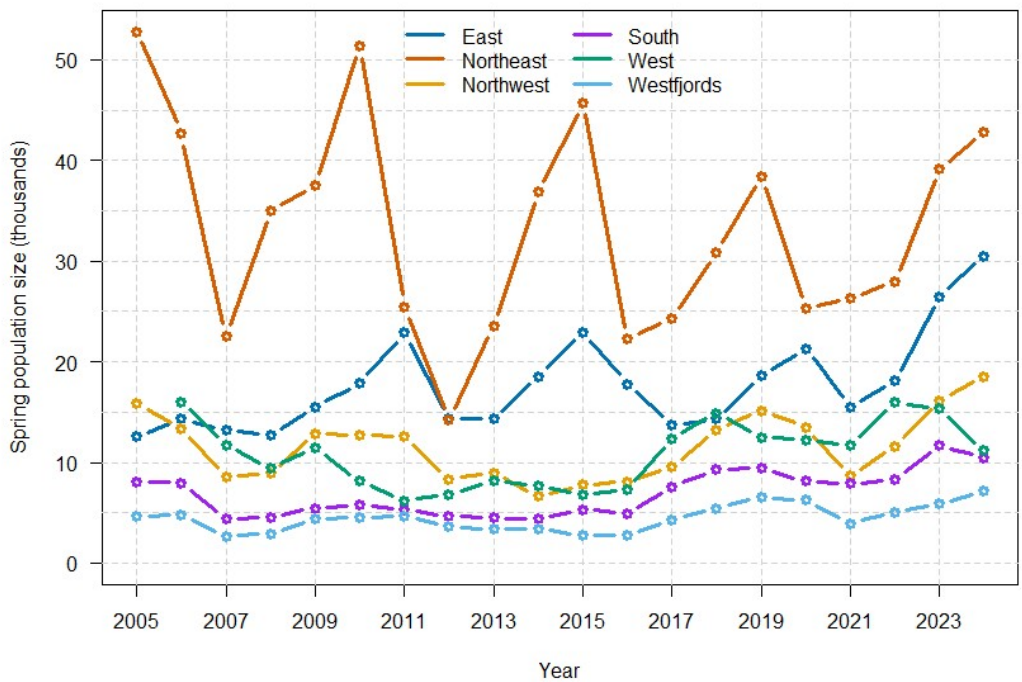

Fig. S-1. Spring population estimates of ptarmigan in six hunting regions of Iceland as derived from IPMs. Credible intervals have been omitted to avoid visual clutter.

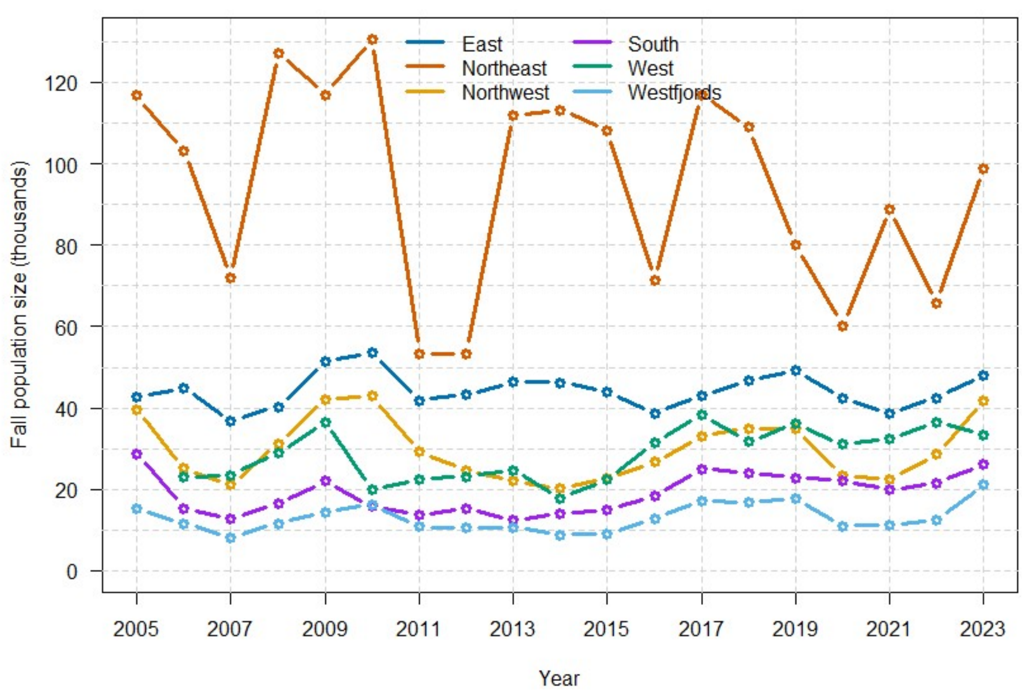

Fig. S-2. Fall population estimates of ptarmigan in six hunting regions of Iceland as derived from IPMs. Credible intervals have been omitted to avoid visual clutter.

Population Status and Demography

We relied on ptarmigan monitoring data collected and compiled by the Icelandic Institute of Natural History and the Environment Agency to update the integrated population models (IPMs) developed in 2023. We partitioned data into six regions used for setting hunting seasons in Iceland: East, Northeast, Northwest, South, West, and Westfjords (Fig. 1). For each region, we compiled transect-based estimates of spring abundance, hunting-season age ratios, spring age ratios (where and when available), total harvests, and the number of days afield by hunters.

For each hunting region, we used the same basic structure for population dynamics of the spring breeding population:

$$N_{t+1} = N_t \cdot s_t \cdot (1 - h_t) \cdot [r_t \cdot w_t + s_t]$$

where N_t is population size at time t, s is a six-month survival of adults from natural causes, h is harvest rate, r is reproductive rate (i.e., post-breeding ratio of juveniles to adults), and w is winter (6-month) survival of juveniles from natural causes. We assume that natural mortality of adults is evenly distributed throughout the year. The post-breeding (fall) population can be defined as:

$$F_t = N_t \cdot s_t \cdot [1 + r_t]$$

In each region, the first spring is in 2005 (2006 in the West) and the last spring is in 2024. Thus, the last fall and winter begins in late 2023.

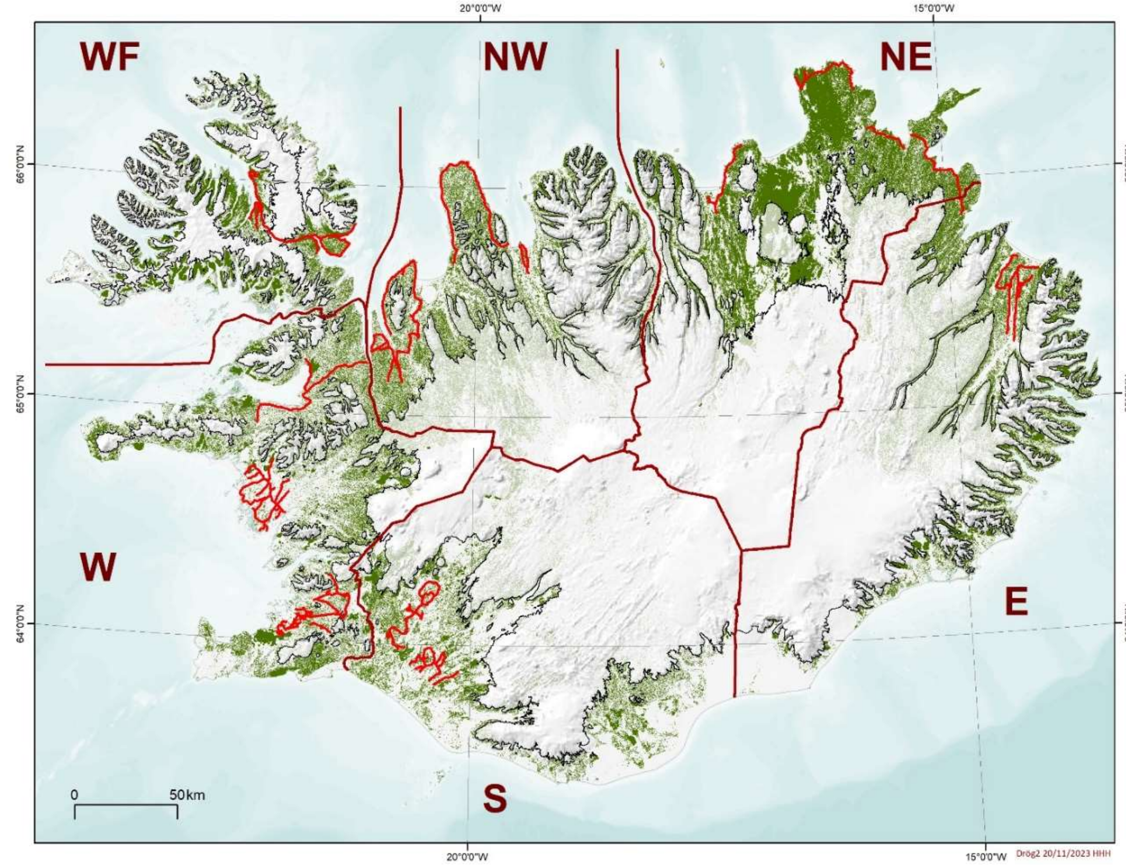

Fig. 1. The six hunting regions in Iceland (dark red), areas of ptarmigan habitat (green), and road transects used to estimate ptarmigan densities (bright red). The thin black line represents the 400m a.s.l. contour line. E – East, NE – Northeast, NW – Northwest, S – South, W – West, and WF – Westfjords.

Reproductive rate was defined as being potentially density dependent:

$$r_t = e^{(\beta_0 + \beta_1 N_t + \varepsilon_t)}$$

where β_0 is the intercept and β_1 is the slope and $\varepsilon_t \sim N(0, \sigma^2)$ is a random-year effect

We modeled harvest rate as a function of hunter-days as:

$$h_t = 1 - e^{-c(hunter\_days)}$$

where c is a "catchability" coefficient.

The IPMs are updated annually as monitoring data are accumulated. The reader should be aware that all estimates from updates of the IPMs may differ from those reported previously. This is because the IPMs use the complete set of monitoring data each year to better estimate population size and demography for the entire period of record. More details about the methods used to fit the IPMs are available upon request from the author at fred.johnson@ecos.au.dk.

Harvest Strategies

We calculated optimal, regional harvest strategies for ptarmigan that account for environmental variation in survival and recruitment. The harvest strategies are state dependent, meaning they provide an optimal season length for each spring ptarmigan abundance that might be observed. The strategy is adaptive in the sense that it is updated each year based on an update of the IPM (using the most recent monitoring data). We used the computation algorithm called stochastic dynamic programming, which can explicitly account for various sources of uncertainty in modeled systems. For each region, we parameterized annual variation in seasonal survival of adults and juveniles, and annual variation is post-breeding age ratio not explained by changes in spring population size, based on posterior distributions from the regional IPMs. A management objective that balances the tradeoff between hunting opportunity and ptarmigan abundance was used to derive optimal harvest strategies (Umhverfisstofnun | Rjúpa (ust.is)). We considered season lengths in increments of 5 days up to a maximum of 45 days. Finally, we note that optimal season lengths might be different in two regions even if the spring population sizes are the same. This is because the harvest strategies account for not only population sizes but regional differences in demography and hunting pressure.

Each region's harvest strategy is also adaptive with respect to the uncertainty about how season length affects ptarmigan harvest rates. For each region, there are two hypotheses: H0, which predicts that harvest rates continue to increase with season lengths beyond those observed since 2005; and H1, which predicts that harvest rates remain largely unchanged with increases in season length:

$$\mathrm{H0}: h_t = \frac{season_t}{b_1 * season_t}$$

$$\mathrm{H1}: h_t = \frac{a_2 * season_t}{b_2 * season_t}$$

where h is harvest rate, $season$ is season length in days, t is year, and b_1, a_2, and b_2 are parameters to be estimated. The two hypotheses are re-fitted to the data with each annual update of the IPMs, and then weighted based on their ability to fit empirical data. A weighted average of the two hypotheses is used to calculate optimal season lengths. Because the two hypotheses are updated each year as the results become available from each hunting season, the harvest strategy can "evolve" over time based on experience gained with varying season lengths.

East Region

The spring population size in 2024 of about 30 thousand in the East is somewhat higher than that in 2023, and well above the average of about 18 thousand (Table 1, Fig. 2). Despite relatively low productivity in 2023 (Fig. 3), the spring population did not decline between 2023 and 2024 due to a combination of low harvest and high over-winter survival of juveniles. Both harvest rate and harvests have declined over the period of record (Fig. 4 and 5).

Table 1. Estimates of ptarmigan population size and demography in the **East** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	mean (sd): 2005 – present
Spring population size (2023)	26.5 (19.5 – 37.6) thousand	17.8 (4.9) thousand
Fall proportion of young (2023)	0.56 (0.52 – 0.60)	0.68 (0.06)
Fall population size (2023)	47.9 (32.2 – 68.0) thousand	44.2 (4.4) thousand
Harvest rate (2023)	0.13 (0.11 – 0.16)	0.25 (0.05)
Harvest (2023)	6.5 (4.5 – 8.3) thousand	10.9 (2.9) thousand
Hunter-days (2023)	1.9 thousand	3.7 (0.9) thousand
Annual survival – adults (2023)	0.56 (0.25 – 0.84)	0.54 (0.07)
Annual survival – juveniles (2023)	0.47 (0.21 – 0.76)	0.25 (0.10)
Spring population size (2024)	30.5 (14.6 – 50.9)	17.8 (4.9) thousand

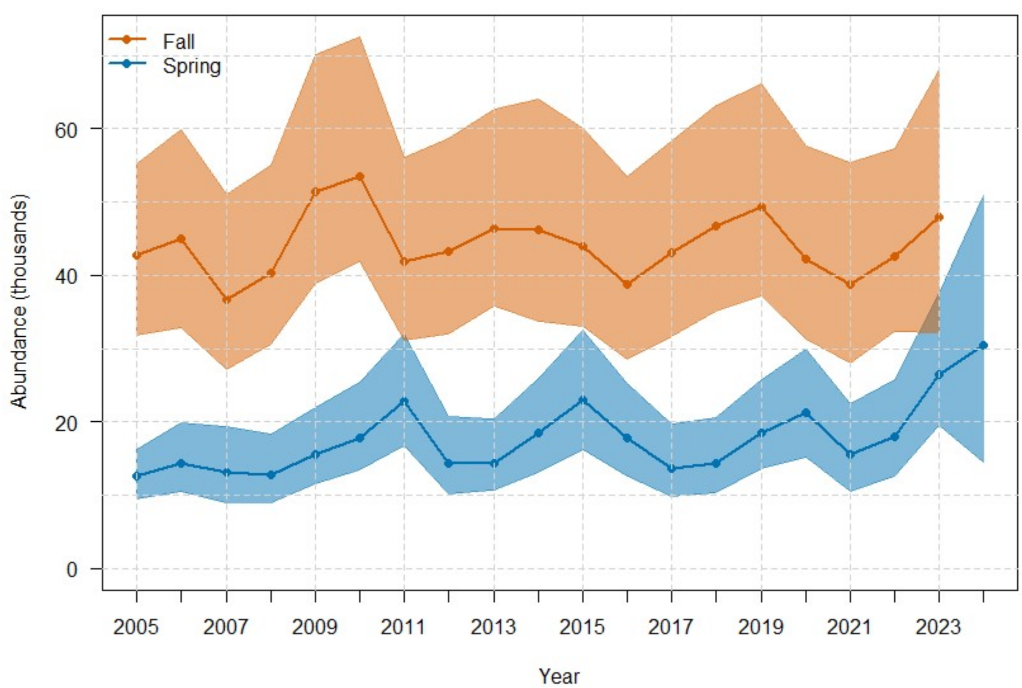

Fig. 2. Population estimates of ptarmigan in the **East** hunting region of Iceland as derived from an IPM.

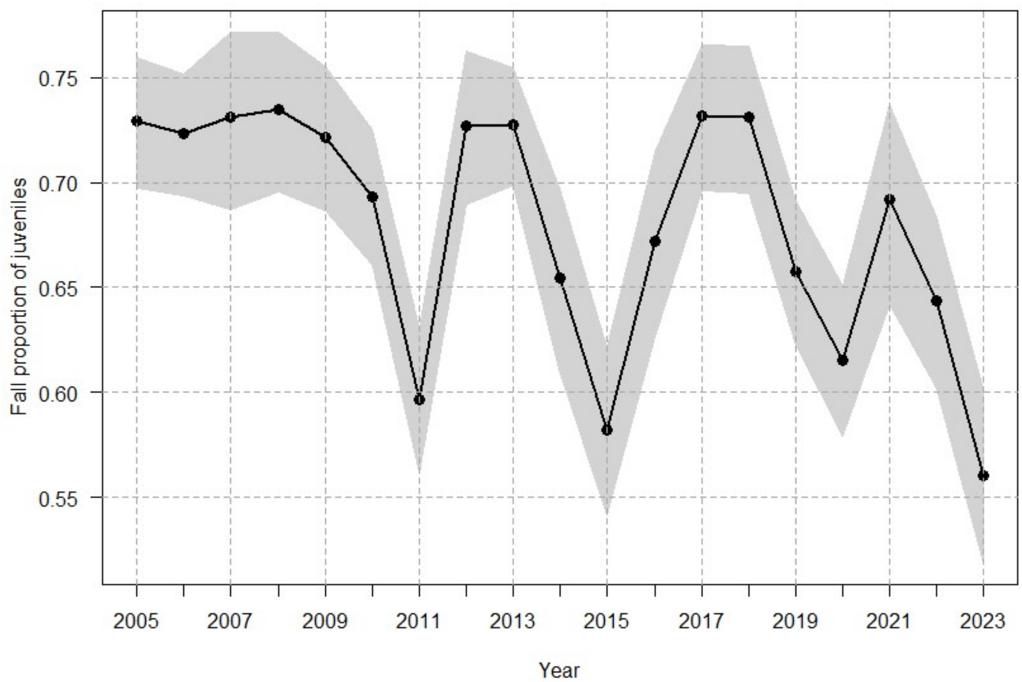

Fig. 3. The proportion of juvenile ptarmigan in the fall in the **East** hunting region of Iceland as derived from an IPM.

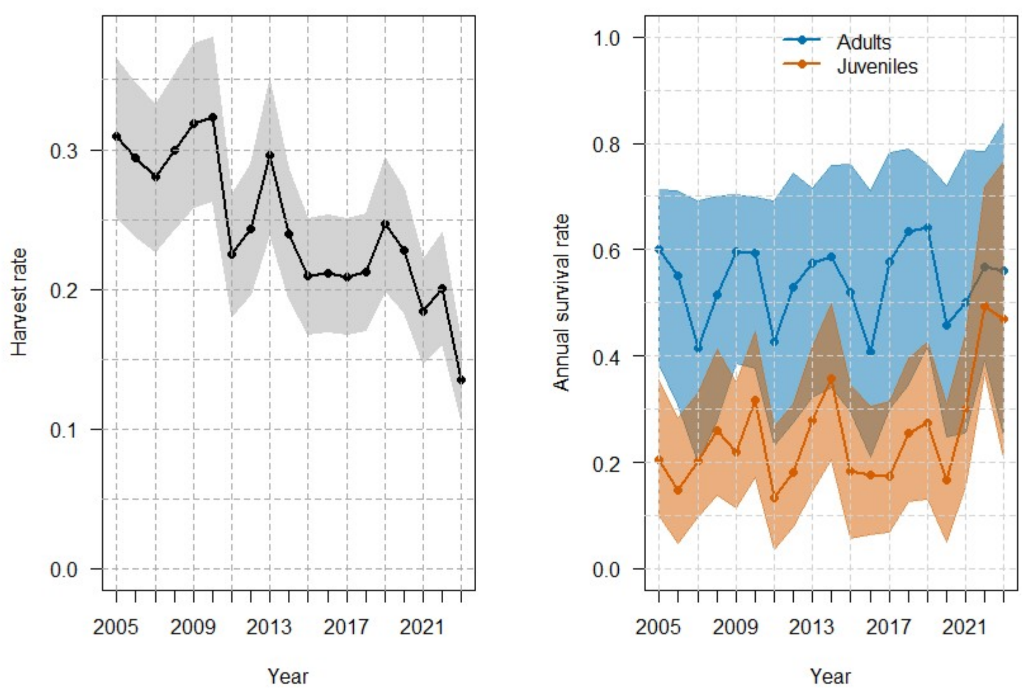

Fig. 4. Estimates of ptarmigan harvest rates and annual survival in the **East** hunting region of Iceland as derived from an IPM.

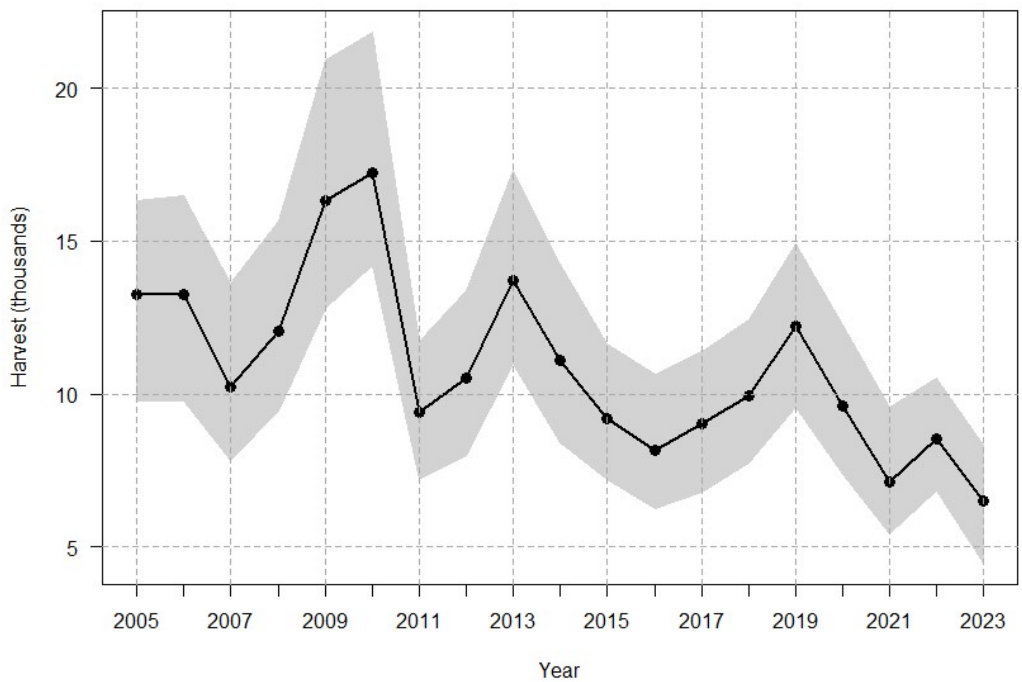

Fig. 5. Estimates of ptarmigan harvest in the **East** hunting region of Iceland as derived from an IPM.

The two hypotheses relating harvest rate to season length are provided in Fig. 6. Based on available data, H1 is clearly preferred over H0, but the weighted-average hypothesis is slightly different than H1 because the weight on H0 is not negligible. Based on the weighted-average hypothesis and spring population of 30 thousand, the optimal season length for the East hunting region is 45 days in 2024 (Fig. 7). If the optimal harvest strategy were followed in the future, we could expect an average population size in spring of about 20 thousand, which is similar to the average of about 18 thousand since 2005.

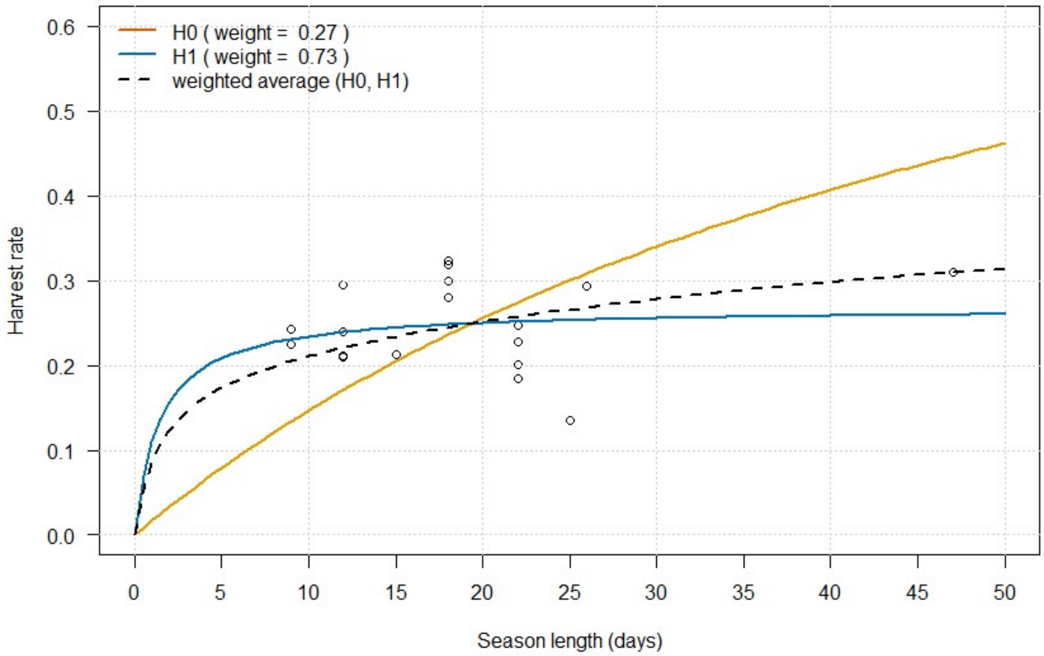

Fig. 6. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **East** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

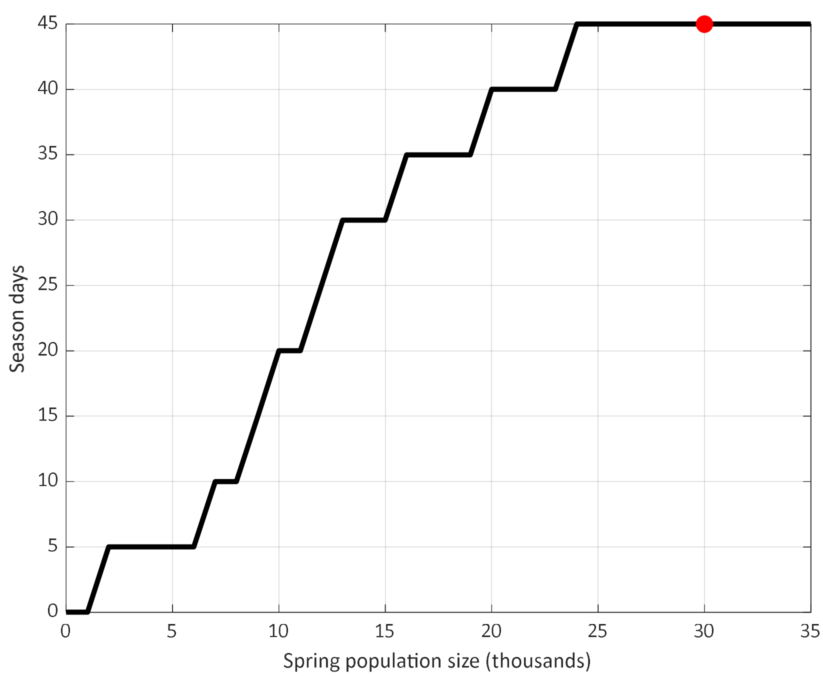

Fig. 7. Optimal harvest strategy for ptarmigan in the **East** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

Northeast Region

The spring population size in 2024 of about 43 thousand was slightly higher than that in 2023, and well above the average of about 33 thousand (Table 2, Fig. 8). Despite relatively low productivity in 2023 (Fig. 9), the spring population did not decline between 2023 and 2024 due to a low harvest rate and high annual survival (Fig. 10). Both harvest rate and harvests (Fig. 11) have declined over the period of record.

Table 2. Estimates of ptarmigan population size and demography in the **Northeast** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	mean (sd): 2005 – present
Spring population size (2023)	39.1 (33.0 – 55.5) thousand	33.2 (10.6) thousand
Fall proportion of young (2023)	0.69 (0.67 – 0.72)	0.75 (0.06)
Fall population size (2023)	98.7 (83.8 – 135.7)	94.6 (25.5) thousand
Harvest rate (2023)	0.06 (0.05 – 0.07	0.12 (0.03)
Harvest (2023)	5.9 (4.8 – 7.8) thousand	12.1 (5.0) thousand
Hunter-days (2023)	1.2 thousand	3.9 (0.9) thousand
Annual survival – adults (2023)	0.55 (0.38 – 0.82)	0.46 (0.15)
Annual survival – juveniles (2023)	0.24 (0.16 – 0.37)	0.19 (0.09)
Spring population size (2024)	42.8 (35.3 – 67.2) thousand	33.2 (10.6) thousand

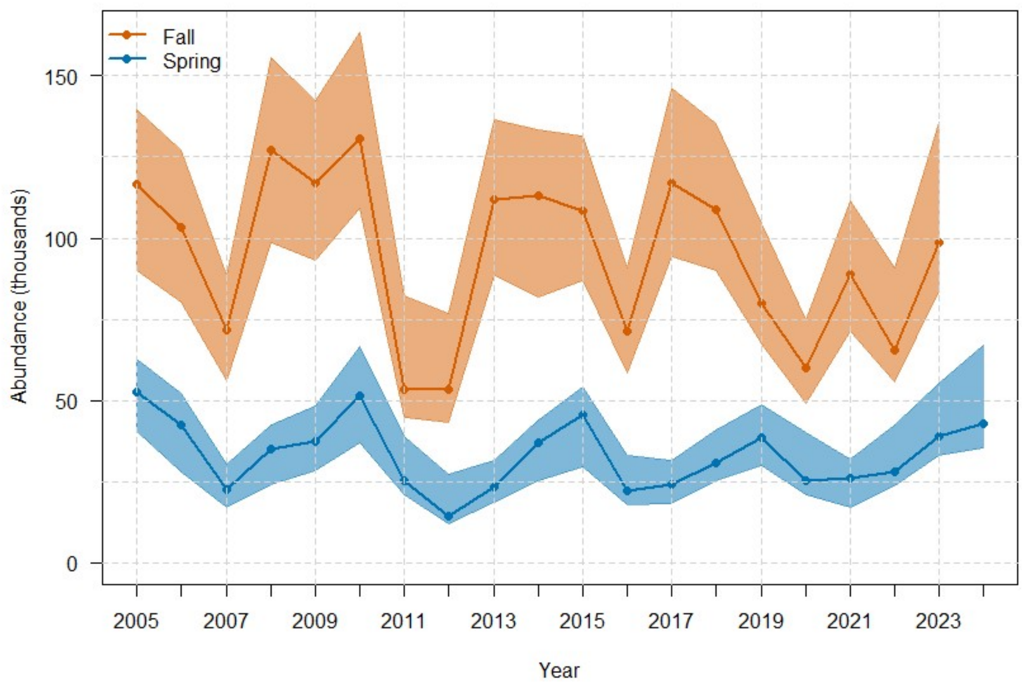

Fig. 8. Population estimates of ptarmigan in the **Northeast** hunting region of Iceland as derived from an IPM.

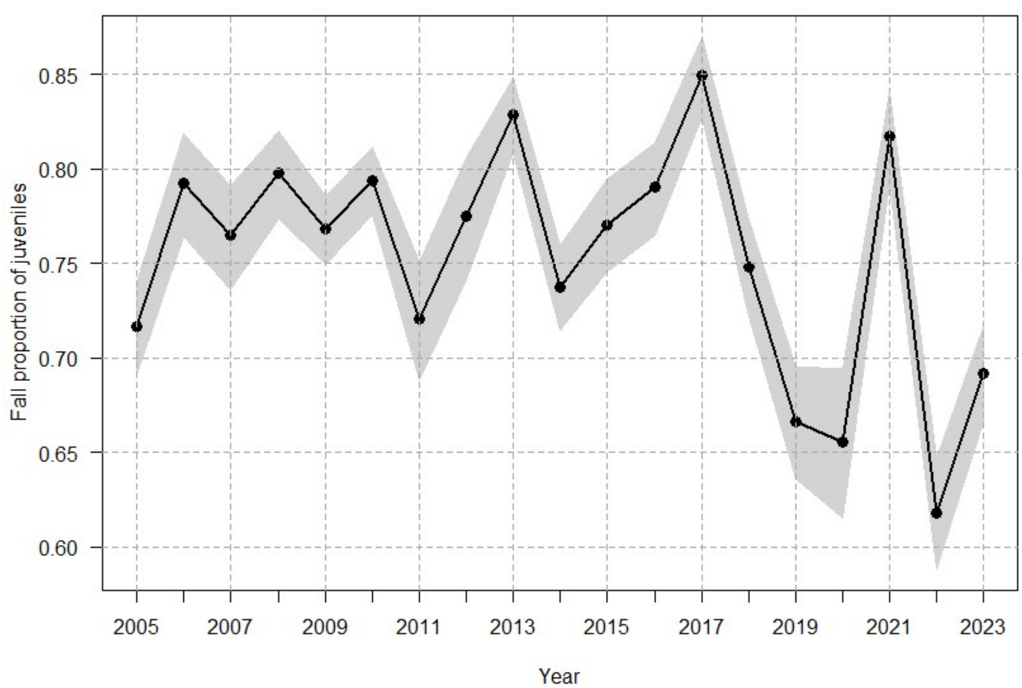

Fig. 9. The proportion of juvenile ptarmigan in the fall in the **Northeast** hunting region of Iceland as derived from an IPM.

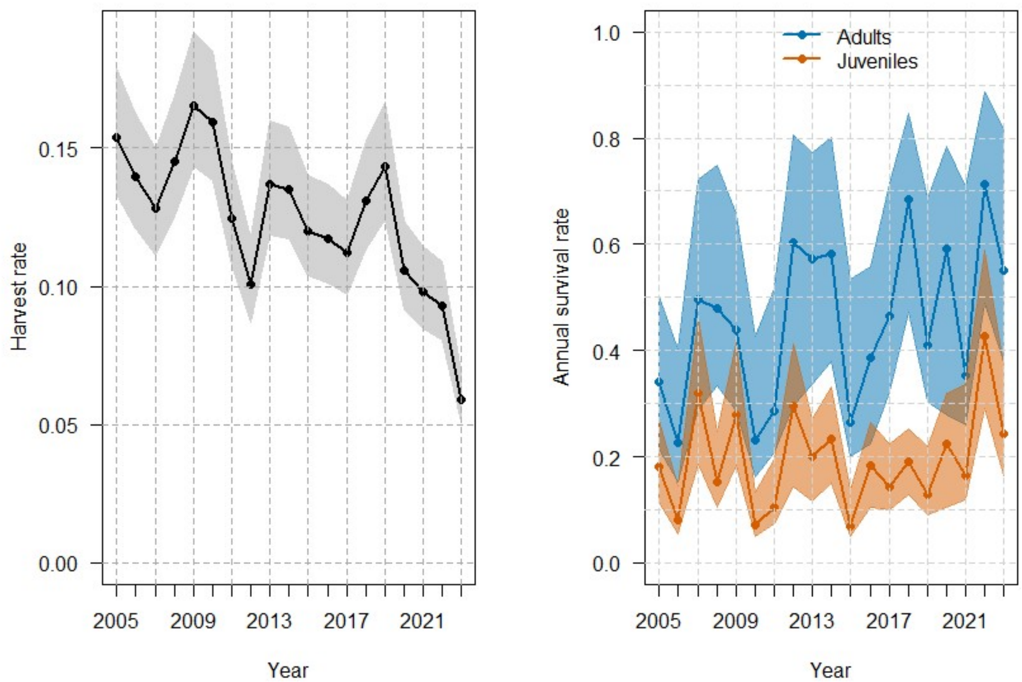

Fig. 10. Estimates of ptarmigan harvest rates and annual survival in the **Northeast** hunting region of Iceland as derived from an IPM.

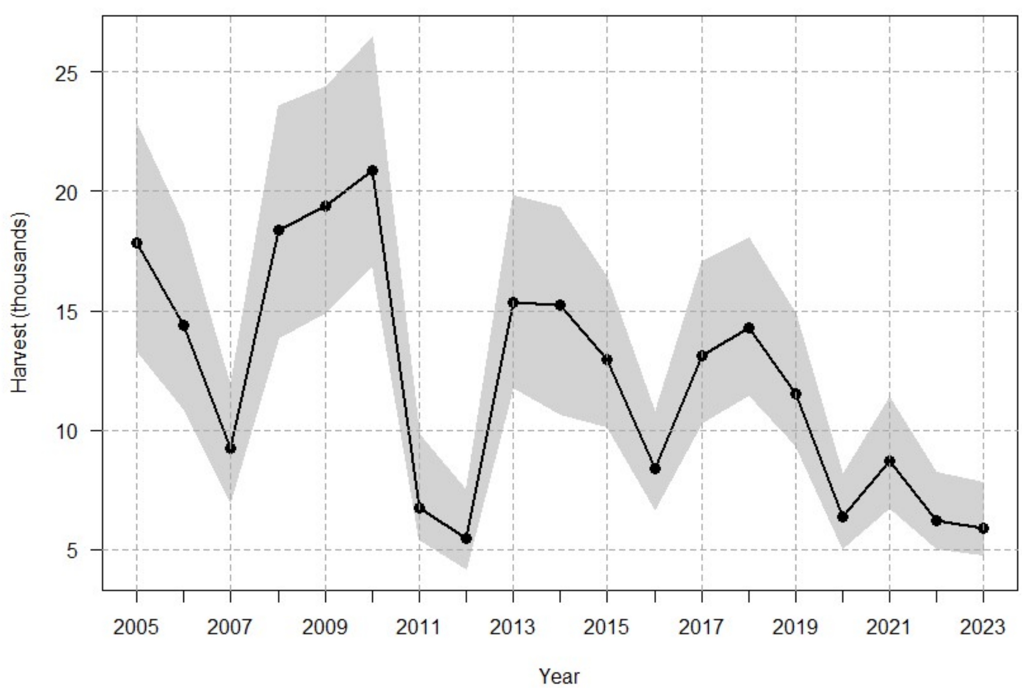

Fig. 11. Estimates of ptarmigan harvest in the **Northeast** hunting region of Iceland as derived from an IPM.

The two hypotheses relating harvest rate to season length are provided in Fig. 12. As in the East region, H1 is heavily preferred over H0, but both hypotheses express a much weaker relationship between harvest rate and season length than in the East. The optimal harvest strategy in the Northeast is also much more conservative than in the East, principally because density-dependent reproduction seems to be much weaker in the Northeast (Fig. 13). Preliminary investigations also suggest that summer precipitation has a more pronounced effect on productivity than in the other regions, and future research efforts should seek to clarify this relationship. Based on the weighted average hypothesis and a spring population of 43 thousand, the optimal season length for the Northeast hunting region is 20 days in 2024. If the optimal harvest strategy were followed in the future, we could expect an average population size in spring of about 36 thousand individuals, which is slightly higher than the mean since 2005.

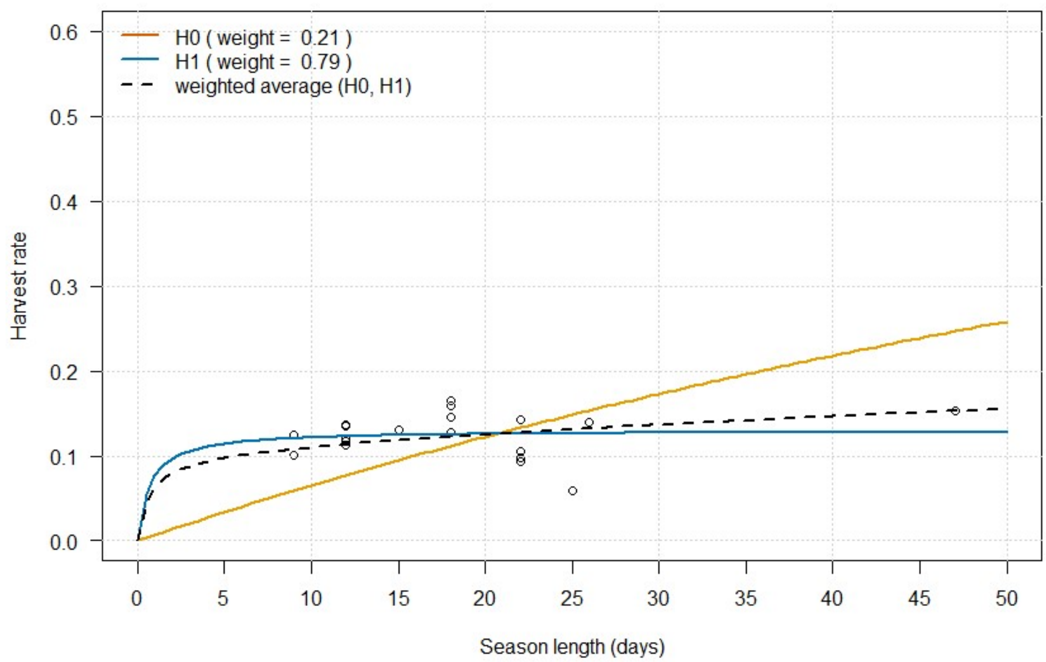

Fig. 12. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **Northeast** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

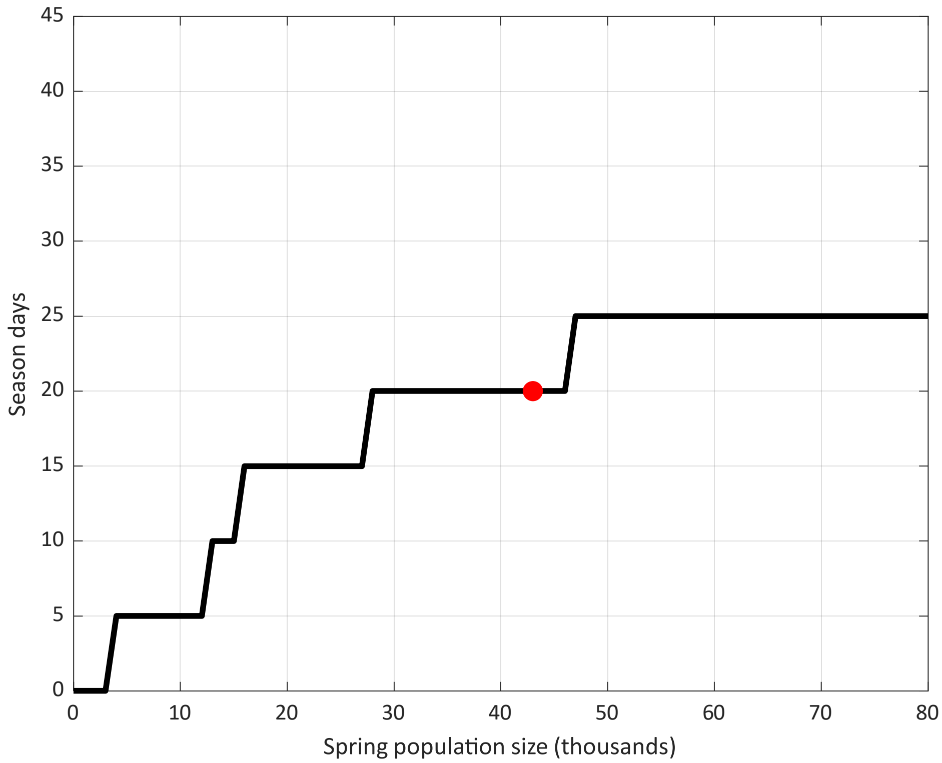

Fig. 13. Optimal harvest strategy for ptarmigan in the **Northeast** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

Northwest Region

The spring population size in 2024 of about 19 thousand in the Northwest is higher than that in 2023, and well above the average of about 12 thousand (Table 3, Fig. 14). Productivity in 2023 was about average (Fig. 15), but when combined with the relatively high spring population, it produced a fall population considerably larger than average. Hunter-effort and harvest rate in 2023 were lower than average, and harvest rates have generally declined over the period of record (Fig. 16). Harvests have been variable and generally have tracked changes in fall population size (Fig. 17).

Table 3. Estimates of ptarmigan population size and demography in the **Northwest** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	mean (sd): 2005 – present
Spring population size (2023)	16.1 (12.7 – 20.7) thousand	11.5 (3.3) thousand
Fall proportion of young (2023)	0.66 (0.60 – 0.71)	0.68 (0.05)
Fall population size (2023)	41.9 (32.4 – 51.4) thousand	29.8 (7.7) thousand
Harvest rate (2023)	0.16 (0.14 – 0.18)	0.28 (0.05)
Harvest (2023)	6.9 (5.3 – 7.9) thousand	8.4 (3.3) thousand
Hunter-days (2023)	1.6 thousand	2.9 (0.6) thousand
Annual survival – adults (2023)	0.68 (0.41 – 0.83)	0.54 (0.10)
Annual survival – juveniles (2023)	0.26 (0.15 – 0.39)	0.23 (0.08)
Spring population size (2024)	18.5 (12.5 – 25.5) thousand	11.5 (3.3) thousand

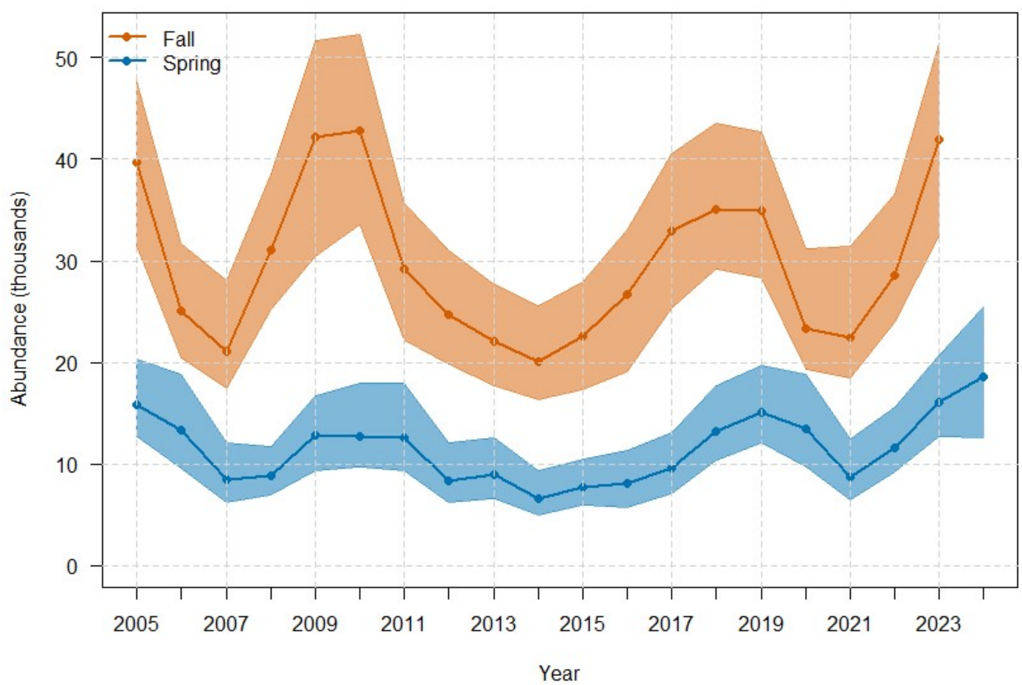

Fig. 14. Population estimates of ptarmigan in the **Northwest** hunting region of Iceland as derived from an IPM.

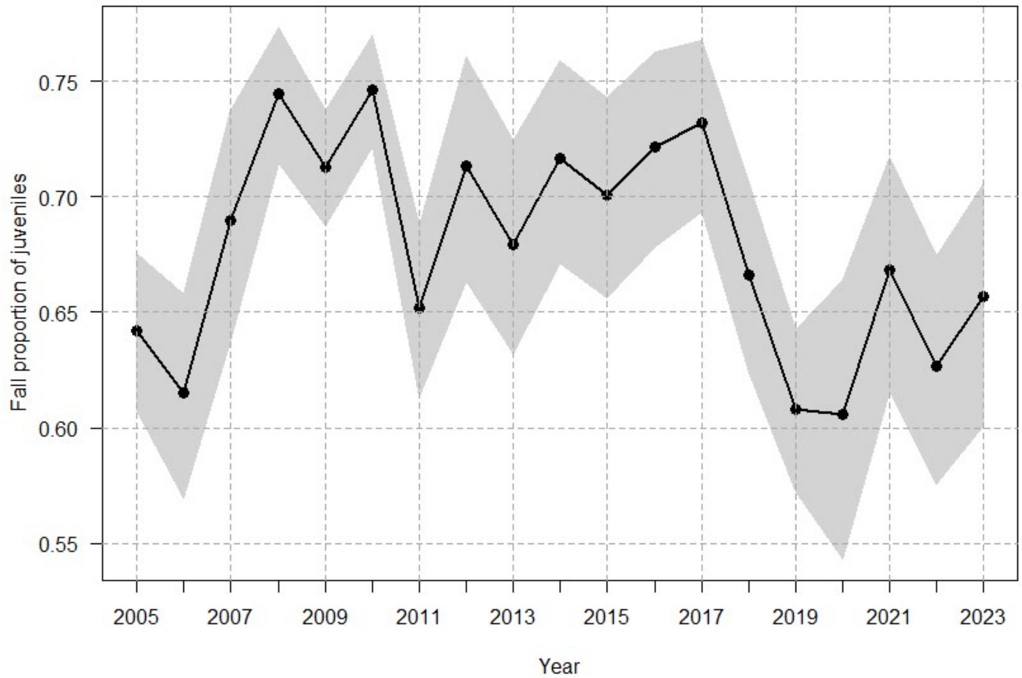

Fig. 15. The proportion of juvenile ptarmigan in the fall in the **Northwest** hunting region of Iceland as derived from an IPM.

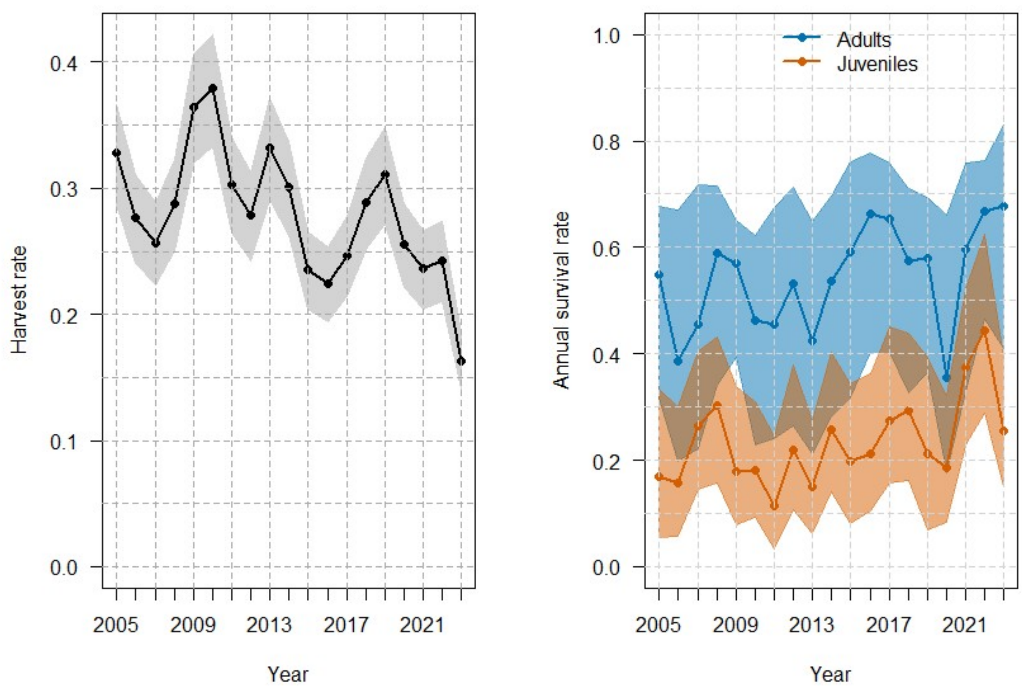

Fig. 16. Estimates of ptarmigan harvest rates and annual survival in the **Northwest** hunting region of Iceland as derived from an IPM.

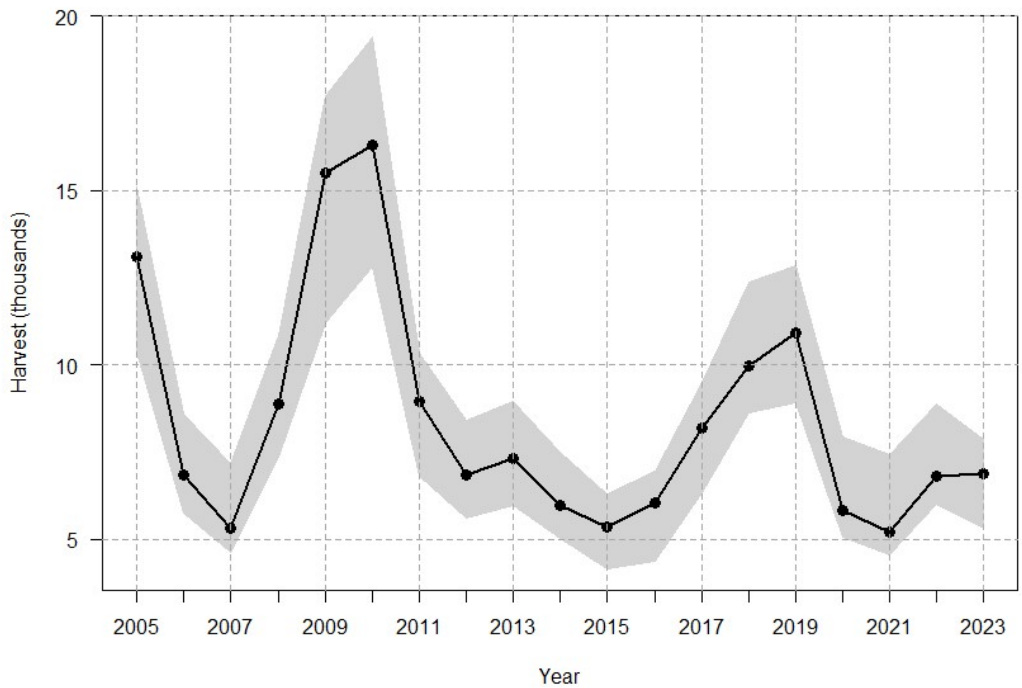

Fig. 17. Estimates of ptarmigan harvest in the **Northwest** hunting region of Iceland as derived from an IPM.

The relationship between season length and harvest rate in the Northwest is similar to that in the East. Here again, the weight of evidence is on hypothesis H1 (Fig. 18). According to the optimal harvest strategy, the optimal harvest season length never exceeds 25 days, and is only 15 days for an average population size of about 12 thousand (Fig. 19). The spring population size of about 19 thousand in 2024 suggests an optimal season length of 20 days. Following the optimal harvest strategy in the future could be expected to produce an average population size in spring of about 13 thousand, a bit higher than the 2005 – 2024 average.

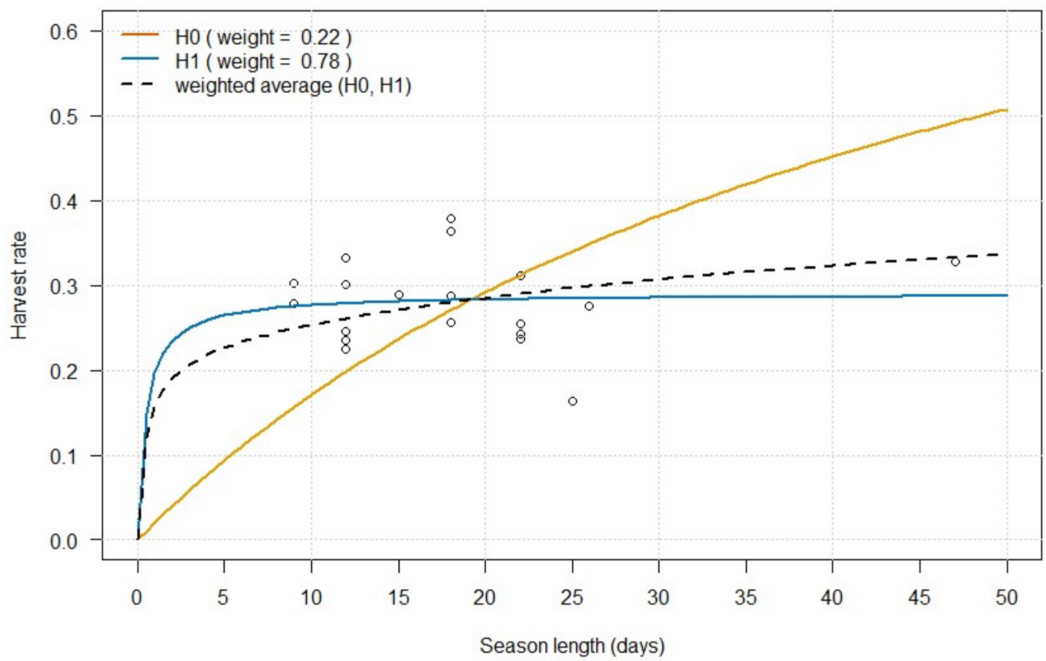

Fig. 18. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **Northwest** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

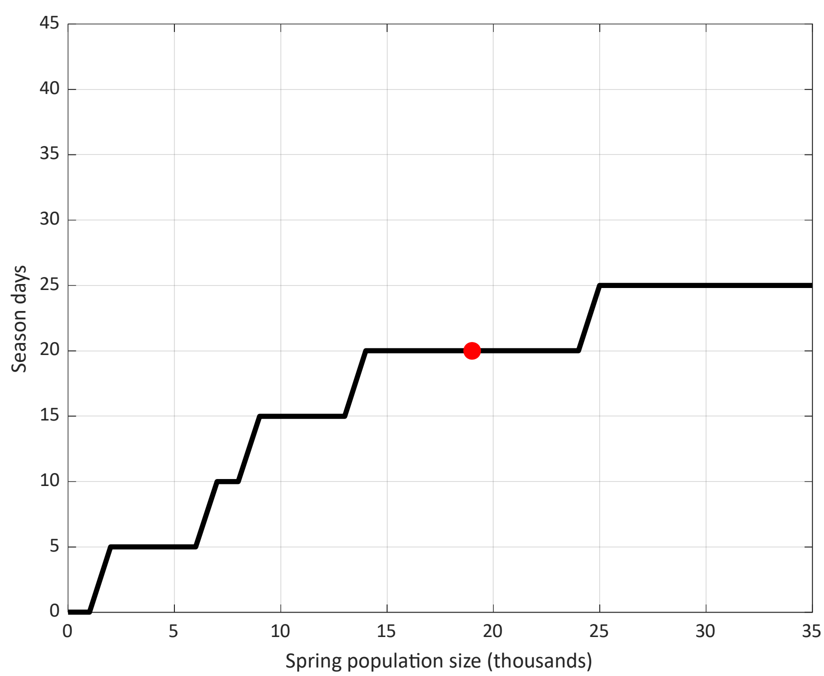

Fig. 19. Optimal harvest strategy for ptarmigan in the **Northwest** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

South Region

The spring population size in 2024 of about 10 thousand in the South is only slightly lower than that in 2023, but above the average of about 7 thousand (Table 4, Fig. 20). Productivity in 2023 was about average (Fig. 21), but when combined with the relatively high spring population, it produced a fall population considerably larger than average. Hunter-effort and harvest rate in 2023 were lower than average, and harvest rates have generally declined over the period of record (Fig. 22). Harvests have been variable and generally have tracked changes in fall population size (Fig. 23).

Table 4. Estimates of ptarmigan population size and demography in the **South** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	mean (sd): 2005 – present
Spring population size (2023)	11.6 (7.9 – 18.1) thousand	6.9 (2.2) thousand
Fall proportion of young (2023)	0.66 (0.60 –0.71)	0.71 (0.05)
Fall population size (2023)	26.1 (20.0 – 36.5) thousand	19.0 (4.9)
Harvest rate (2023)	0.19 (0.14 – 0.24)	0.30 (0.06)
Harvest (2023)	4.9 (4.2 – 5.4) thousand	5.7 (2.1)
Hunter-days (2023)	1.6 thousand	2.7 (0.7) thousand
Annual survival – adults (2023)	0.49 (0.26 – 0.78)	0.50 (0.07)
Annual survival – juveniles (2023)	0.22 (0.10 – 0.41)	0.21 (0.06)
Spring population size (2024)	10.5 (6.0 – 18.1) thousand	6.9 (2.2) thousand

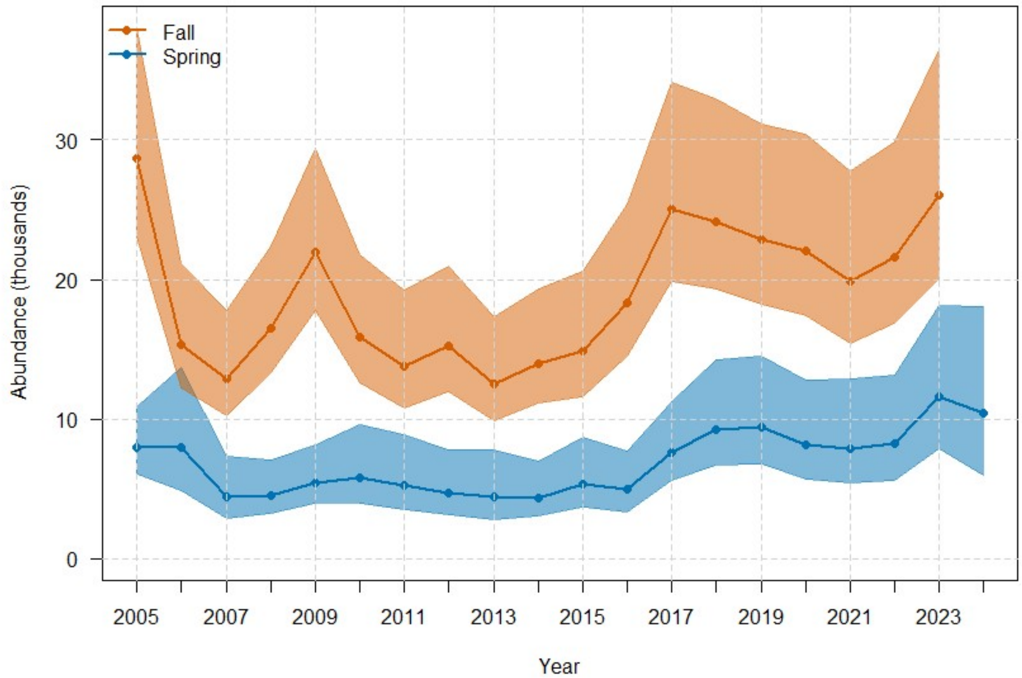

Fig. 20. Population estimates of ptarmigan in the **South** hunting region of Iceland as derived from an IPM.

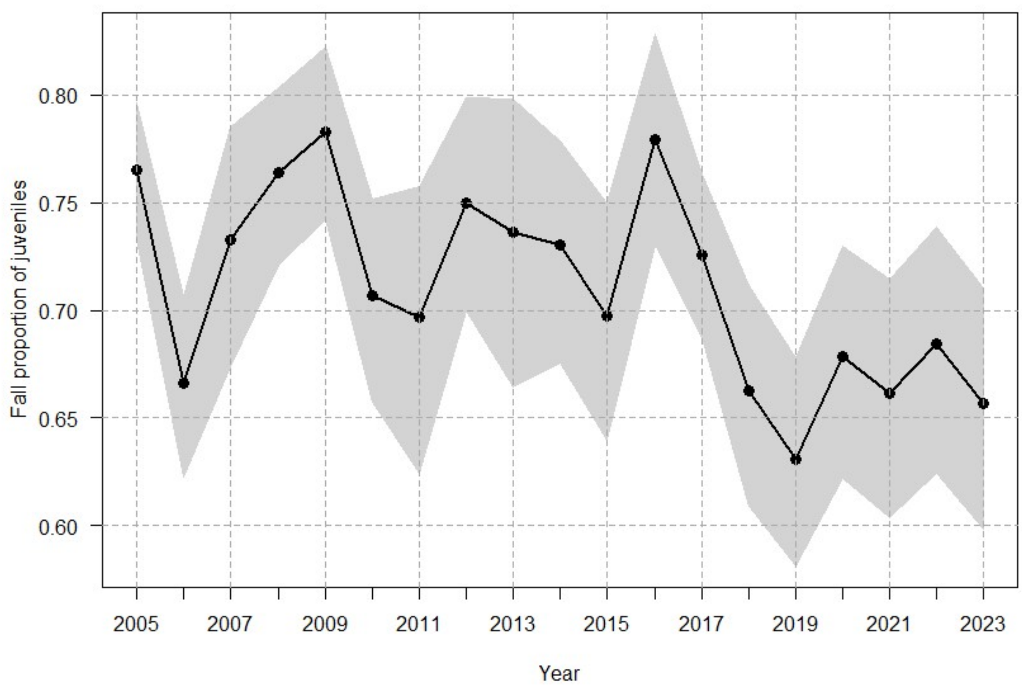

Fig. 21. The proportion of juvenile ptarmigan in the fall in the **South** hunting region of Iceland as derived from an IPM.

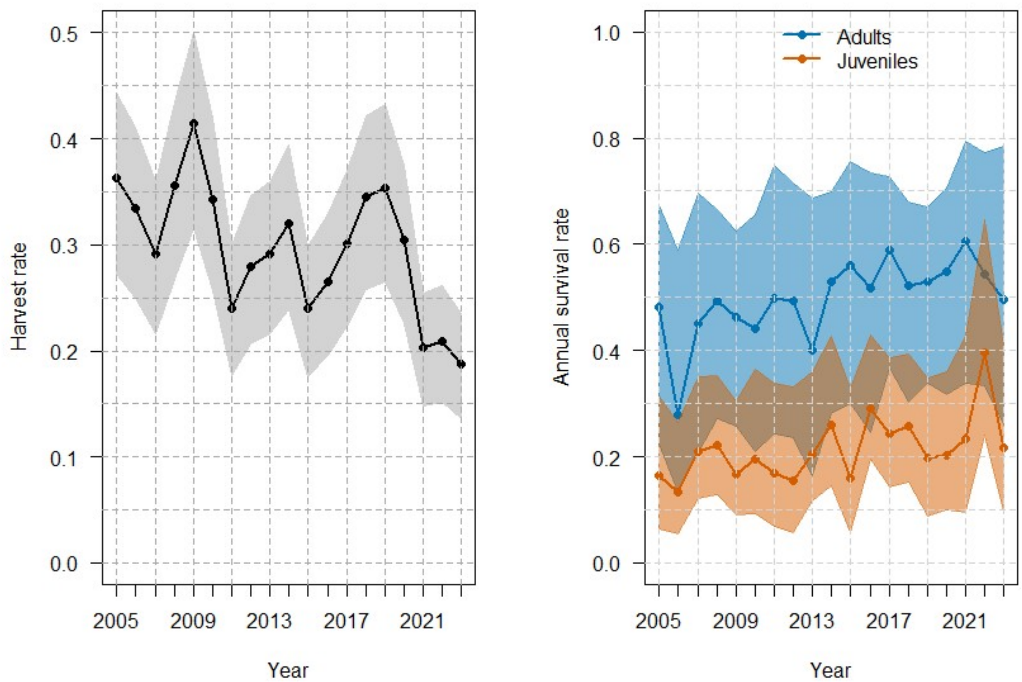

Fig. 22. Estimates of ptarmigan harvest rates and annual survival in the **South** hunting region of Iceland as derived from an IPM.

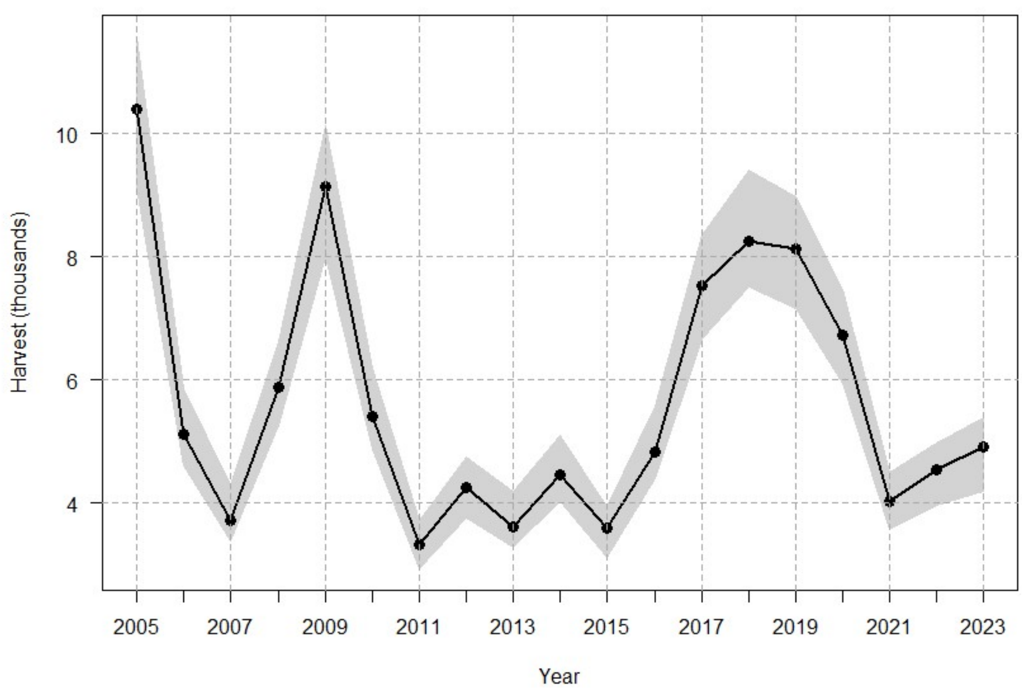

Fig. 23. Estimates of ptarmigan harvest in the **South** hunting region of Iceland as derived from an IPM.

As in the other regions, the evidence favors hypothesis H1 concerning the relationship between season length and harvest rate (Fig. 24). According to the optimal harvest strategy calculated based on the weighted hypotheses, the optimal harvest season length never exceeds 30 days, and is only 15 days for an average population size of about 7 thousand (Fig. 25). The spring population size of about 10 thousand in 2024 suggests an optimal season length of 20 days. Following the optimal harvest strategy in the future could be expected to produce an average population size in spring of about 8 thousand, which is slightly higher than the 2005 – 2024 average.

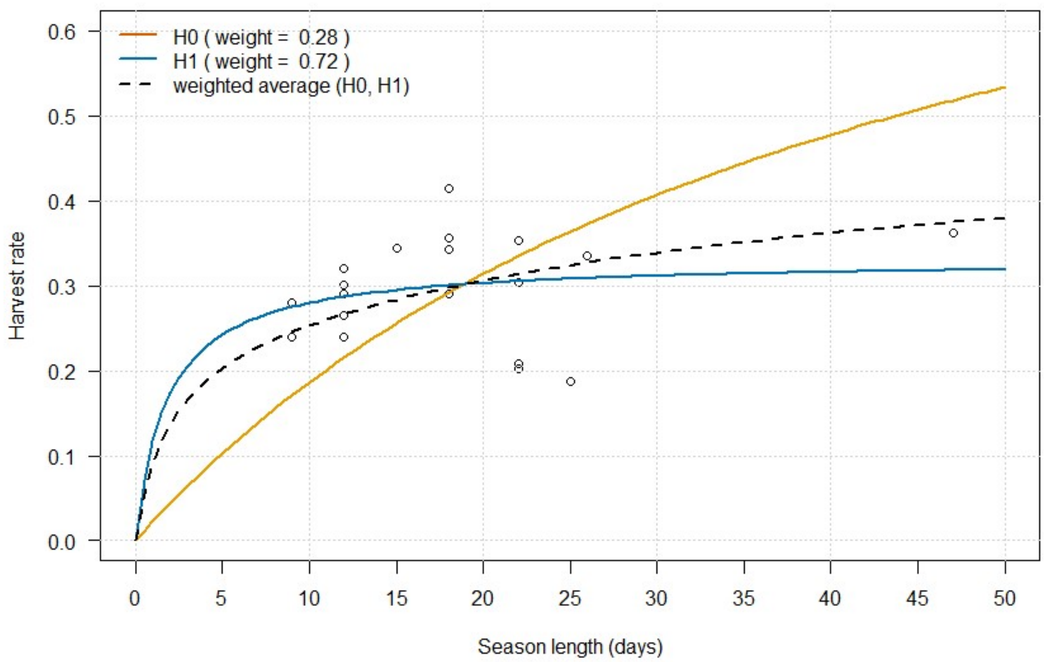

Fig. 24. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **South** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

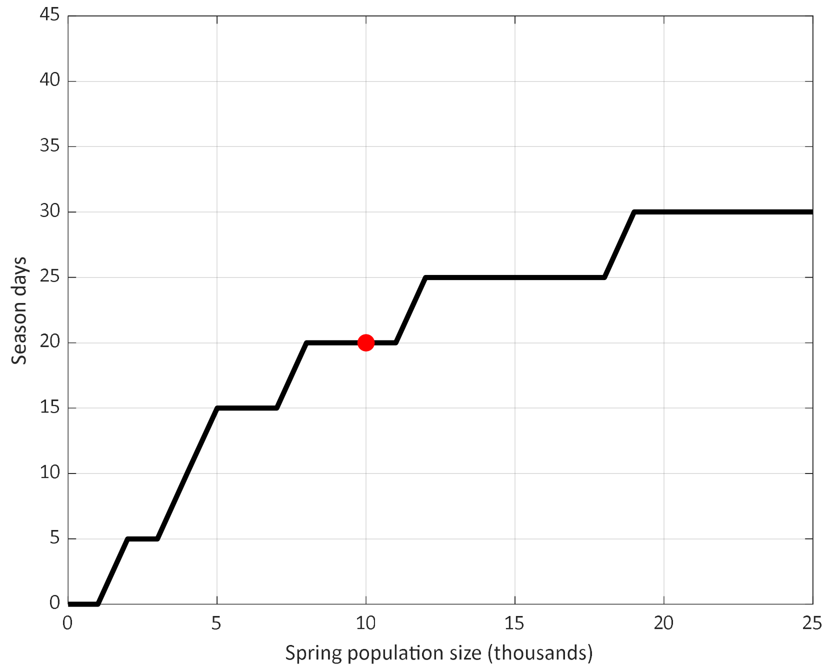

Fig. 25. Optimal harvest strategy for ptarmigan in the **South** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

West Region

The spring 2024 population size in the West region of about 11 thousand was lower than the 2023 estimate of about 15 thousand (Table 5, Fig. 26). The fall proportion of young in 2023 was about average (Fig. 27). Even though the harvest rate in 2023 was lower than average, the spring population appears to have declined due to relatively high natural mortality, as reflected in relatively low annual survival, especially of juveniles (Fig. 28). Harvests have been variable and generally have tracked changes in fall population size (Fig. 29).

Table 5. Estimates of ptarmigan population size and demography in the **West** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	mean (sd): 2005 – present
Spring population size (2023)	15.3 (12.3 – 18.6) thousand	10.8 (3.3) thousand
Fall proportion of young (2023)	0.67 (0.62 – 0.71)	0.69 (0.06)
Fall population size (2023)	33.3 (27.7 – 43.2) thousand	28.5 (6.5) thousand
Harvest rate (2023)	0.19 (0.17 – 0.21)	0.29 (0.05)
Harvest (2023)	6.4 (5.2 – 8.2) thousand	8.2 (2.5) thousand
Hunter-days (2023)	2.1 thousand	3.3 (0.7) thousand
Annual survival – adults (2023)	0.42 (0.32 – 0.70)	0.51 (0.12)
Annual survival – juveniles (2023)	0.16 (0.11 – 0.27)	0.23 (0.07)
Spring population size (2024)	11.2 (9.3 – 17.5) thousand	10.8 (3.3) thousand

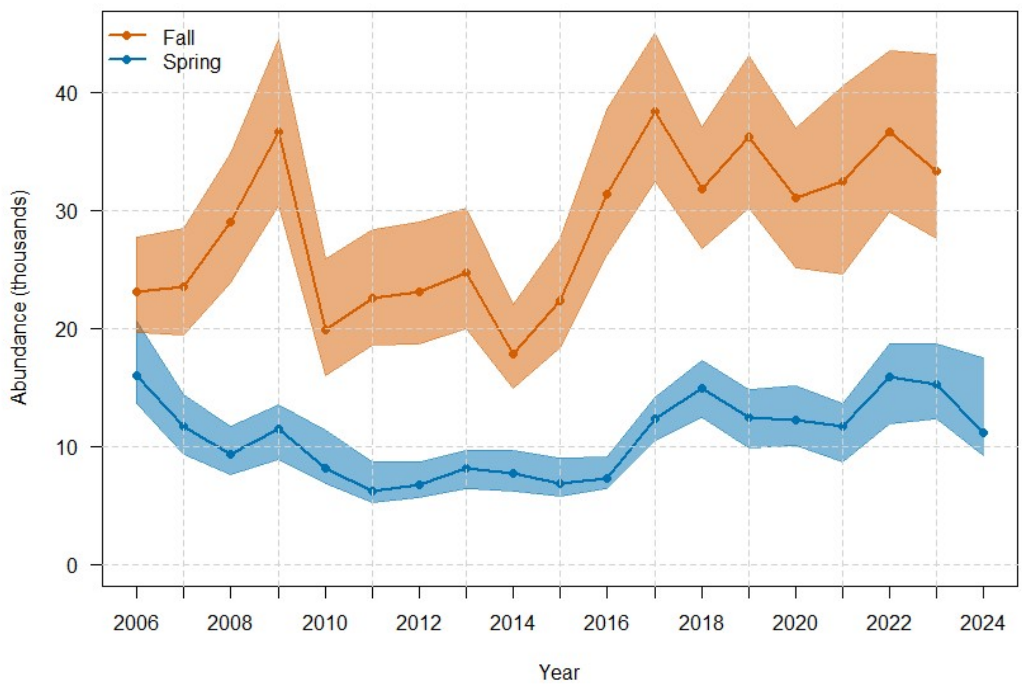

Fig. 26. Population estimates of ptarmigan in the **West** hunting region of Iceland as derived from an IPM.

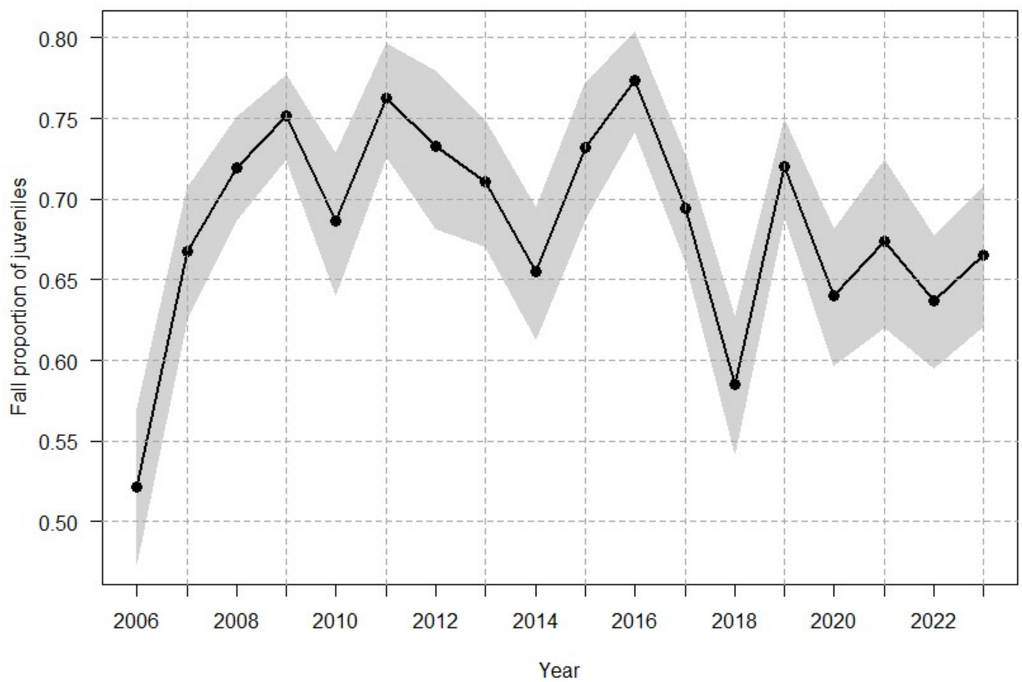

Fig. 27. The proportion of juvenile ptarmigan in the fall in the **West** hunting region of Iceland as derived from an IPM.

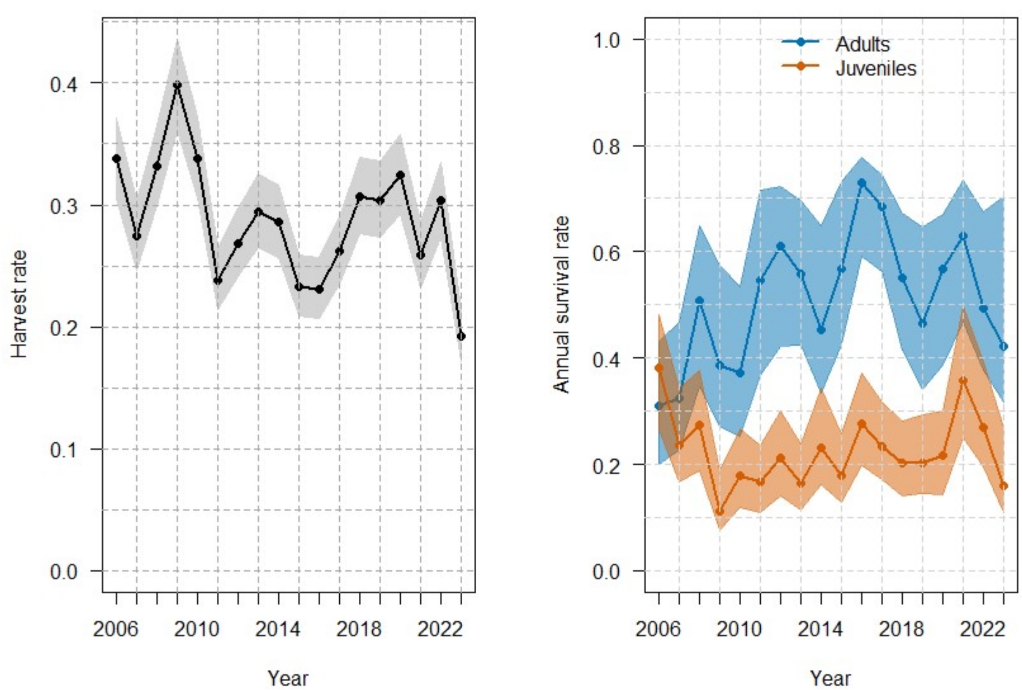

Fig. 28. Estimates of ptarmigan harvest rates and annual survival in the **West** hunting region of Iceland as derived from an IPM.

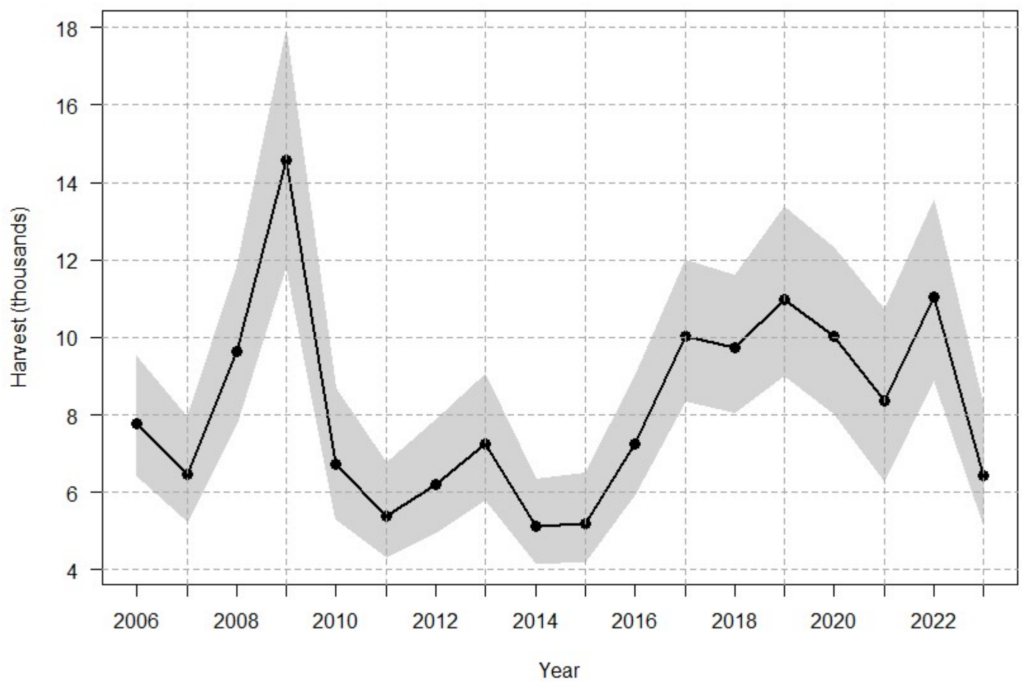

Fig. 29. Estimates of ptarmigan harvest in the **West** hunting region of Iceland as derived from an IPM.

The two hypotheses relating harvest rate to season length are provided in Fig. 30. Based on available data, H1 is clearly preferred over H0, but the weighted-average hypothesis is slightly different than H1 because the weight on H0 is not negligible. Based on the weighted-average hypothesis and spring population of 11 thousand, the optimal season length for the West hunting region is 20 days in 2024 (Fig. 31). If the optimal harvest strategy were followed in the future, we could expect an average population size in spring of about 11 thousand, which is similar to the average.

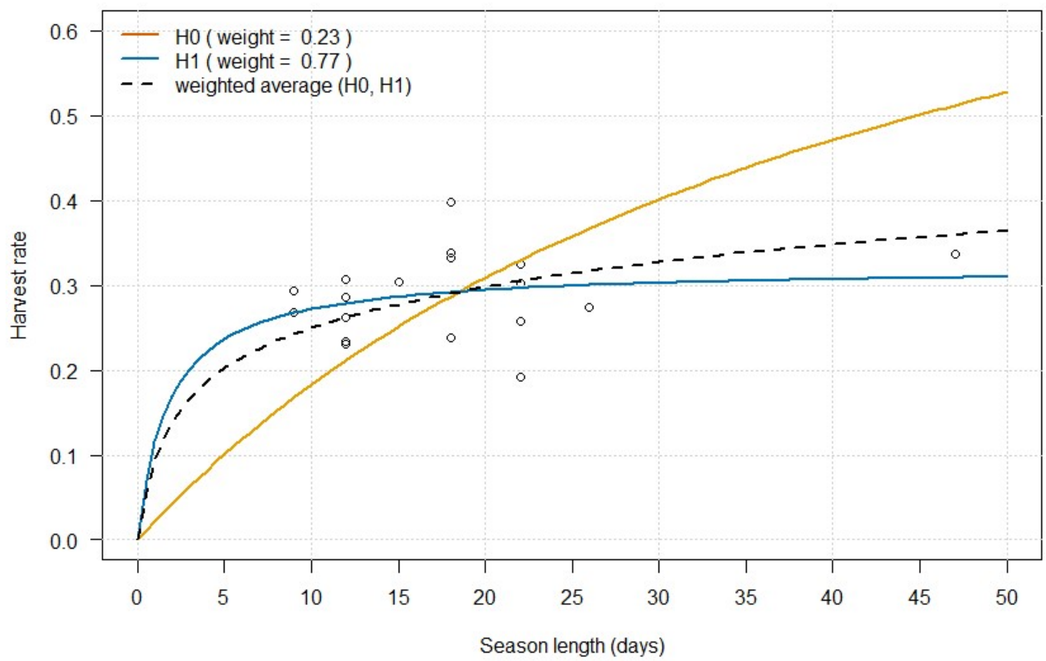

Fig. 30. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **West** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

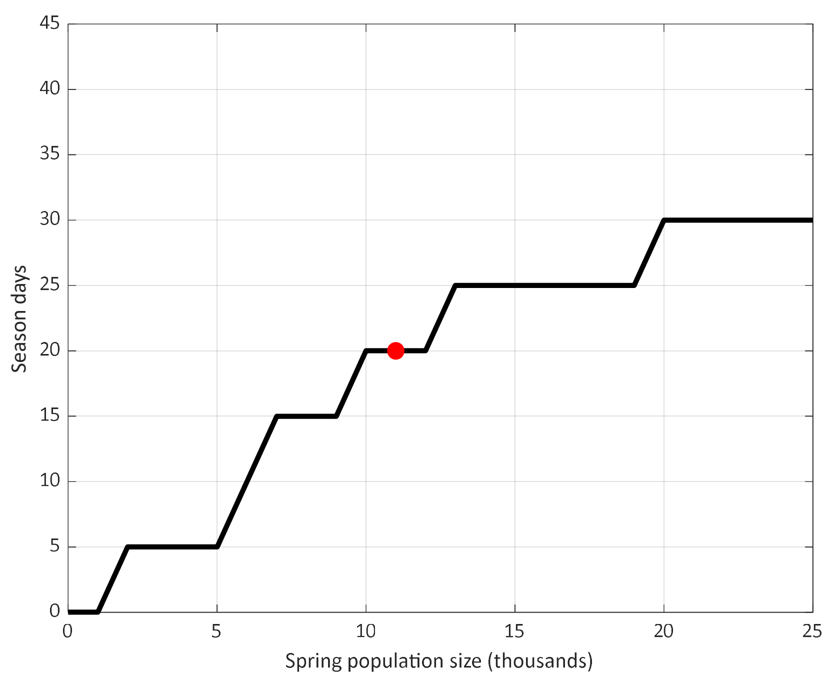

Fig. 31. Optimal harvest strategy for ptarmigan in the **West** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

Westfjords Region

The spring 2024 population in the Westfjords region was about 7 thousand, up slightly from 6 thousand in 2023 (Table 6, Fig. 32). Productivity in 2023 was about average (Fig. 33), and the modest increase appears to be due to a combination of a relatively low harvest rate and low natural mortality of adults (Fig. 34). Harvest rates have generally declined during the period of record. Harvests have been variable and generally have tracked changes in fall population size (Fig. 35).

Table 6. Estimates of ptarmigan population size and demography in the **Westfjords** hunting region of Iceland as derived from an IPM.

Parameter	Recent estimate (95% CI)	2005 – present mean (sd)
Spring population size (2023)	5.9 (3.8 – 8.7) thousand	4.4 (1.3) thousand
Fall proportion of young (2023)	0.74 (0.71 – 0.78)	0.72 (0.06)
Fall population size (2023)	21.1 (13.1 – 29.5) thousand	13.0 (3.5) thousand
Harvest rate (2023)	0.19 (0.14 – 0.23)	0.34 (0.07)
Harvest (2023)	4.0 (2.5 –4.8) thousand	4.4 (1.4) thousand
Hunter-days (2023)	0.9 thousand	1.8 (0.5) thousand
Annual survival – adults (2023)	0.70 (0.40 0.82)	0.49 (0.09)
Annual survival – juveniles (2023)	0.19 (0.10 – 0.29)	0.22 (0.06)
Spring population size (2024)	7.1 (3.8 – 11.3) thousand	4.4 (1.3) thousand

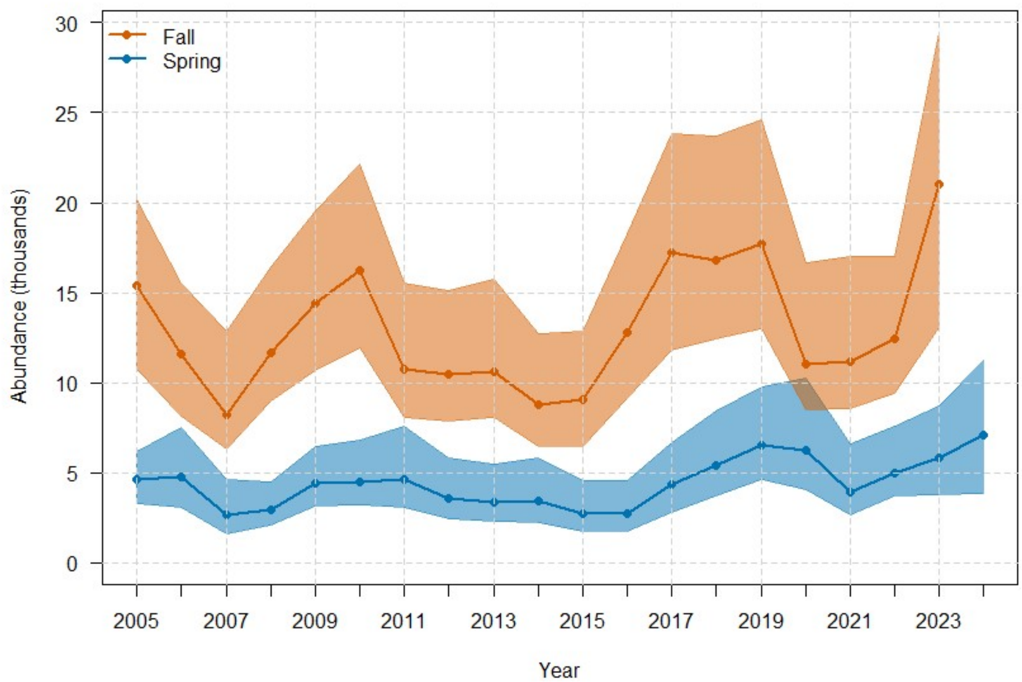

Fig. 32. Population estimates of ptarmigan in the **Westfjords** hunting region of Iceland as derived from an IPM.

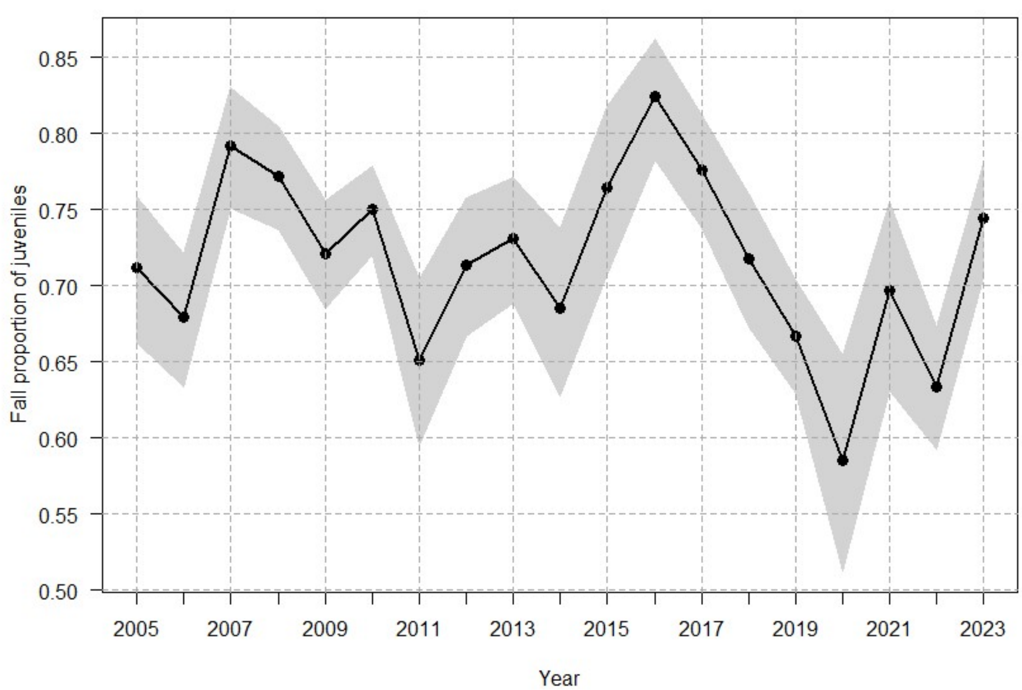

Fig. 33. The proportion of juvenile ptarmigan in the fall in the **Westfjords** hunting region of Iceland as derived from an IPM.

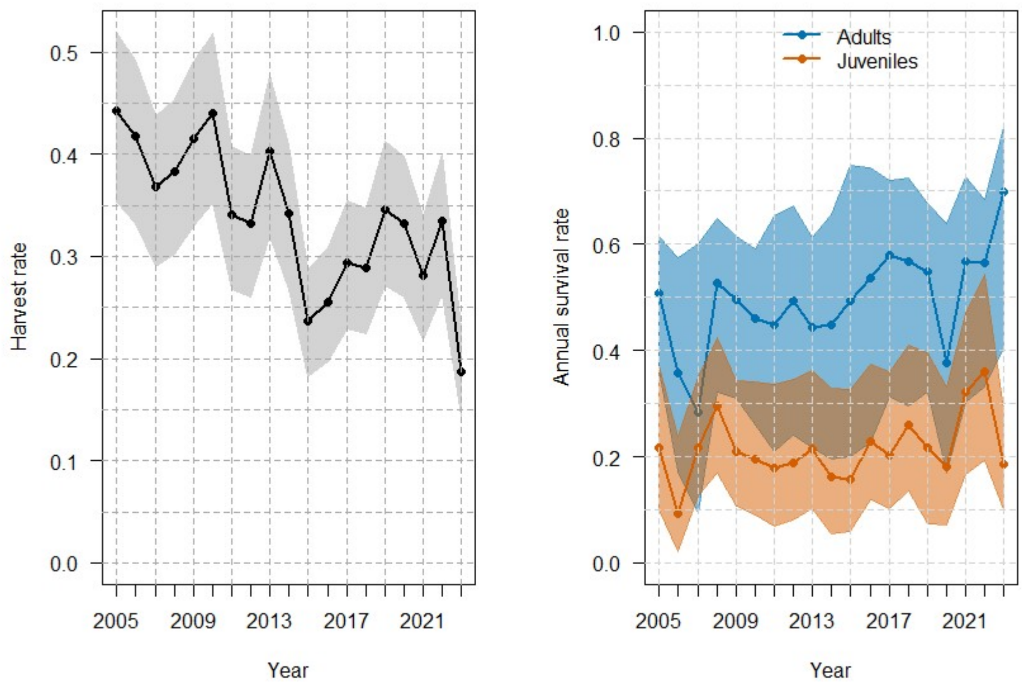

Fig. 34. Estimates of ptarmigan harvest rates and annual survival in the **Westfjords** hunting region of Iceland as derived from an IPM.

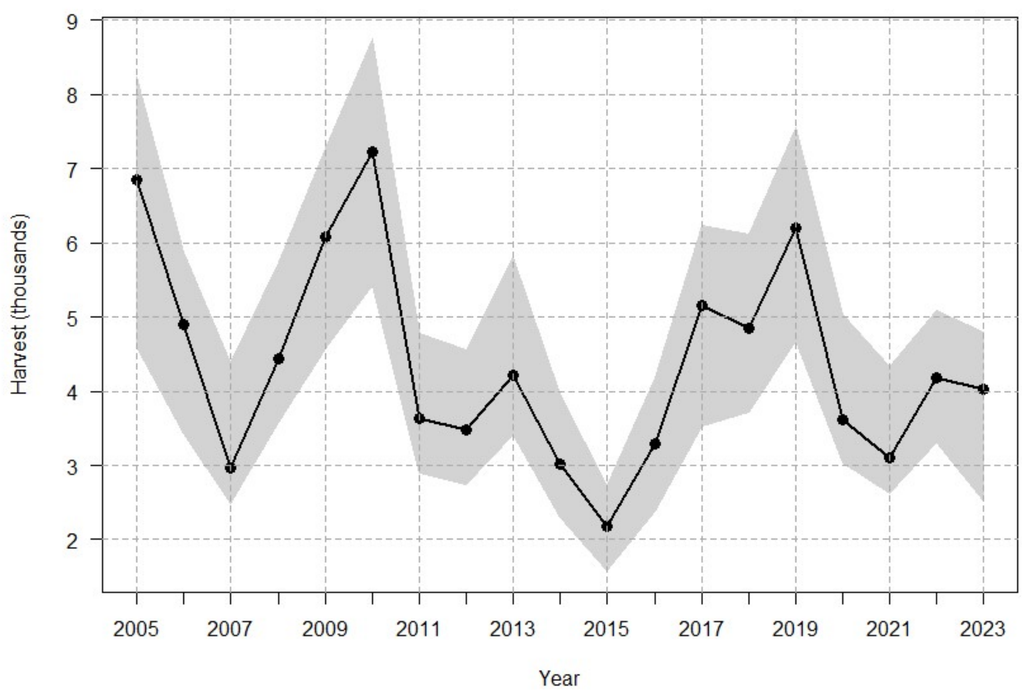

Fig. 35. Estimates of ptarmigan harvest in the **Westfjords** hunting region of Iceland as derived from an IPM.

As in the other regions, the hypothesis H1 is greatly favored by the weight of evidence. Based on the weighted average hypothesis and spring population of 7 thousand, the optimal season length for the Westfjords hunting region is 25 days in 2024 (Fig. 31). If the optimal harvest strategy were followed in the future, we could expect an average population size of about 5 thousand in spring, which is slightly above the average of about 4 thousand since 2005.

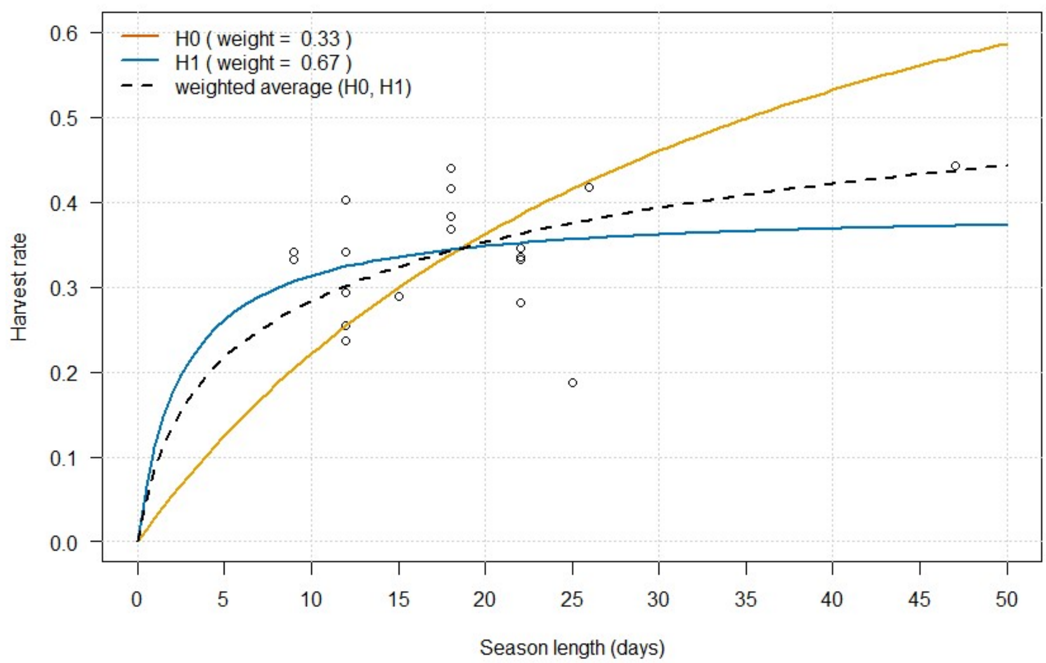

Fig. 36. Two hypotheses concerning the relationship between season length and harvest rate of ptarmigan in the **Westfjords** hunting region of Iceland. The weighted average hypothesis is used to calculate an optimal harvest strategy. Weights may change each year as experience is gained with varying season lengths.

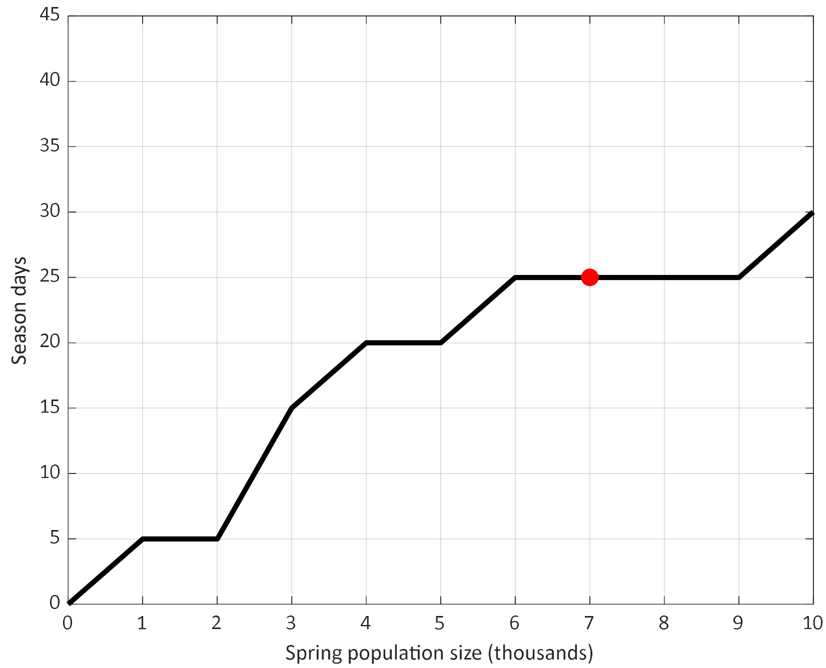

Fig. 37. Optimal harvest strategy for ptarmigan in the **Westfjords** hunting region of Iceland for 2024. The optimal season for 2024 is indicated by the red circle.

Issues Requiring Further Attention

- There is some question about the number of hunter-days provided for 2020 – 2023 because they are not the product of the # of hunters and average days/hunter. To maintain consistency with previous analyses, we have continued to calculate the product for use as regional hunter-days. Further clarification about how the Environment Agency calculates hunter statistics by region would be helpful.

- A preliminary investigation of summer precipitation and productivity suggested strong to moderate effects in at least some of the regions. The relationship seems particularly strong in the Northeast and may be over-riding any effects of density dependence. The apparent lack (or weakening) of density dependence in the Northeast with the 2024 update of the IPM caused convergence problems in calculating the optimal harvest strategy. For that reason, we retained the density-dependent relationship estimated with last year's update of the IPM. Further work on the roles of weather and density dependence in productivity in all regions is warranted.

- Harvest rates have been declining in recent years despite relatively stable season lengths. In the Northwest, the best-fitting model describing the relationship between harvest rate and season length actually suggests decreasing harvest rates with increasing season length, which seems to fly in the face of common sense. I have thus retained the model from last year, which describes a positive (albeit small) effect of season length. It seems that other variables, perhaps more important than season length, are now affecting hunter effort and success. Understanding this situation is key to regulating harvests in the future.

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