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Regulation of the hunting season as a tool for adaptive harvest management – first results for pink-footed geese *Anser brachyrhynchus*

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Adjustment of hunting season length is often used to regulate harvest of waterbirds but the effects are disputed. We describe the first results of season length extension on the harvest of the pink-footed goose, which has been selected as the first test case of adaptive harvest management of waterbirds in Europe. In Denmark, the season (previously 1 September to 31 December) was extended to include January in 2014–2015 with the aim to increase the harvest and, in the longer term, reduce the population size. The total harvest in Denmark increased by 52% compared to previous years, and almost 50% of the Danish harvest was taken in the January extension. In the course of the hunting season, the proportion of adults in the bag increased. In this case, the outcomes from the first extension of season suggest that season length adjustment can be an effective tool to regulate harvest, though dependent on winter weather conditions and hunters' motivation for shooting geese.

Hunting of waterfowl species has a long history in northwest Europe, and today hunting of ducks and geese is still considered to be of high recreational value (Todd 1979, Kear 1990). Hunting affects population numbers directly by increased mortality, and although this mortality may be additive or partially compensated (Cooch et al. 2014), several studies have documented that hunting can restrict population growth of quarry species (Gauthier et al. 2001, Duncan et al. 2002). As a consequence, hunting can serve as a management tool to control species abundance.

Regulation of the impact of hunting is most often done by either placing a limit on the number of individuals shot (bag limits), adjusting the length of the open season or the timing of the season. While bag limits can effectively confine the annual harvest by reducing numbers shot (Martin and Carney 1977, Boyd 1983), this approach has so far not been used in a European waterfowl hunting context and been met by skepticism among hunters because of its restrictions on personal liberty and proportionally large impact on a small group of hunters. On the other hand, adjusting the length or the timing of the hunting season affects all hunters equally, and has been used to regulate hunting by law across several European countries (Sinclair et al. 2006, Christensen and Hounisen 2014). Recently, however, Sunde and Asferg (2014) pointed out that changes in season length might not always translate into a corresponding effect on harvest of a given game population. This may partly be due to the fact that the changes were not of sufficient length to make a significant difference or because hunters compensated for the shorter season by going out more often. Hence, it remains questioned whether the length of the hunting season can reliably predict harvest (or rate).

In light of uncertainties of what drives waterbird population dynamics, their response to management actions as well as the effectiveness of various tools to regulate harvest, adaptive harvest management has been introduced to regulate harvest of waterbirds in North America (Nichols et al. 2007) and, more recently, for so far one goose population in Europe (Madsen and Williams 2012, Johnson et al. 2014a). In this context, the first European test case of an International Species Management Plan on the Svalbard breeding population of the pink-footed goose *Anser brachyrhynchus*, including an adaptive harvest management framework (<http://pinkfootedgoose.aewa.info/>), is a valuable example to learn from experiences of controlling harvest andmight be used to guide decisions on sustainable harvest of migratory birds in the future. In the case of pink-footed geese, adaptive harvest management has been chosen as an instrument to maintain a total spring population size of approximately 60 000 birds (in order to avoid excessive crop damage and degradation of vulnerable tundra vegetation). In 2012, when the management plan was officially adopted by the parties of the African–Eurasian Waterbird Agreement (AEWA), the population had been increasing and totaled >80 000 birds despite hunting. The initial management task was therefore to increase harvest and reduce numbers (Johnson et al.

2014a). To achieve this goal the Danish government decided on a temporary extension of the pink-footed goose hunting season, and thus for the 2014/2015 winter the existing open season running from September to December (and including January on the marine territory) was extended to include January on land as well.

In this study we evaluate the early results of extending the pink-footed goose hunting season, and assess to what degree the regulation of season length affected total harvest and population size. In addition, we investigate how numbers and age composition of shot birds developed during the September–January period, to better understand what impact the one month extension had on the total bag.

Methods

Focal population

The Svalbard-breeding population of the pink-footed goose migrates via Norway to wintering grounds in Denmark, the Netherlands and Belgium. It has increased from less than 20 000 in the 1960s to more than 80 000 around 2010–2012, but has declined to a level around 60 000–70 000 in 2014 (Madsen et al. 2015a, b; <http://pinkfootedgoose.aewa.info/node/195/>; accessed 30 March 2016). The pink-footed goose has an open hunting season in Norway (10 August to 23 December), including Svalbard (20 August to 31 October) and Denmark (1 September to 31 December on land; on the marine territory and outside EU Special Protection Areas until 15 January and, since 2011, until 31 January). The species is protected in the Netherlands and Belgium. Despite that intensive marking of the population has taken place since the late 1980s, there are very few recoveries of dead ringed birds outside Denmark and Norway, suggesting that only few geese originating from the Svalbard population are shot outside these two countries (Madsen et al. 2014, Madsen unpubl.).

The AEWA International Species Management was launched to find management solutions to increasing agricultural conflicts in wintering and staging areas as well as signs of increasing grazing impacts on vulnerable tundra vegetation in the breeding areas (Madsen and Williams 2012).

Total hunting bag

The total Danish hunting bag of pink-footed geese was obtained from the Danish bag statistics run by the Danish Nature Agency and the Danish Centre for Environment and Energy (DCE), based on hunters' obligation to report shot game by the end of the hunting season. Until 2010 hunters reported their bags in groups of species (e.g. "geese", "dabbling ducks" etc.), and the proportional contribution of individual species to this group was inferred from the distribution of wings available from the Danish Wing Survey based on voluntary contributions from hunters across Denmark (<www.bios.au.dk/vinger>). From 2011 onwards reporting to the Danish bag statistics were made species-specific, and hunters hereafter reported the number of shot game on a level of individual species. As a consequence, the method used to derive total bag of pink-footed geese differed slightly before and after this change, but data from recent years (where both approaches have been run in parallel) show that they produce very similar results (Christensen unpubl.). The wing survey has been maintained in order to estimate seasonal and age distributions of harvest.

In Norway, hunters must pay for a hunting license with a mandatory species-specific hunting bag report to Statistics Norway (<www.ssb.no/>). Numbers of species shot at county level are reported and data is available from 1992 onwards.

Temporal distribution of harvest

The temporal distribution of the total Danish harvest within the September–January open season was assessed from the temporal distribution of wings from pink-footed geese reported in the Danish wing survey, and temporal distribution of marked birds reported shot during the open season. Goose wings submitted to the wing survey always include date of retrieval, and therefore give a measure of the temporal distribution of the entire bag. Recoveries of marked birds by hunters is likewise accompanied by date of the harvest, and although sample size is relatively small compared to the wing survey data, this data set serves as a valid independent measure of harvest distribution across the open season.

Age composition of the hunting bag

All wings submitted to the Danish wing survey were identified to species and aged as juveniles (first-winter birds produced in the previous breeding season) or adults (older birds), respectively, based on feather characteristics (Boyd et al. 1975, Carney 1993). This ageing enables a description of age distribution of the bag across the entire hunting season, and should indicate whether the proportion harvested of different age groups changed during this period. It is well established for both pink-footed geese (Madsen 2010) and other waterfowl species (Calvert et al. 2005, Mitchell et al. 2008, Clausen et al. 2013) that juvenile birds are overrepresented in the hunting bag compared to the free-ranging population. Flocking behavior and naivety of young birds seems to be the most important drivers of this phenomenon (Madsen 2010). As a consequence, age distribution of shot birds cannot be used as a reliable measure of juvenile proportions in the population as a whole.

Results

Total hunting bag

The pink-footed goose hunting bag for the 2014/2015 season totaled 14 800 birds, of which 89% were shot in Denmark and 11% in Norway (Fig. 1). The total Danish harvest increased from an average level of 8676 birds (95% CI: 7848–9503) in 2010–2013 to 13 200 in 2014, i.e. an increase of 52.1%. In 2010–2013 the Norwegian harvest totaled a mean of 2625 birds (95% CI: 1427–3822) which was not significantly different from the 1600 birds shot in 2014.

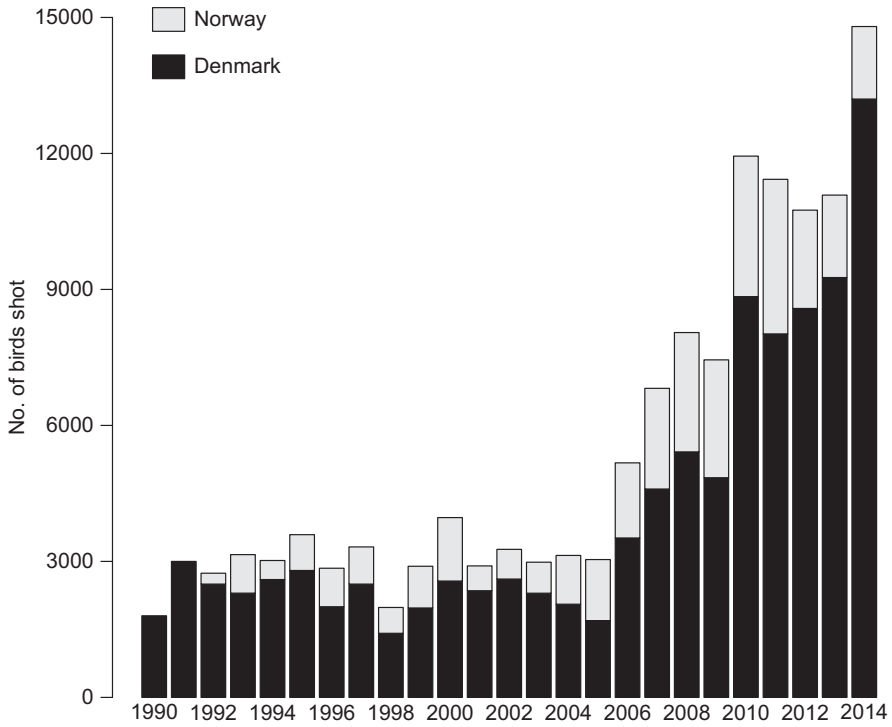

Figure 1. Total hunting bag of Svalbard-breeding pink-footed geese during 1990–2014.

Distribution of harvest

Data from the Danish wing survey and recoveries of shot marked birds both strongly indicated that most birds were shot in January, and thereby the extended period of the open season. 47% of all wings from pink-footed geese submitted to the wing survey (n = 383) were shot during the January extension, corresponding to approximately 6200 birds (Fig. 2). Likewise, 57% of all recovered marked birds (n = 23) were received during the same period (Fig. 3). Collectively these two data sets strongly point towards a large effect of extending the open season to include January. Before the January extension of hunting on land, an average of 3.4% of the annual harvest (equivalent to 285 birds) was taken in January on the marine territory.

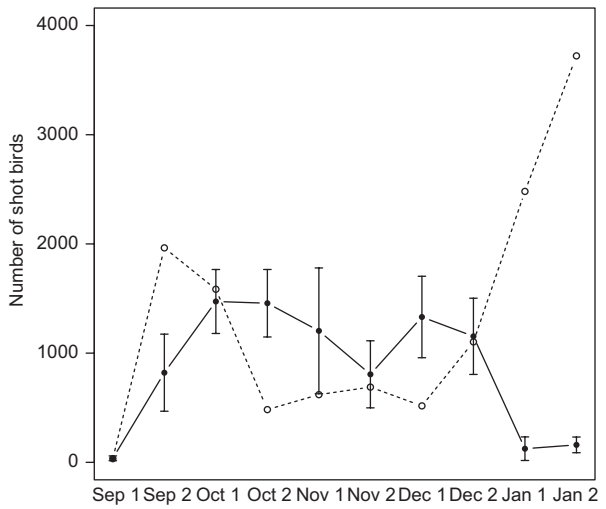

Figure 2. Seasonal distribution of the hunting bag of pink-footed geese in Denmark derived from the total annual harvest divided into half-monthly intervals based on the relative distribution of wings submitted to the Danish wing survey in 2010/2011–2013/2014 (solid line; n = 679) and 2014/2015 (dashed line; n = 383). Error bars indicate the standard error for each period across the four years.

Age composition of the hunting bag

In 2014/2015 age composition of the Danish bag changed during the course of the season ($\chi^2 = 45.52$, DF = 4, $p < 0.001$; Fig. 4). In September the bag was composed of 53% juveniles and 47% adults, gradually declining to 11%

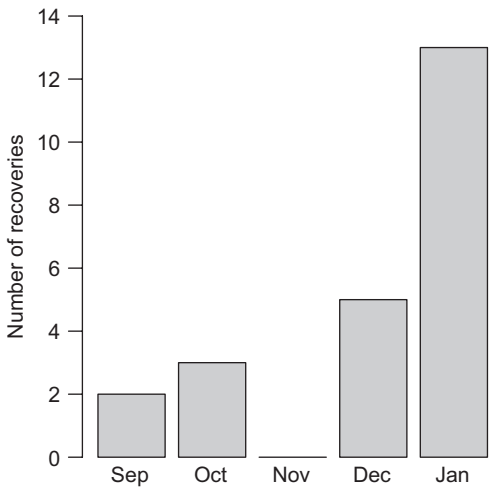

Figure 3. Temporal distribution of shot and recovered marked pink-footed geese during September–January 2014/2015 (n = 23).

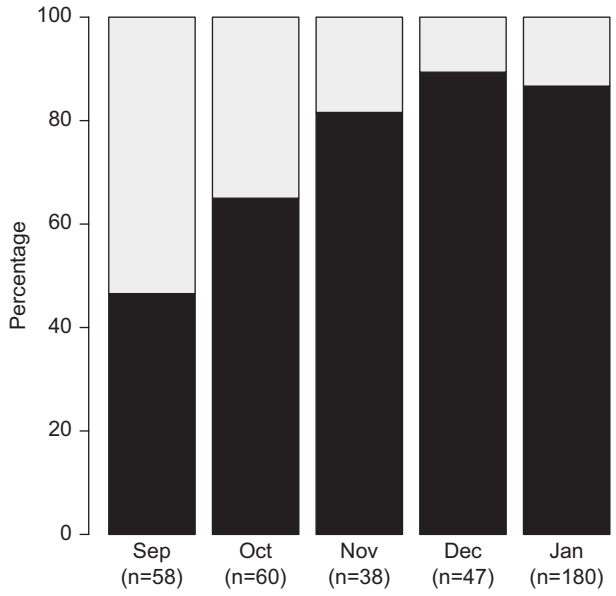

Figure 4. Age composition of the pink-footed goose hunting bag during September–January 2014/2015, based on voluntarily submitted wings to the Danish Wing Survey. Black: adults; grey: juveniles.

and 89% in December and 13% and 87% in the extended January period.

Discussion

Following the January 2015 extension of the pink-footed goose hunting season on land, total hunting bag was considerably higher than all previous years with available data. The harvest of pink-footed geese in Denmark has grown considerably in the recent decade, partly explained by a parallel growth in population size, partly by a sudden change in migratory behavior whereby an increasing proportion of the population remained in Denmark during autumn and winter, exposing the population to a higher hunting pressure (Madsen et al. 2015a). However, the increase in the 2014/2015 season cannot be explained by these relationships as both the population size as well as the proportion of geese staging in Denmark have stagnated in recent years (Madsen et al. 2015b). In Norway where no change in season length or other regulation took place in recent years, the number of pink-footed geese shot remained relatively stable. The temporal distribution of harvest within the season in Denmark indicated that the January extension accounted for roughly half of the entire harvest, strongly suggesting a growing hunting pressure as a result of the longer season. Hunters' response to changes in season length is obviously an important factor for the outcome of such initiatives; in this case hunters clearly took advantage of the extra hunting opportunity by increasing their activity rather than spreading out the number of outings over the extended hunting season.

Although our first data indicate a strong effect of extending the open season of pink-footed geese, a recent review of effects of changes in season length reveal that this might not always be the case (Sunde and Asferg 2014). Explanations of the strong response in pink-footed goose harvest may relate to several factors. For one thing, pink-footed geese are known to return from more southerly wintering grounds in Belgium and the Netherlands to Denmark during late December–early January, thereby boosting the number of geese present in the period of the extension (Madsen et al. 1999). Within the most recent decade the majority of geese have actually remained in Denmark throughout the autumn and winter (Madsen et al. 2015a). Also, the number of waterbird species with an open January season on land is rather restricted (e.g. hunting season of dabbling ducks closes on 31 December), and mainly open to specialized offshore waterfowl hunting. The majority of traditional waterfowl hunters may therefore, and to a greater extent than expected, have turned towards the novel opportunity of terrestrial goose hunting in January, including hunting of pink-footed geese. In addition, January is probably a time of relatively little available food, and geese might have to move further inland and scatter in several smaller flocks, potentially increasing their exposure to hunters. When conditions get too harsh, however, pink-footed geese leave Denmark and move to more southern wintering areas in the Netherlands and Belgium (Madsen et al. 1999). In years with cold and snowy January conditions, January harvest may therefore be substantially less than reported here, as January 2015 was relatively mild in Denmark (average 3.0°C versus 1.5°C for 2001–2010; <www.dmi.dk/vejr/arkiver/maanedsaesonaar/vejret-i-danmark-vinteren-2014-2015>; accessed 30 March 2016). However, since the start of the marking program on pink-footed geese in the late 1980s, there has only been three winters with a cold spell induced exodus of birds from Denmark in January (Madsen et al. 1999, 2014); hence the situation in January 2015 can be regarded as normal. December 2014 was also milder than average (3.3°C versus 2.2°C); hence, the increased level of hunting in January cannot be explained by hunters compensating for reduced opportunities due to adverse weather in the month before.

The gradual decline in juvenile proportions across the open season might be explained by a combination of factors. The temporal changes in age composition of the hunting bag may be driven by the comparatively higher hunting mortality of juvenile birds, leading to a reduction in the juvenile segment of the population as the season progresses. However, juveniles may also increasingly learn to avoid hunting, leading to a gradual decline in the juvenile age bias of the hunting bag, further strengthening these patterns. Such changes in the age bias of shot birds across a single season have also been reported for greater snow geese *Chen caerulescens atlanticus* (Calvert et al. 2005) and wigeon *Anas penelope* (Fox et al. 2015). It has previously been shown that adult survival is the most important demographic driver of population dynamics in species which are relative long-lived such as geese (Lebreton and Clobert 1991). As a consequence, the proportionally higher take of adult birds in the late season and January extension are likely to have greater impacts on population change than early season harvest when juveniles make up a larger proportion of the bag.

Simulation modelling of the impacts of harvest on the population size of pink-footed geese has predicted that an

increase to ca 15 000 geese harvested per year will cause a decline of the population size, and that the target of 60 000 is likely to be reached within approximately three years (Johnson et al. 2014b). Population surveys in the spring of May 2015, i.e. after just one season with increased harvest, resulted in an estimated population size of 59 000 geese; however, subsequent surveys in the autumn of 2016 have indicated that the May 2015 estimate must have been too low (<http://pinkfootedgoose.aewa.info/node/195/>; accessed 30 March 2016); nevertheless, the suggestion is that the population is starting to decline as a result of the increased level of harvest (see data on <http://pinkfootedgoose.aewa.info/node/189/>; accessed 30 March 2016).

Although this study had to rely on only a single year of data, our findings suggest that when conditions are right, regulation of hunting season length might be an effective tool in adaptive harvest management of waterfowl species. Extending the season with one month resulted in a substantially larger harvest of pink-footed geese, and a very large proportion of this harvest took place in the extended January period. As pointed out above, the effect of such an extension will invariably rely on many mutually dependent factors such as population phenology and, hence, hunting exposure, weather conditions and hunter behaviour. Additional years, and similar evaluations for other waterfowl species, are important next steps to follow up on the certainty and generality of season length regulations as a tool of adaptive harvest management.

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