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Challenges of managing a European brown bear population; lessons from Sweden, 1943–2013

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‘Adaptive management’, which has been defined as the repeated iteration between management action, scientific assessment and revised management action, leading to a strengthened foundation for management, is required by Swedish law to be incorporated into the management of large carnivores. We have evaluated whether the size and/or trend of the brown bear *Ursus arctos* population in Sweden corresponded to management-decided national objectives during five management regimes during the past 70 years (1943–2013). We found that the objective had been met in only one period, when it had been worded very vaguely. During the last period studied (2008–2013), when management was carried out on the county level and adaptive management was required by the Swedish Government, four of six counties met their trend objectives, but only one of six met the population objectives, although one was close to meeting them. Sociological studies have documented major problems in communication among the members of the county delegations responsible for the management of large carnivores. As adaptive management apparently never has been implemented successfully in brown bear management in Sweden, we recommend that the Delegations for Game Management be mandated to integrate up-to-date, scientifically documented biological information into their decisions. This is not done consistently today. Researchers should be involved in the process to inform about relevant, available information, design testable scientific ‘experiments’ based on the predicted results of management decisions, and evaluate the results in relation to the predictions, perhaps as members of a ‘boundary organization’ consisting of researchers, managers and stakeholders. This would require a new management paradigm, because many in Sweden seem to be skeptical to the idea of involving researchers in management.

Caughley (1977) listed the four general objectives of wildlife management as: 1) make a population increase, 2) make it decrease, 3) harvest it for a continuing yield, or 4) do nothing except monitor the population. Ideally, these objectives should be the result of a planning process, building on a policy-based mission, and resulting in quantifiable objectives that can be evaluated experimentally, usually using a monitoring process, although this ideal situation is rarely met (MacNab 1983, Holechek et al. 2000). It is extremely important for managers to be aware of how wildlife populations have responded to management actions in the past, to better predict how they might respond to new management actions in the future.

The management of wildlife populations is difficult, because of a lack of adequate knowledge of the system and, perhaps more importantly, the uncertainty surrounding knowledge about demographic parameters and hunter behavior, when relevant, in relation to the management actions (Linnell et al. 2010, Bischof et al. 2012, Artelle et al. 2013). In addition, humans show a number of biases when making decisions, including a tendency to overestimate their ability to predict future events, thus highlighting the need for decision-making models that incorporate uncertainty and feedback on the efficacy of the actions (Riley and Gregory 2012, Iftexhar and Pannell 2015). One such approach is adaptive management, which is the repeated iteration between management action, scientific assessment, and revised management action, leading to a strengthened foundation for management (Enck et al. 2006, Theberge et al. 2006). By explicitly recognizing uncertainty and testing

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a range of management alternatives over time, adaptive management helps identify and rectify ineffective management more quickly than the more traditional normative approach (Robertson and Hull 2001, Iftekhar and Pannell 2015).

Adaptive management can be passive, involving historical data and research literature to develop hypotheses and a model of system performance, with the intent to assess system changes over time to improve our knowledge of wildlife responses to management. It can also be active, which is management by experiment (Riley and Gregory 2012). Perhaps one of the best-known examples of successful active adaptive management is the management of the harvest of mallards *Anas platyrhynchos* in midcontinental North America since 1995 (Conn and Kendall 2004). However, there are few cases of successful retrospective examinations of the response of wildlife populations to management (Linnell et al. 2010, Riley and Gregory 2012, Artelle et al. 2013) and few published descriptions of the sustainable harvest of large carnivores (Linnell et al. 2010).

Swedish public policy regarding the brown bear *Ursus arctos* has changed greatly through the centuries. Early on, the national policy was to exterminate the species and bounties were introduced in 1647 as a measure to help reach that objective. However, changing opinions among academics, hunters, and the public resulted in a paradigm shift at the end of the 1800s, leading to the abolishment of bounties in 1893 (Swenson et al. 1995). Several other measures to protect bears, such as restrictions on where they could be killed and making any dead bear the property of the State, additionally contributed to the subsequent population increase (Swenson et al. 1995).

However, the management paradigm changed in 1943, when hunting seasons were introduced. Here we describe the changes in the brown bear population in Sweden during the 70 years of management with legally defined hunting seasons. Our analysis begins with the first population estimate, made in 1942, and the first hunting season in 1943, and ends with a population estimate for 2013. Whereas accurate population estimates with variance estimates are only available from recent years, more qualitative estimates are available from the entire period. We evaluate how the population responded to five management regimes in relation to five objectives regarding population size or trend during these 70 years. Thus, we evaluate the results in a passive adaptive management perspective, by asking: did the chosen management regime yield the desired objective? We hope that this historical knowledge will be useful for managers charged with managing the Swedish population towards future objectives, particularly because the current political policy states that large carnivore populations shall be managed using an adaptive management approach (Pettersson et al. 2007). However, it should also be useful for managers of large carnivore populations generally, because it is difficult to harvest large carnivores sustainably, even when harvest controls and monitoring data are available (Linnell et al. 2010). Our results should be especially relevant for managers of brown bears in other European countries, because the European populations of brown bear are quite similar regarding body size, reproductive investment, and productivity, being more productive than North American populations (Swenson et al. 2007, Zedrosser et al. 2011).

Methods

This is primarily a literature study. We describe the management and management objectives for each of the five management periods as they were communicated by management authorities. We then evaluated the objectives by comparing them with published and unpublished population and trend estimates (Fig. 1). Much of our information came from management reports and reports from the Scandinavian Brown Bear Research Project (available at <www.bearproject.info>). Data on legal harvest based on 'hunting year' from 1911–1966 were obtained from the Swedish Forest Enterprise (Domänstyrelsen) and based on calendar year from 1967 and onwards from the Swedish Environmental Protection Agency (SEPA) and the National Veterinary Institute of Sweden. Data on hunter-killed bears were obtained from successful brown bear hunters, who were required to provide information about the harvested bear to the Swedish Association for Hunting and Wildlife Management (SAHWM) (1986–2001) and the National Veterinary Institute of Sweden (after 2001) (Bischof et al. 2008). The National Veterinary Institute of Sweden also provided information on bears known to have died of causes other than hunting.

Results

Data on the number of hunter-killed bears per county in Sweden during 1856–1927 are available in Lönnberg (1929). To make more recent data more easily accessible, we present supplementary tables at the end of this paper with the number of bears killed in Sweden by county and year during 1911–1980 (Supplementary material Appendix 1 Table A1). For the period 1981–2013, we have summarized the quota size and known kill based on cause of death for each year by county (Supplementary material Appendix 1 Table A2–A8). In the following text, we describe the major events in the management of brown bears in Sweden. To assist the reader, we have summarized these chronologically in Table 1.

Period 1. Before hunting quotas; 1943–1980

The first population estimate of bears in Sweden was carried out by a government-appointed expert commission in 1942, based on interviews with local people within the bear's area of distribution. The result was an estimate of 294 bears nationally (Table 2), with a reported increasing number in many areas. Due to the methods, the results are uncertain, although the independent Swedish Organization for Nature Protection agreed with the estimate of size and generally increasing trend (Selander and Fries 1943). As a result of the population evaluation in 1942, a hunting season was recommended to start in 1943, with an objective to reduce the population and to decrease the damages that the bears were causing (Selander and Fries 1943). The recommended hunting season was 1 May–15 June and 1 September–15 October.

This recommended hunting season apparently was not followed, as the hunting season during this period only lasted two months in September and October in the four

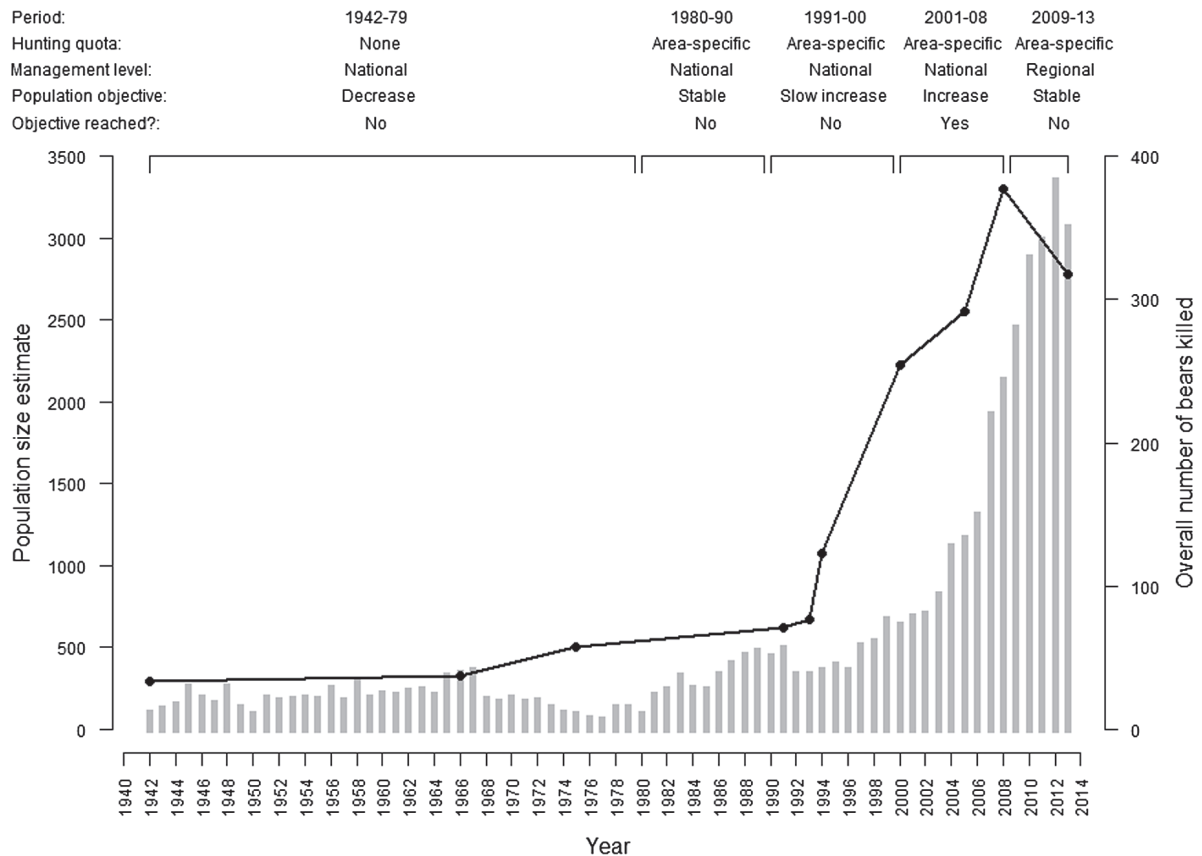


Figure 1. An illustration of the management periods for brown bears in Sweden, as defined in this paper, with the brown bear population size estimates (black line), annual number of bears killed (gray columns), type of hunting, organizational level of management, population objective, and whether or not the objective had been reached.

Table 1. A time line of the important events in Swedish brown bear management, excluding population estimates, which are summarized in Table 2.

Year	Event	Period
1943	Hunting of bears started	1
1967	Swedish Environmental Protection Agency (SEPA) established	
1973	(or earlier) Cubs of the year and their mothers are protected	
1981	Quotas established	2
1986	All members of bear families received protecting	
1991	SEPA issues the first large carnivore management policy	3
1991	Bears protected in an area next to the Norwegian border	
1992	Female quotas adopted	
1993	Quotas were set based on subpopulation distribution	
1995	Sweden joins the European Union	
1997	Bear protection next to the Norwegian border removed	4
1999	No longer female or subpopulation quotas	
2000	SEPA publishes "Action plan for the conservation of brown bears"	
2001	Hunting using baits is forbidden	
2001	Parliament adopts the First national policy on large carnivores	
2002	Nation-wide hunting start set at 21 August	
2005	County administrations produce regional management plans	
2007	County administrations greatly increase management kills	
2009	Parliament adopts the Second national policy on large carnivores	5
2009	County Delegations for Game Management established	
2010	Delegations propose minimum population sizes for their counties	
2011	SEPA sets minimum national population size objectives	
2013	Parliament decides reference area and population size boundaries for favorable conservation status	
2013	SEPA sets reference population size	
2013	Hunting with baits allowed	

Table 2. Summary of the available nationwide estimates of the brown bear population in Sweden. ‘Estimate’ means the estimated number of individuals present.

Year	Estimate	Method	Source
1942	294	A government-appointed expert committee obtained information via meetings and discussions with local people within the bear’s distribution	Selander and Fries 1943
1966	330	Reports from local employees of the Swedish Forest Service	Bjärvall 2007, Haglund 1968
1966	350–450	Tracking surveys and discussions with locals	Haglund 1968
1975–1976	400–600	Questionnaires to Sámi areas, and local offices of the Hunter’s Organization, Forest Service, and forest companies, with some helicopter surveys	Bjärvall 1980
1991	620 (771*)	CMR method using helicopter surveys of radiomarked and unmarked bears in two areas and extrapolation to all of Sweden. (* corrected estimate due to documented underestimate from the helicopter survey (Solberg et al. 2006))	Swenson et al. 1994, Kindberg and Swenson 2010
1993	669 (834*)	As above.	Swenson et al. 1995, Kindberg and Swenson 2010
1994	950–1200	Using corrected numbers from 1991 and 1993 and the documented population growth rate to 1994 (Sæther et al. 1998).	Kindberg and Swenson 2010
2000	2222 (2006–2465)	CMR estimates based on DNA in collected scats and trend estimates from effort-corrected bear observations from the most recent year of estimate and backdated to 2000	Kindberg and Swenson 2010
2005	2550 (2350–2900)	CMR estimates based on DNA in collected scats and trend estimates from effort-corrected bear observations from the most recent year of estimate to 2005	Kindberg and Swenson 2006
2008	3298 (2968–3667)	CMR estimates based on DNA in collected scats and trend estimates from effort-corrected bear observations from the most recent year of estimate to 2008	Kindberg et al. 2011
2013	2782	CMR estimates based on DNA in collected scats and trend estimates from effort-corrected bear observations from the most recent year of estimate to 2013	Kindberg and Swenson 2014

northernmost counties (Fig. 2), although there were a number of restrictions that protected bears (Haglund 1964). In the two northernmost counties, Norrbotten and Västerbotten (Fig. 2), bears occurred primarily on public lands or above the ‘odlingsgränsen’, which was legally defined in 1890 as the

western (upper) limit of new habitation in order to secure the higher altitudes for Sámi domestic reindeer *Rangifer tarandus* herding (Lundmark 2006). In both of these areas, hunters needed a special license issued by the county administration to hunt bears. In Jämtland County, many bears occurred on

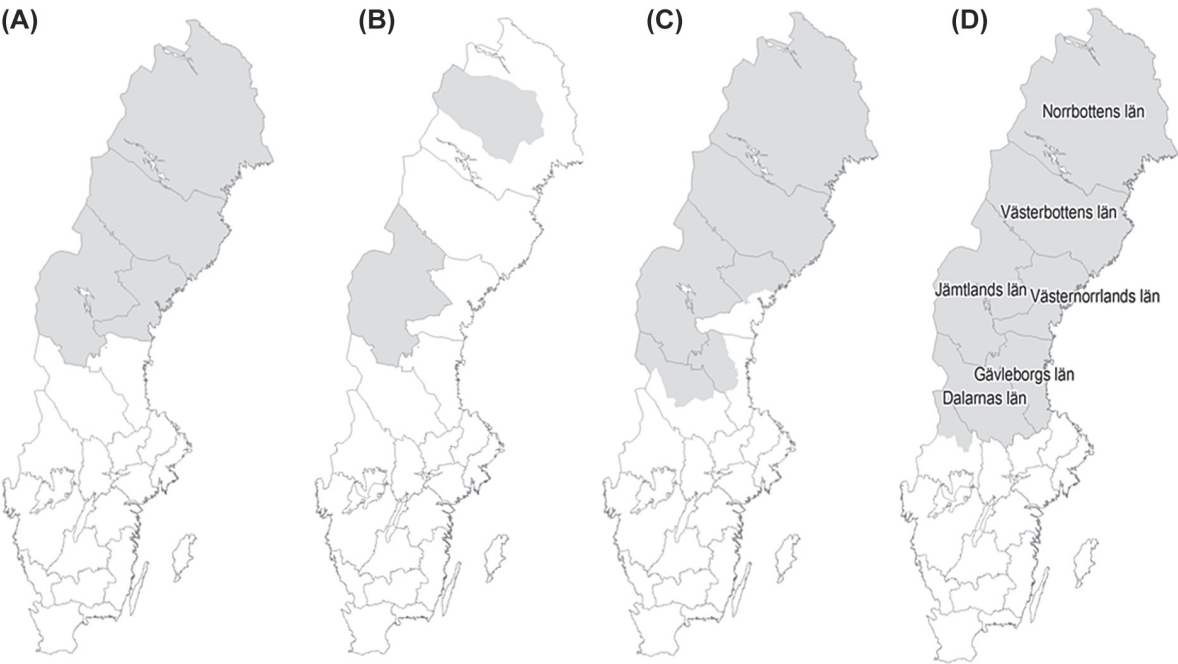


Figure 2. Areas open to hunting of brown bears in Sweden (shaded) in (A) 1964, (B) 1973, (C) 1981–1993, and (D) 2013.

private lands, where they could be hunted, but many forestry companies protected them on their lands. The indigenous Sámi people had the right to hunt bears above the 'odlingsgränsen' to reduce the number of depredating bears where they kept their reindeer. Sámi hunters killed 42% of the legally killed bears during 1951–1963, 25% during the autumn hunting season and 17% outside of it, based on their right to kill depredating bears (Haglund 1964). It appeared that some individual Sámi hunters had killed several bears. Other local hunters killed 55%; 33% were killed by hunters hunting bears and 22% by hunters hunting primarily moose *Alces alces*.

We have not found references to bear hunting regulations for the period 1963–1973. By 1973, bear hunting had been restricted to two municipalities in Norrbotten County (Jokkmokk and Gällivare) and all of Jämtland County (Bjärvall 2007) (Fig. 2). The hunting season was during September in Norrbotten and during September and October in Jämtland, except for Härjedalen Municipality, where it was 1–15 October. Cubs of the year and their mothers were protected by 1973 (Bjärvall 1980), although it is unclear when this protection had been initiated.

Four population estimates were made between 1942 and 1975–1976 (Table 2), all based primarily on input from local experts who were knowledgeable about bears, i.e. people who worked in the local offices of the SAHWM, Swedish Forest Service, forestry companies, etc. These people were considered to have the best knowledge of the occurrence, numbers, and trends of the bear population in their areas. Even though these methods are inherently inaccurate, in all these surveys, the local experts reported a generally increasing population (Selander and Fries 1943, Haglund 1968, Bjärvall 1980). The estimates suggested that the brown bear population increased slowly, from about 300 in 1942 to 400–600 in 1975–1976 (Table 2). This is an increase of about 67% in 34 years, or 1.6% annually (Table 3), which means that the original objective of reinstating hunting to reduce the population (Selander and Fries 1943) had not been met. Hunters' reports to the SAHWM indicated a perception of a generally stable or slowing increasing population from the mid-1960s to the mid-1970s (Swenson and Sandegren 1996). The low number of harvested bears in the early 1970s (Supplementary material Appendix 1 Table A1) lead to the perception that the population was declining, which was the reason why the SEPA initiated the population estimation and survey in 1975–1976 (Bjärvall 1980). One of the findings of this survey was that bears were unevenly distributed within the country.

Period 2. The Swedish Environmental Protection Agency is responsible for bear management; 1981–1990

The SEPA was established in 1967 as a national environmental management agency under the Ministry of the Environment. Based on the 1975–1976 population survey, the SEPA proposed that the general hunting season for bears be replaced by a quota system, with area-specific quotas issued by the SEPA (Bjärvall and Nilsson 1977). The reason for the proposed change was to steer harvest from areas with few bears to areas with higher bear densities and hopefully to reduce the level of illegal hunting, which was suspected to equal the legal harvest (Bjärvall 2007). This proposal was initiated in the autumn of 1981, but without a national objective regarding population size or trend. However, the quota was set at 6% of the population estimate, which was considered to be the level that would keep a constant population, based on North American data (Miller 1990, Bjärvall 2007). We interpret this to mean that the objective therefore was to keep the population constant. This marked the start of modern bear management in Sweden, and it was carried out at the national level by the SEPA.

During this and Period 3, the SEPA made many changes in bear management, often in response to the wishes of the county administrations, local hunters, and the national SAHWM. For example, there was a huge variation in the starting dates for the hunting season during 1981–2001; 24 and 25 August, 1, 2, 4, 7, 11, 16, 17, 19, 24 and 25 September, and 8, 9 and 10 October, often because the bear hunting season started concurrently with the moose hunting season, which varied throughout the country, or to avoid conflicts with other outdoor recreation, such as berry and mushroom picking. In 1986, all members of bear family groups received protection, including young older than cubs of the year, which was a strengthening of the previous regulations that only protected cubs of the year and their mothers (Bjärvall 2007). The quotas were set at various spatial scales during this period, often at the municipal level, or one quota for several municipalities (Swenson et al. 1994, 1998). However, some areas in municipalities that were open for bear hunting were closed due to administrative decisions, landowner decisions, or inclusion of the area within a national park, where all legal bear hunting is forbidden (Swenson et al. 1998).

The objective of population stability was not met, because the population increased from the estimate-based estimate of 400–600 in 1975–1976 (Bjärvall 1980) to about 770 in 1991 (Table 2). The latter estimate is based on a

Table 3. Summary of national brown bear population objectives and actual results based on management actions in Sweden.

Period	Management action	Objective	Result	Objective reached?
1) 1942–1980	initiation of a general hunting season	population reduction	annual population increase of 1.6% (1942–1975)	no
2) 1981–1990	area-specific quota-based harvest (6% hunting mortality)	population stability	annual population increase of 2.6% (1975–1991)	no
3) 1991–2000	continuation of harvest system as above	slow population growth and expansion	annual population increase of 11.2% (1991–2000)	no
4) 2001–2008	continued conservative hunting	continued growth and expansion	annual population increase of 4.5% (2000–2008)	yes
5) 2009–2013	regional management	stability at national level, but allowing local reductions	annual population reduction of 3.3% (2008–2013)	no

mark–recapture estimate based on bears observed from helicopters in the breeding season and a later finding based on a mark–recapture estimate based on DNA in collected scats, which showed that the helicopter method underestimated the population by about 25% (Swenson et al. 1994, Solberg et al. 2006, Kindberg and Swenson 2010). Thus, the population increased about 54% over 17 years or 2.6% annually (Table 3). Although changes in methods make this estimate of rate of increase uncertain, we are confident that the population was, in fact, increasing during this period.

Period 3. Swedish Environmental Protection Agency's bear management policy; 1991–2001

In 1991, the SEPA issued its first management policy for large carnivores (Frisén and Eriksson 1991). Regarding bears, the SEPA decided that harvest could be maintained at the present level, in order to allow the population to continue to increase slowly in size and distribution. At that time, the population had been estimated to be about 620 bears (Swenson et al. 1994), although this was later adjusted to about 770 bears (Kindberg and Swenson 2010), as stated above (Table 2). The SEPA was not able to set an objective for population viability, but stated the need for more research and monitoring of the population.

The SEPA made other changes in the hunting system during this period. It established female quotas in 1992, where the female quota was based on the desired number of females to be harvested and a total quota that was three times the female quota, in order to allow the hunters to kill more males. It was soon evident that hunters did not distinguish between males and females, which resulted in the 'extra' quota rarely being filled and a reduced total harvest, compared with earlier years (Bischof et al. 2008). This was unpopular among the hunters, and the regulation was abandoned after the 1998 hunting season. A zone near the Norwegian border was closed to bear hunting in 1991 in order to promote emigration of bears from Sweden to Norway, but this area was reopened to hunting in 1997, when the Swedish hunters asked to be allowed to hunt bears rather than having them killed as sheep depredators in Norway (Björvall 2007). Bear depredation on unguarded, free-ranging sheep is a great problem in Norway, but is not a problem in Sweden, where sheep are not free-ranging (Swenson and Andrén 2005). Starting in 1993, the SEPA set subpopulation quotas, based on the distribution of females, i.e. the four female core areas that were recognized by researchers at that time (Swenson et al. 1998), rather than on political units (counties). Based on the public comments to the season proposals, this subpopulation quota system was unpopular with the county administrations and hunters, who were not used to cooperating over county borders. This system was abandoned following the 1998 hunting season and quotas were again issued based on county borders. Sweden joined the European Union (EU) in 1995. This resulted in the brown bear becoming a protected species. However, hunting continued as previously, using the exceptions (derogations) allowed in the EU Habitats Directive. In 2000, the SEPA published an action plan for the conservation of brown bears in Sweden (Naturvårdsverket 2000).

In 2001, hunting bears using baits was forbidden, primarily because of concerns regarding human safety (Naturvårdsverket 2000). A retrospective analysis concluded that the ban had no immediate effect on the age or sex of hunter-killed bears or the use of the remaining legal hunting methods (Bischof et al. 2008).

During 1991–2001, the management objective had been to continue the harvest rate as before to allow slow population growth and expansion. However, the population increased about 190% in 10 years or 11.2% annually, from ca 770 in 1991 to about 2220 (2006–2465) in the year 2000 (Kindberg and Swenson 2010). Thus, the objective was not met, as the population grew much faster than anticipated (Table 2). In fact, the annual population growth rates in two areas during this period, as determined by a demographic analysis of data from radiomarked bears, rather than comparing population estimates, were the highest ever reported for brown bears; 14 and 16% (Sæther et al. 1998).

Period 4. A national political policy of brown bear management, 2001–2008

In January 2000, a commission appointed by the Swedish Government presented its recommendation for a national policy for large carnivores (Ekström and Ingman 1999). The Government responded by proposing a national policy on large carnivores in 2000 (Regeringen 2000), which was adopted by the Swedish Parliament in 2001. No population estimate was available for bears in 1999, but the expert opinion was that the population consisted of at least 900 bears in Sweden. However, a retrospective analysis based on DNA-based censuses (Bellemain et al. 2005, Solberg et al. 2006) indicated that there really had been about 2220 (2006–2465) bears in 2000 (Kindberg and Swenson 2010). Not knowing this, Ekström and Ingman (1999) recommended a minimum population objective of 1000 bears, which was more than what was considered to be a minimum viable population size in the short term. Ekström and Ingman (1999) recommended that the population be allowed to increase to perhaps 2000–2500 individuals, which they considered to be enough to ensure population viability in the long term, and to increase the distribution. No objective for maximum population size was proposed, except that a maximum level would depend on the amount of damage that bears caused to reindeer owners and summer cattle farmers, in addition to human injuries (Ekström and Ingman 1999). They recommended that hunting should continue. The Parliament set the minimum population objective at 100 reproducing females per year, corresponding to about 1000 individuals, with no upper limit for population size and with an additional objective that the population's distribution should increase in order to allow low-density areas between the existing high-density core areas to be occupied and that the expansion to the south be allowed to continue. It also concluded that the hunter harvest could be increased as the population increased (Regeringen 2000). Thus, the objective for this period was an unspecified continued population growth.

In 2002, the SEPA set a common start date of 21 August for bear hunting throughout the country and gave the county administrations (Länsstyrelser) the right to issue permits to

kill depredating bears under certain circumstances. The areas where bear hunting was banned on private lands or portions of municipalities gradually decreased. Around 2005, the county administrations produced regional management plans for large carnivores, including population objectives for bears in their counties.

During this period, the brown bear population in Sweden increased from about 2220 (2006–2465) in 2000 (Kindberg and Swenson 2010) to 3298 (2968–3667) in 2008 (Kindberg et al. 2011). This was an increase of about 50% in nine years or 4.5% annually. This was consistent with the political objective of a general population increase, although no indication of the desired rate of increase or population size had been given.

Period 5. Brown bear management is delegated to the counties; 2009–2013

Another commission appointed by the Swedish Government to evaluate the management of large carnivores presented its recommendations in 2007 (Pettersson et al. 2007). The Government followed these recommendations and proposed a new management regime, with the SEPA continuing its national role and responsibility for carrying out the national policy and monitoring the counties' management. However, the operative responsibility for large carnivore management, including hunting and issuing kill permits for depredating bears, was proposed to be moved to the regional level, including county administrations and their Delegations for Game Management, which were to be established (Regeringen 2009). No changes in the objectives regarding brown bear population size and distribution were proposed. The Swedish Parliament accepted this change in management paradigm in October 2009, dividing the country into three regions for large carnivore management, within which the county-based delegations were to cooperate.

The Delegations for Game Management were established to be an institution consisting of a mix of governmental and nongovernmental actors within each county administration with the mandate to make overarching decisions regarding the management of game species, especially moose, wild boar *Sus scrofa* and large carnivores. The delegations consist of 12–16 members with a four-year mandate representing important stakeholders, including hunting, farming, forestry, livestock husbandry, outdoor recreation, nature conservation, tourism, reindeer herding and fisheries in counties where they are present, and, in some counties, the police, which contribute knowledge on issues regarding traffic and illegal hunting. Five politicians appointed by the County Council (Landstinget) represent the general public. The leader of the county administration heads the delegation in that county and county administration provides the secretary functions. The delegation is a forum for interaction and discussion and, as such, a forum for a strong stakeholder involvement in game management (Matti et al. 2014). However, this system has not included transferring formal powers of significance from the central to the regional level, perhaps because of the central authorities' fear of losing control over natural resources and the outcome of large carnivore management (Sandström et al. 2009).

Among other things, the Delegation for Game Management proposes objectives for numbers and distribution of the brown bear in their county and works to meet these objectives. Proposing a suitable minimum level of brown bear population size for their county to the SEPA was one of the first issues dealt with by the newly established delegations in 2010. The delegations within each large carnivore management region were charged to cooperate to reach the minimum objective for each region, which, however, already had been proposed by the Government in 2009 (Regeringen 2009). Based on these recommendations, the SEPA set minimum objectives in 2011: 75 yearly reproductions (about 750 bears) in the northern large carnivore management region and 32 reproductions (about 320 bears) in the central region (Naturvårdsverket 2011). No objective was set for the southern region, because no bears occur there and no females are expected to arrive there in the foreseeable future (Regeringen 2009). Interestingly, the county administrations and their delegations in the central large carnivore region had recommended increasing the minimum regional objective from 25, which the Government had proposed and the Parliament had accepted, to 32 reproductions per year.

Neither the county administrations, their delegations, the SEPA, nor the Government proposed decreasing the minimum population objectives for bears, and the Government stated clearly that there was no need to reduce the bear population on the national level (Regeringen 2009). However, the Government also had stated that there may be a need to reduce populations in certain areas. Thus, the objective for the period was population stability at the national and regional level, although variation at the local level was permitted. Importantly for this review, both the Government and the Parliament required that adaptive management be used by large carnivore managers (Regeringen 2009, Riksdagen 2009).

In 2011, another commission appointed by the Government to evaluate the management of large carnivores presented its recommendations regarding reference population levels for favorable conservation status for reporting to the EU. The commission determined the reference population level for the brown bear in Sweden to be 1800 bears and, as the current population was believed to exceed this number, it was concluded that the species therefore enjoyed a favorable conservation status (Liljelund et al. 2011). In 2012, the commission presented its evaluation of the management of large carnivores in Sweden (Liljelund et al. 2012). The commission proposed that the overall objective for bears should be to maintain a favorable conservation status. Based on the commission's two reports and other work, the Government proposed (Regeringen 2013) and the Parliament decided (Riksdagen 2013) 1) that the reference area for distribution for the favorable conservation status of the brown bear in Sweden should be all of Norrbotten, Västerbotten, Jämtland and Västernorrland counties and portions of Dalarna, Gävleborg, and Värmland counties, 2) that the reference population size should be somewhere in between 1100 and 1400 individuals, and 3) that the SEPA should determine the appropriate number within this interval. In December 2013, the SEPA concluded that the reference level regarding population size for favorable conservation status of the

brown bear in Sweden was 1400 individuals (Naturvårdsverket 2013).

During this period, the brown bear population in Sweden decreased from about 3298 (2968–3667) in 2008 (Kindberg et al. 2011) to about 2782 (no confidence intervals calculated) in 2013 (Kindberg and Swenson 2014), or 3.2% annually. This decline was not consistent with the political objective of population stability at the national level, even though local reductions were allowed (Regeringen 2009).

Because population objectives and the management to attain them were set at the county level during this period, we have also evaluated the population size and trend objectives by county during 2008–2013 (Table 4, Kindberg and Swenson 2014). For this evaluation, we compared the county objectives for population size with the point estimate of the population in the county in 2013 and the county objectives for population trend with the trend for that county obtained from the annual ‘large carnivore observations index’ from 2008–2013. Populations were not considered stable if the trend regression line was significantly different from 0. The stated objectives were only met in one of the seven counties (Västerbotten), although it was partially met in another (Jämtland), where the desired declining trend was obtained, but not the desired population size. Also, the objectives were very close to being obtained in Västernorrland, where the population estimate (173) was only slightly below the lower population objective (180) and the trend objective of ‘slight population increase’ was close to the stable result we obtained. Had we used confidence intervals in our evaluations, we would probably have considered one or both of these objectives to have been obtained.

Present rapid changes in challenges to management

At the end of our study period, rapid changes were occurring in bear hunting, which may make it difficult for managers to reach management objectives using knowledge obtained from earlier periods with different hunting regimes, i.e. limiting the relevance of passive adaptive management. For example, the proportion of bears killed by bear-oriented hunters almost doubled from 1981–2004 (46%, Bischof et al. 2008) to 2005–2012 (71 %) and the proportion of bears killed by hunters using dogs doubled. During 1981–2004, bears were killed using the following methods; dogs 37%, still hunting 30%, baiting 18%, and stalking 16% (Bischof et al. 2008). During 2005–2012, the methods were dogs 71%, still hunting 21.5%, stalking 7.5%, and baiting 0.3%. The use of baiting probably will increase in the future, because it was allowed again in 2013. Dog hunters may be tempted to obtain fresh tracks of bears at or near baits, because very few bears visit baits during the legal shooting hours (1 h before sunrise to 2 h before sunset), making baiting an ineffective hunting method by itself (Zedrosser et al. 2013).

Another major development was the increase in hunters specializing in bear hunting. Bischof et al. (2008) reported that during 1981–2003, only 2.1% of the successful bear hunters had killed more than one bear during a single hunting season, with a maximum of three. During 2005–2012, this had increased to 9.5%, with a maximum of 10 (Table 5). This change is also evident in the number of bears killed per hunter during the entire period. In 1981–2003, only 3.1% of the successful hunters had killed more than one bear in the period, with a maximum of 17 bears killed by one hunter during this period of 22 years

Table 4. Comparisons of brown bear population objectives by county during the period of regional management in Sweden, 2009–2014, with estimated population size in 2013, based on genetic sampling, and estimated trend during 2008–2013, based on the ‘large carnivore observation index’ (Kindberg and Swenson 2014).

County	Objectives	Source	Result	Objective reached?
Norrbottn	population decrease, target population level ca 820 (730–910) bears	decision by the GMD ^a , 22 february 2011	annual population decline 8.0%, 593 bears	no; population too small
Västerbotten	stable population, target population level 300 (250–600) bears	regional management plan for the brown bear in Västerbotten county 2006–2007; decision by the GMD, 16 april 2013	stable, 300 bears	yes
Jämtland	population decrease, target population level 650 (500–800) bears	decision by the GMD, 16 june 2011	annual population decline 6.9%, 906 bears	in part; but population too large
Västernorrland	slight population increase, target population level 200 (180–220) bears	regional management plan for large carnivores in Västernorrland county 2006–2010; decision by the GMD, 28 january 2011	stable, 173 bears	almost; population stable and somewhat below target
Dalarna	target population 250 bears	decision by the GMD, 18 may 2010	stable, 412 bears	no; population too large
Gävleborg	stable population at ca 500 bears	decision by the GMD, 8 june 2010	stable, 381 bears	no; population too small
Värmland	population increase	regional management plans for large carnivores in Värmland county 2005–2008 and 2014	stable, 17 bears	no

^aGame Management Delegation for the relevant county.

Table 5. Percent of the hunters in Sweden that have killed more than one brown bear during one year or the entire period during 1981–2003 (from Bischof et al. 2008) and during 2005–2012. The samples sizes are the number of hunters that killed bears in each period.

No. of bears killed by the same hunter	1981–2003 (n = 700)		2005–2012 (n = 1221)	
	Single year	Entire period	Single year	Entire period
2	2.0% (14)	2.3% (16)	6.7% (82)	10.0% (122)
3	0.1% (1)	0.3% (2)	1.5% (18)	2.1% (26)
4	0	0.3% (2)	0.7% (8)	1.5% (18)
5	0	0.1% (1)	0.3% (4)	0.7% (9)
6	0	0	0.1% (1)	0.7% (9)
7	0	0	0.1% (1)	0.1% (1)
8	0	0	0.1% (1)	0.2% (2)
9	0	0	0	0.2% (2)
10	0	0	0.1% (1)	0.1% (1)
11	0	0	0	0.1% (1)
12	0	0	0	0.1% (1)
17	0	0.1% (1)	0	0
23	0	0	0	0.1% (1)
28	0	0	0	0.1% (1)
33	0	0	0	0.1% (1)

(Bischof et al. 2008). In 2005–2012, however, 16.0% of the successful hunters killed more than one bear during this period of eight years, with a maximum of 33 bears killed by one hunter (Table 5).

Bischof et al. (2008) stated that financially motivated guided hunts were rare in Sweden during 1981–2004. We evaluated the possibility that this had changed by examining the proportion of bears killed by hunters with foreign addresses. During 1981–2003, 1.7% of the bears (15 of 887) were killed by foreign hunters; 10 killed by hunters from Norway, 3 from Denmark and 2 from Germany. During 2004–2014, this had increased to 5.0% of the bears (120 of 2409; 94 by hunters from Norway, 10 from Finland, 8 from Denmark, 3 from England, 2 from Germany, and 1 each from the Netherlands, Switzerland and USA). The participation of foreign hunters in the Swedish bear hunting seems to be increasing; in 2013 and 2014, 7.2% of the bears were killed by foreign hunters (41 of 573). This strongly suggests that financially motivated guided hunts are increasing rapidly in Sweden.

Another recent change, which started in 2007, was a great increase in the number of bears killed annually by management agencies (Table 6), primarily in Norrbotten and Jämtland counties (Supplementary material Appendix 1 Table A2–A8). Most of these bears were killed in response to complaints regarding bear depredation on reindeer calves, which can be considerable (Karlsson et al. 2012). On the national level, these management kills increased from an annual average of 1.2 bears (1.9% of all known mortalities) during 1981–2006 to an annual average of 25.6 bears (8.3% of all known mortalities) during 2007–2013 (Table 6, Fig. 3). This mortality is in addition to the greatly increased hunting mortality, which was almost the only legal source of mortality before 2007. This, and the increasing proportion of the harvest that has been taken before the ‘large carnivore observation index’ trend observations have been made in recent years, also may have affected the reliability of the recent trend estimates (Kindberg and Swenson 2014).

Discussion

Adaptive management and attaining stated objectives

Although our review of 70 years of brown bear management in Sweden documents an impressive example of brown bear management from a conservation perspective (Fig. 1), it raises questions regarding the effectiveness of attaining management objectives. The population trend objectives were only attained in one of the five periods we evaluated at the national level and this objective had been formulated vaguely (Table 3). In addition, when management was carried out on the county level and adaptive management was required by the Government (2008–2013), five of seven counties generally met their trend objectives (counting Västernorrland, which had an objective of ‘slight population increase’ and a result of ‘stability’), but only one of six met the population objectives, not counting Västernorrland, which almost met its population objective (Table 4). This is in spite of the fact that the trend of the brown bear population is monitored annually at the county level using effort-corrected observations of bears by moose hunters (Kindberg et al. 2009). The size of brown bear populations is estimated at the county level using periodic DNA-based methods (Bellemain et al. 2005, Solberg et al. 2006), and, during our study period, repeat estimates had been conducted in Västerbotten, Dalarna and Gävleborg counties.

The Scandinavian Brown Bear Research Project (SBBRP) – a research project on brown bears ongoing in Sweden since 1984 – has designed and evaluated the current methods used for estimating population size and trend and carried out these estimates. The SBBRP makes these results publically available and responds to all requests for information from the national and county management authorities. There is presently no requirement that the Delegations for Game Management solicit or incorporate scientific information in their management decisions. However, the Delegations or their secretaries from the county administrations do sometimes ask for information or presentations. This is not done

Table 6. The quotas and known number of human-killed bears and the cause of death in Sweden, during the period of quota hunting, 1981–2013.

Year	Quota	Hunter kill	Known wounding loss	Management kill	Traffic	Other	Total
1981	36	16	0	0	0	2	18
1982	35	21	0	1	0	6	28
1983	42	34	0	0	0	3	37
1984	42	27	0	0	0	2	29
1985	40	27	0	0	0	1	28
1986	45	36	0	0	0	2	38
1987	57	42	0	0	0	4	46
1988	60	45	0	0	1	6	52
1989	59	49	0	2	0	4	55
1990	58	47	0	1	1	2	51
1991	51	47	0	0	1	9	57
1992	50	35	0	0	0	3	38
1993	50	34	0	1	1	2	38
1994	50	30	0	0	1	10	41
1995	50	37	0	1	1	6	45
1996	58	29	1	1	2	8	41
1997	69	47	1	1	0	10	59
1998	78	43	5	1	5	7	61
1999	55	51	1	0	1	24	77
2000	56	57	1	3	1	11	73
2001	60	59	1	2	4	13	79
2002	64	59	3	1	8	10	81
2003	74	74	2	3	6	9	94
2004	101	96	4	4	9	15	128
2005	121	99	11	3	4	16	133
2006	143	124	6	5	5	10	150
2007	184	173	7	12	11	17	220
2008	233	192	3	26	6	17	244
2009	243	242	3	18	9	8	280
2010	288	267	13	21	7	21	329
2011	295	285	12	19	12	14	342
2012	319	294	8	59	6	16	383
2013	307	302	3	24	7	15	351

systematically, as some ask for information, recommendations, or evaluations of proposed quotas much more often than others, and some rarely do.

From this, we can only conclude that adaptive management, at least as we have defined it here from the population management perspective, has not worked, nor has it

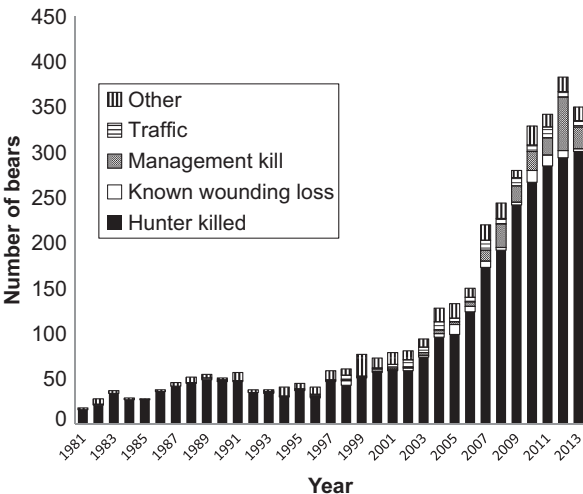


Figure 3. Number of bears known to have died annually in Sweden due to various human causes during 1981–2013.

been implemented systematically in bear management in Sweden. This is surprising, given the availability of scientific knowledge and data on which an adaptive management could be based and the Government requirement that brown bear management be based on adaptive management principles (Regeringen 2009). This is also troubling, given the fact that the character of bear hunting is changing rapidly in Sweden and that the manager-caused mortality has increased greatly. This means that predicting the effects of hunting on future population trends may be more difficult in the future than it was in the past, when hunting methods were more stable and management-caused mortality was uncommon. Nevertheless, our findings are similar to those of Linnell et al. (2010) for Eurasian lynx *Lynx lynx* in Norway. They explained the overharvest of lynx there through a combination of fragmented management, lack of access to centrally produced monitoring data, time lags in reacting to the monitoring data and in including scientific data into management, and an overoptimistic attitude regarding population status and population growth rates. This seems to be a general pattern for decisions regarding natural resource management (Iftekhar and Pannell 2015).

It is important to point out that adaptive management is not as easy as it may sound. As Theberge et al. (2006) have pointed out, most adaptive management plans operate on short time scales (3–5 years), due to social considerations,

whereas population biology and scientific assessment, especially with the wide variances commonly associated with large and long-lived carnivores, requires substantially more time, typically > 10 years, assuming that no major changes are occurring in the species' population dynamics or in the management system. In Sweden, estimates of the size of the bear population generally occur every five or more years, which means that the estimates usually are not current, although an annual trend index is generated each year (Kindberg et al. 2009, 2011). Importantly, changes in bear hunting practice and management have been coming progressively more rapidly in Sweden, making it difficult to maintain a long-term management strategy or evaluate the effects of former management policies. In addition, although adaptive management has the potential to keep a population within some bounded limits, fluctuations are inevitable (Linnell et al. 2010). Nevertheless, it is not surprising that adaptive bear management in Sweden has not worked, because it has rarely been implemented.

Recommendations for improving the adaptive management of bears in Sweden

Why has adaptive bear management not been implemented systematically in Sweden, even during the period when it has been mandated by the Government? This is, of course, a difficult question to answer, and the answer is more elusive the farther back in time one wishes to examine. We have therefore decided to focus on the most recent management period. In addition, this period is the most relevant for the future management of large carnivores.

Our evaluation of the effectiveness of adaptive management has been based on biological criteria. Of course, the human dimension is also very important in wildlife management and the management process must be supported by communication that facilitates the exploration, understanding, and coordination of the knowledge contributed by those involved in management (Hallgren and Westberg 2015). Several recent social science studies, including environmental communication, political science, social anthropology and environmental psychology, have examined the functioning of the Swedish game management delegations during the most recent management period. These studies suggest that institutionalized organizational problems within the delegations and public management agencies may be hindering the intended system of adaptive management. Sandström et al. (2009) concluded that the corporatist character of the system ensures that there is no formal upward and only informal downward accountability and that each member of a delegation is accountable to their own organization or authority. Thus, the accountability process is dependent on the internal effectiveness and interests of the organizations within the delegations (Sandström and Lindvall 2006). Internal effectiveness seems to be hindered by the formation of primarily two significantly different advocacy coalitions, based on shared policy beliefs; one for and one against large carnivores (Matti and Sandström 2011, 2013, Lundmark and Matti 2015). In addition, the communication practice of the delegations seems to constrain the coordination of knowledge, which is required by adaptive management (Hallgren and Westberg 2015). Although multiple

perspectives are presented at delegation meetings, there is often not enough time for them to be evaluated in a rational way and some delegates try to 'win' the debate, with the consequence that the validity and relevance of knowledge included in management decisions often are not assessed adequately, which inhibits adaptive management (Hallgren and Westberg 2015). It is important that both pro- and anticarnivore coalitions are present in the delegations, in order to reduce human conflicts regarding large carnivores and increase management legitimacy. However, Lundmark and Matti (2015) concluded that the delegates should gain a deeper understanding of the opposing views, which could be obtained through reasoned debate, i.e. a respectful and mutual exchange of experiences and arguments. Lundmark and Matti (2015) recommended therefore that the delegates focus more on reasoned debate. These are general conclusions, however, and these studies documented differences in communication and effectiveness among counties. In addition to these specific studies from Sweden, experimental studies have shown that humans generally are not good at systematic learning, which adaptive management was designed to promote (Iftekhar and Pannell 2015).

Thus, large carnivore management consists of a difficult combination of complicated sociopolitical and biological challenges (Sjölander-Lindqvist et al. 2015). In order to incorporate adaptiveness into bear management, as is required by Swedish law, it appears that the present management system should be changed. From a biological perspective, our results suggest that the delegations generally are not fulfilling the requirements of adaptive management, as the Swedish Parliament apparently assumed they would do when it required adaptive management. Obviously, a delegation cannot manage in an adaptive manner without integrating up-to-date, scientifically documented and relevant biological information into their decisions more than they do today. This is not always easy, because decision makers generally tend to ignore scientifically tested relevant information (Iftekhar and Pannell 2015) and, in Sweden, Hallgren and Westberg (2015) reported that delegation chairpersons often closed discourses asking for needed, relevant information before making a decision. We suggest a mandate that researchers participate in the process in a more systematic manner than they do today, in order to inform about the relevant information that is available, design testable scientific 'experiments' based on the predicted results of management decisions, and evaluate the results of the decisions in relation to the predictions. This would help increase the delegations' skill development, which also has been mandated by the Parliament, and is the only way to evaluate the ability of the management decisions to meet a quantitative objective with scientific rigor. Our proposal would require a new management paradigm, involving researchers in bear management in Sweden more than is the case today. We are aware that this involves risks of conflicts of interest. Researchers risk losing their independence if they become too involved in management and managers risk losing acceptance of their management decisions if they accept and implement measures based on scientific research without considering the policy process (Lynch et al. 2008).

Obviously, there are many ways that the brown bear management regime could be revised to make it more

adaptive. Lynch et al. (2008) described one possibility; boundary management, which is an interface between researchers, decision makers and interest groups that can facilitate the communication, translation, and mediation necessary to successfully resolve management issues. Often, boundary management is performed in a boundary organization, which is a neutral institution that facilitates knowledge exchange between different parties. Lynch et al. (2008) described the Interagency Grizzly Bear Study Team in the Yellowstone Ecosystem in the United States as a successful example of a boundary organization. This team is composed of researchers that have a mandate to study grizzly bear *Ursus arctos* population trends, determine their use of habitats, and examine land management policies in relation to preserving the grizzly bear in the Yellowstone Ecosystem, and representatives of the relevant federal and state agencies that have the management responsibility. In Sweden, a possible boundary organization could be a cooperation between the delegations and, for example, the SBBRP, which could be given a role to assist the managers in implementing the mandated adaptive management of brown bears. If successful, this model might be useful to introduce adaptive management to the entire multispecies system of large carnivores and their hunted prey.

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Supplementary material (available online as Appendix wlb-00251 at <www.wildlifebiology.org/appendix/wlb-00251>). Appendix 1.