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SHORT COMMUNICATION

Short communication articles are short scientific entities often dealing with methodological problems or with byproducts of larger research projects. The style is the same as in original articles

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Reserves that are closed to hunting are important to wintering wildfowl *Anatidae*. Reserves can also benefit local hunters, because they are often used as day-roosts by birds prior to nocturnal feeding in surrounding wetlands. In this study, we used annual hunting bags from 45 hunting estates in the Camargue, southern France, to study the relationship between hunting success and distance to the nearest duck day-roost, which are generally located in protected areas. Five dabbling duck species *Anas* spp. and a diving duck species (pochard *Aythya ferina*) were studied. The relationship between hunting bag and distance from roost was negative in all cases except mallard *Anas platyrhynchos*, which is subject to specific hunting management practices (i.e. raise and release). However, a significant trend was not found for wigeon *A. penelope* and shoveler *A. clypeata*. This supports the hypothesis that hunting estates closer to protected areas are more successful. However, the decrease in hunting bags with increasing distance from the nearest roost could be seen in as little as a few thousands of metres in all species. This suggests that only hunting grounds with a distance of < 2-3 kilometres from the nearest roost may actually have increased hunting accessibility for certain duck species.

Key words: Camargue, day-roost, distance, hunting bag, wildfowl, winter

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Wildfowl *Anatidae* are sensitive to human activities during the hunting season (e.g. Bell & Owen 1990, Tamisier et al. 2003, Triplet et al. 2003, Blanc et al. 2006) and often gather in large numbers in disturbance-free protected areas (Cox & Afton 1997, Fox & Madsen 1997, Madsen et al. 1998). Refuges can also benefit hunters when they are used by birds as roosts. Ducks departing from refuges for nocturnal feeding or other activities are more exposed to hunting activities (Bellrose 1954, Griffith 1957, Anonymous 1961, Bell & Owen 1990, Mathevet & Tamisier 2002). Some duck species commute two times within a 24-hour period, moving from day-roosts to nocturnal foraging areas. These two habitats are considered their functional unit (Tamisier 1978). Regular commuting patterns during dusk and dawn increase the ducks' vulnerability to hunting. Different studies have shown that the average distance ducks fly between roosting and foraging areas varies among species and environmental conditions (e.g. adverse weather) and can range from 0.8-50 km (Fog 1968, Frazer et al. 1990). However, it seems intuitive that ducks would minimise travel distance given the energetic cost of flight. Distance between day-roosts and nocturnal foraging habitats is therefore generally limited to a few kilometres (Tamisier & Tamisier 1981, Jorde et al. 1983, Guillemain et al. 2002, Legagneux et al. 2008). It is hypothesised that hunting areas adjacent to day-roosts, whether protected or not, experience greater hunting harvests. One study in Camargue in the south of France demonstrated that habitats protected from hunting and comprising a major roost influenced surrounding land management practices, which became more hunting-orientated. As a result, the price of hunting leases in the vicinity of the reserve increased to more than 1800 euros per hunter per year (Mathevet & Tamisier 2002). More information concerning duck movements is necessary to assess the distance travelled in regards to land management procedures. Knowledge of duck movements could influence decisions to protect or manage nocturnal foraging habitats in addition to day-roosts, or to establish buffer areas around reserves (Fox & Madsen 1997, Rodgers & Smith 1997). This information could also be important for understanding the local dispersal of propagules (seeds or invertebrates (Green et al. 2002)) or the spread of diseases by ducks, such as avian influenza viruses (Gauthier-Clerc et al. 2007, Saad et al. 2007 for teal *Anas crecca*).

Our research evaluated hunters' harvests from various private hunting estates in the Camargue, southern France, to test the relationship between hunters' harvests and distance from hunting estates and nearest day-roosts.

Study area and methods

The Camargue encompasses 145,000 ha of the Rhône Delta (see Tamisier & Dehorter 1999 for a general description). The Camargue is a site of international importance to waterbirds and exceeds the criterion of international importance for several duck species (Scott & Rose 1996). More than 85,000 ha of the delta are wetlands, and 78% of the wetlands are divided into approximately 180 private estates that integrate hunting activities (Dehorter & Tamisier 1996). As part of a research programme on hunting practices and wildfowl population dynamics in the Camargue (Mondain-Monval et al. 2006), hunting bags are collected annually for as many estates as possible. In the present study, we used data from 45 estates which provided duck bags for at least three hunting seasons, together with an indication of hunting pressure (number of hunter-days). Data ranged from the 1926-1927 to the 2004-2005 hunting seasons. However, most of the estates provided data sets beginning in the 1980s or 1990s (Appendix 1), which allows for comparison by site and also relates to the period when the list of duck day-roosts was established by aerial counts (see below). The number of annual data ranged from 3-68 years between the 45 estates (median = 9 years). The inclusion of the 13 estates with <5 years of data led to a 22-33% increase in the variance of the daily bag per hunter, depending on duck species, compared to the reduced data set made of the 32 estates with ≥ 5 years of data. However, the results concerning the relationship between daily bag and distance from the nearest roost were exactly the same in terms of significant and non-significant patterns. The complete 45 estate data set was thus used to cover the largest geographical area possible. Data sets were interrupted in some cases, due to changes in landlords and/or hunting lease holders. Three data sets also abruptly ended when the hunting estates became natural reserves. In each estate, the average daily bag per duck species per hunter was calculated for each year, and then averaged for all available years (see Appendix 1).

Although owners of hunting estates sometimes manage water levels, salinity and frequency of disturbance so as to promote duck roosting within their property, most ducks spent daylight hours in the >20,000 ha of protected areas in the Camargue. Based on long-term (1964-65 to 1994-95) aerial monitoring of wintering wildfowl, Tamisier & Dehorter (1999: 352-353) provided a list of the main day-roosts for the different duck species based on the average number of birds of each species they hosted over the monitoring period. We determined the central point of each of these roosts for each species through GIS software (Arcview 3.1 GIS, ESRI 1998). The central point of each of the 45 hunting estates was also computed using the same methodology, allowing calculation of the distance in kilometres between each estate and the nearest day-roost for each duck species (NB: the nearest day-roost was possibly different for different duck species in a given hunting estate). This method therefore established a distance equal to zero in the case of day-roosts within hunting estates.

The distribution of hunting bag values was non-normal (Kolmogorov-Smirnov tests: all d values >0.20, all $P<0.01$), and usual transformations (such as logarithm, square-root, etc) did not solve this problem. Given the distribution of the data, we used maximum-likelihood ratio statistics based on a quasi-Poisson distribution of the variables. The relationship between hunting bag and distance from the nearest roost in each duck species was analysed with a non-linear regression model, using a negative exponential relationship. Pintail *Anas acuta*, red-crested pochard *Netta rufina* and tufted duck *Aythya fuligula* were not included in the analyses, because they were either absent or represented only a small part of the total bag of the 45 studied hunting estates (0.005-0.063 individuals per hunter per day on average on 20 estates, and 25 estates with no single individual ever harvested in tufted duck). The data set therefore included mallard *Anas platyrhynchos*, teal, gadwall *Anas strepera*, shoveler *Anas clypeata*, wigeon *Anas penelope* and pochard *Aythya ferina* hunting bags.

Results

All six duck species except mallard showed the same pattern of decreasing daily bag per hunter with increasing distance from the nearest day-roost, although this was non-significant in shoveler and marginally so in wigeon (Fig. 1, Table 1). All species' hunting bags were highly variable among estates close to day-roosts. The range was as wide as 0.1-4.5 teal per hunter per day for estates <2 km from a day-roost.

In all cases, the decrease in hunting bag with increasing distance was very rapid, since estates >5 km from a roost harvested very limited numbers of individuals of a given species (see Fig. 1). Using the significant trends for the teal, gadwall and pochard models (see Table 1), we calculated the average expected daily bag per kilometre of distance from the nearest roost, and determined the threshold distance above which this value no longer exceeded 10% of the expected bag within the first kilometre. For teal, gadwall and pochard, the threshold values were 9, 5 and 3 kilometres, respectively (i.e. an estate located more than 3 km from any pochard day-roost could not expect a daily bag per hunter higher than 10% of the daily bag of an estate within 1 km from such a roost).

Discussion

All daily hunting bags decreased (though a significant threshold was not reached in wigeon and shov-

Table 1. Non-linear regressions of average daily hunting bags per hunter and the distance between hunting estates and the nearest day-roost, per duck species. The equation is given where model fit was significant.

Species	Likelihood Ratio	χ^2	P-value	Model equation
Teal *Anas crecca*	-51.11	9.35	0.0022	Daily Bag = EXP(0.8062-0.0003 × Distance)
Gadwall *A. strepera*	-21.63	10.11	0.0015	Daily Bag = EXP(0.1393-0.0005 × Distance)
Mallard *A. platyrhynchos*	-54.67	2.71	0.1000	
Shoveler *A. clypeata*	-24.16	1.78	0.1837	
Wigeon *A. penelope*	-12.91	3.47	0.0624	
Pochard *Aythya ferina*	-11.68	6.49	0.0109	Daily Bag = EXP(-0.8824-0.0011 × Distance)

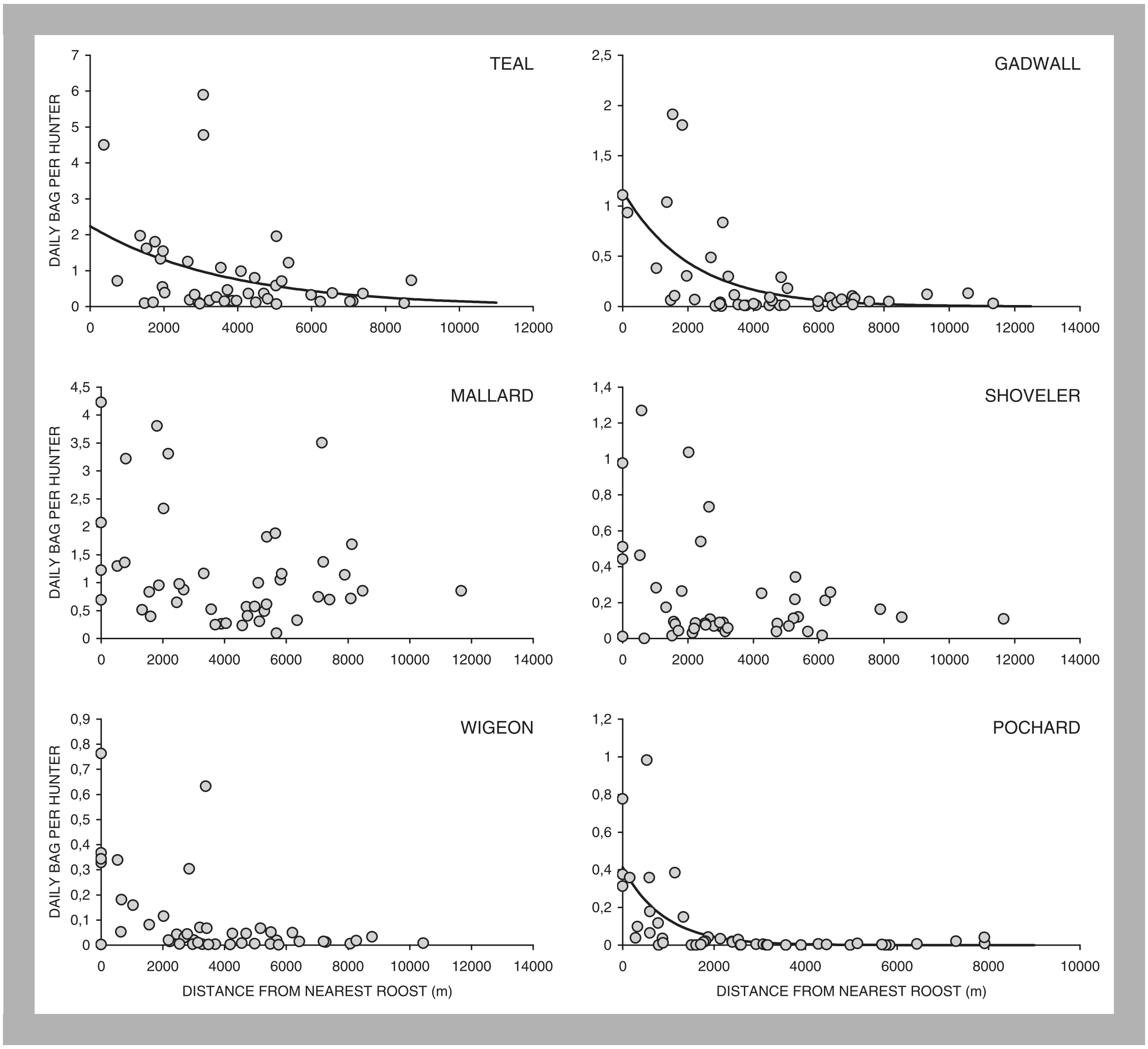

Figure 1. Relationship between daily bag per hunter and distance between hunting estate and nearest day-roost in the six duck species. See Table 1 for statistics. Regression curves are shown where significant.

eler) in an exponential manner with increasing distance from the nearest day-roost with the exception of mallard. This is consistent with central place foraging and refuge theories, in which animals try to limit their travelling distance between a central protected area and their feeding areas (e.g. review in Stephens & Krebs 1986, Cox & Afton 1996). The fact that daily bags differed among estates < 1 kilometre from a roost probably reflects management options as well as the differences in hunting estate sizes. Estates are managed and decisions are made depending on the priority species that the managers aim to attract (e.g. by selecting different water regimes, water levels or salinity) and the habitat constraints (e.g. water salinity). For example, if an estate is close to both a teal and a pochard day-roost, the management options and habitat will favour one of the species. Furthermore, some hunting estates adjacent to or encompassing day-roosts allow shooting during a few daylight hours during the morning (as opposed to dusk and dawn shooting during duck commuting flights between day-roost and nocturnal feeding areas), which is obviously a more efficient hunting technique. Depending on species, ducks virtually disappeared from hunting bags in estates located > 3-10 km from the day-roosts and in all cases were mostly shot within 2-3 km range. It is interesting to note that these distances between roosts and selected foraging areas are within the same ranges determined from earlier studies using radio-tracking methodologies. Radio-tracking studies suggest that ducks generally travel from a few hundred metres up to 10 km to feed, this range being species-specific (Tamisier & Tamisier 1981, Jorde et al. 1983, Frazer et al. 1990, Cox & Afton 1996, Guillemain et al. 2002, Legagneux et al. 2008). The present study suggests that larger home ranges (including up to 50 km travels) (e.g. Bellrose 1954, Fog 1968, references in Jorde et al. 1983) probably represented extreme travel distances or areas where no suitable habitat was available to the birds within their preferred travel distance. Some of these previous studies considered ring recoveries, indicating that the distance travelled may have been over several days.

The insignificant relationship between daily bag and distance from roost in mallard was unexpected, but could be explained by hunting management practices for this species. Most mallards in the Camargue are harvested in the beginning of the season and many of which are young individuals hatched on the estate during the previous spring or raised and released in spring and summer, a common practice in France. The exact number of such released mallards is not known, but has been estimated to be around 20-30,000 individuals in the Camargue (Tamisier 2004). The uptake of locally-released or locally-hatched individuals within the hunting estates at the beginning of the season may therefore hide a potential relationship between hunting bag and distance from a roost that may occur in natural wild conditions. This practice is, however, unlikely to have affected the uptake of other ducks, since the average daily bag in estates releasing ($N = 10$ properties) or not releasing mallard ($N = 35$ properties) did not differ significantly in any of the species (t-tests, all t absolute values < 1.33, all $P > 0.1917$). The lack of significance in shoveler and wigeon was essentially due to the high variance in hunting bags for estates close to day-roosts (0-0.8 wigeon per hunter per day and 0-1.3 shoveler per hunter per day for estates < 1 km from nearest roost). However, the wigeon and shoveler average daily hunting bag also tended to decrease exponentially with increasing distance from the roost (see Table 1).

From a hunting management point of view, this study suggests that management practices leading to roost establishments within the hunting estate may indeed lead to larger daily bags (especially if this allows diurnal shooting). Similarly, the present results show that the higher prices of hunting leases around protected duck day-roosts observed by Mathevet & Tamisier (2002) can be explained by higher expected shooting opportunities in adjacent estates. However, private properties are not affected by roosts located >2-3 km away. On the other hand, we suggest that where the protection of duck species is a priority over hunting considerations, the establishment of hunting-free buffer areas around core wildfowl refuges (e.g. Fox & Madsen 1997) could be an effective strategy since the radius of such buffer zones may be as little as a few kilometres (as opposed to 20-50 kilometres in some earlier studies) for most species.

If they do disperse seeds, invertebrate eggs or disease locally during their feeding travels, the management implications of our results are that dabbling and diving ducks are most likely to do so over short distances during their daily movements. This does not take into consideration the long distances they may cover during migration which can be associated with long-distance dispersal of seeds or invertebrates (Green & Figuerola 2005). This conclusion is only based on indirect information provided by birds shot by hunters, therefore future research using electronic devices to determine actual nocturnal movements of ducks should be carried out. This may also allow for future testing to determine if wintering wildfowl actually have longer daily travel distances in order to avoid hunted estates and move between protected areas as observed in the past in western France (Guillemain et al. 2002).

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Appendix 1. Hunting pressure (average annual number of hunter-days) and hunting bag (average number of pieces of game per hunter per day) for each of the 45 hunting estates studied in the Camargue, in the south of France. Values are means ± SE. The names of the estates are not provided because of confidentiality agreements with the landowners and holders of hunting leases.

Estate	No of years	Range	Hunting pressure (hunter-days)	Bag (number of ducks per hunter per day)					
				Teal	Gadwall	Mallard	Shoveler	Wigeon	Pochard
Estate 1	8	1997-2004	478.4 ± 51.0	0.55 ± 0.07	0.30 ± 0.03	0.95 ± 0.08	0.28 ± 0.04	0.16 ± 0.02	0.04 ± 0.01
Estate 2	4	2001-2004	209.0 ± 3.0	0.09 ± 0.03	0.05 ± 0.03	0.49 ± 0.08	0.34 ± 0.06	0.02 ± 0.01	0.00 ± 0.00
Estate 3	3	2002-2004	179.7 ± 21.4	0.15 ± 0.04	0.01 ± 0.00	0.52 ± 0.09	0.07 ± 0.02	0.02 ± 0.00	0
Estate 4	68	1926-2004	116.2 ± 3.6	5.89 ± 0.35	1.80 ± 0.18	3.31 ± 0.24	1.27 ± 0.09	0.63 ± 0.09	0.36 ± 0.08
Estate 5	10	1979-1997	389.8 ± 24.4	0.36 ± 0.06	0.10 ± 0.02	0.57 ± 0.07	0.21 ± 0.03	0.05 ± 0.01	0.01 ± 0.00
Estate 6	21	1984-2004	100.5 ± 4.2	1.62 ± 0.20	1.91 ± 0.11	2.08 ± 0.26	0.44 ± 0.06	0.07 ± 0.01	0.78 ± 0.24
Estate 7	26	1979-2004	108.0 ± 6.1	4.50 ± 0.71	0.29 ± 0.04	3.80 ± 0.58	0.26 ± 0.04	0.01 ± 0.00	0.02 ± 0.00
Estate 8	10	1993-2004	275.0 ± 7.9	1.80 ± 0.24	0.93 ± 0.15	1.30 ± 0.21	0.46 ± 0.08	0.07 ± 0.02	0.98 ± 0.17
Estate 9	3	1984-2004	554.7 ± 121.5	0.32 ± 0.03	0.00 ± 0.00	0.40 ± 0.22	0.03 ± 0.01	0.01 ± 0.00	0.03 ± 0.01
Estate 10	10	1993-2004	115.2 ± 4.5	0.17 ± 0.03	0.30 ± 0.08	0.83 ± 0.11	0.09 ± 0.03	0.08 ± 0.02	0.04 ± 0.03
Estate 11	10	1990-2004	391.6 ± 53.4	1.08 ± 0.14	0.02 ± 0.01	0.70 ± 0.08	0.09 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
Estate 12	6	1999-2004	283.3 ± 8.3	0.73 ± 0.09	0.13 ± 0.02	3.51 ± 0.18	0.12 ± 0.03	0.05 ± 0.02	0.01 ± 0.01
Estate 13	29	1973-2004	438.1 ± 4.1	1.97 ± 0.23	1.04 ± 0.10	1.36 ± 0.14	0.98 ± 0.08	0.34 ± 0.05	0.10 ± 0.02
Estate 14	10	1990-2004	302.1 ± 57.4	1.33 ± 0.46	0.09 ± 0.02	1.82 ± 0.57	0.12 ± 0.03	0.00 ± 0.00	0
Estate 15	6	1999-2004	244.5 ± 1.5	0.98 ± 0.19	0.49 ± 0.10	3.22 ± 0.30	0.54 ± 0.07	0.30 ± 0.03	0.02 ± 0.00
Estate 16	15	1981-1995	192.7 ± 23.8	1.25 ± 0.16	1.11 ± 0.13	1.88 ± 0.23	0.73 ± 0.16	0.76 ± 0.09	0.38 ± 0.09
Estate 17	4	2001-2004	322.5 ± 7.5	0.46 ± 0.11	0.01 ± 0.01	0.57 ± 0.09	0.09 ± 0.05	0.01 ± 0.00	0
Estate 18	4	1994-2004	554.0 ± 82.1	0.80 ± 0.17	0.01 ± 0.00	1.16 ± 0.32	0.11 ± 0.02	0.05 ± 0.02	0.01 ± 0.00
Estate 19	8	1997-2004	356.8 ± 25.2	0.58 ± 0.08	0.08 ± 0.01	0.74 ± 0.07	0.26 ± 0.05	0.33 ± 0.06	0.06 ± 0.03
Estate 20	6	1998-2004	68.2 ± 4.1	0.39 ± 0.11	0.01 ± 0.01	0.64 ± 0.13	0	0.04 ± 0.04	0
Estate 21	4	2001-2004	393.3 ± 45.6	0.15 ± 0.04	0.05 ± 0.02	1.05 ± 0.10	0.02 ± 0.00	0.01 ± 0.00	0
Estate 22	17	1988-2004	506.1 ± 23.2	1.22 ± 0.14	0.38 ± 0.06	4.23 ± 0.71	0.51 ± 0.07	0.03 ± 0.01	0.38 ± 0.10
Estate 23	4	2000-2003	309.3 ± 9.9	0.21 ± 0.08	0.01 ± 0.01	0.39 ± 0.13	0.08 ± 0.04	0.00 ± 0.00	0
Estate 24	4	2001-2004	107.8 ± 18.7	0.09 ± 0.05	0.06 ± 0.02	1.22 ± 0.31	0.01 ± 0.01	0.00 ± 0.00	0
Estate 25	3	1997-2004	318.0 ± 114.0	0.11 ± 0.06	0.01 ± 0.01	0.31 ± 0.17	0.06 ± 0.02	0.02 ± 0.01	0.01 ± 0.01
Estate 26	26	1977-2004	576.0 ± 25.2	0.13 ± 0.03	0.02 ± 0.00	0.32 ± 0.05	0.04 ± 0.01	0.02 ± 0.00	0.00 ± 0.00
Estate 27	6	1994-1999	422.0 ± 0.0	0.18 ± 0.05	0.00 ± 0.00	1.16 ± 0.06	0.07 ± 0.01	0.03 ± 0.01	0.18 ± 0.06
Estate 28	12	1986-1997	224.5 ± 12.8	0.36 ± 0.07	0.03 ± 0.01	0.85 ± 0.05	0.11 ± 0.02	0.01 ± 0.00	0.04 ± 0.03
Estate 29	20	1977-2004	351.9 ± 11.9	0.26 ± 0.05	0.11 ± 0.01	0.51 ± 0.04	0.17 ± 0.02	0.07 ± 0.01	0.15 ± 0.07
Estate 30	11	1992-2003	458.5 ± 38.9	0.38 ± 0.05	0.04 ± 0.01	0.87 ± 0.08	0.11 ± 0.02	0.01 ± 0.00	0.02 ± 0.01
Estate 31	9	1996-2004	454.0 ± 17.3	1.54 ± 0.18	0.06 ± 0.02	0.26 ± 0.03	0.02 ± 0.00	0.01 ± 0.00	0
Estate 32	9	1993-2001	424.1 ± 12.2	0.16 ± 0.05	0.12 ± 0.01	1.14 ± 0.12	0.16 ± 0.03	0.37 ± 0.07	0.02 ± 0.00
Estate 33	9	1996-2004	317.1 ± 30.0	0.15 ± 0.03	0.05 ± 0.01	1.37 ± 0.23	0.08 ± 0.02	0.18 ± 0.04	0.04 ± 0.02
Estate 34	3	2002-2004	233.3 ± 31.7	0.71 ± 0.33	0.04 ± 0.02	0.97 ± 0.20	0.08 ± 0.04	0.01 ± 0.01	0.03 ± 0.01
Estate 35	3	2002-2004	288.0 ± 6.9	0.07 ± 0.05	0.03 ± 0.01	0.72 ± 0.39	0.04 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Estate 36	14	1988-2004	155.6 ± 12.5	0.14 ± 0.03	0.02 ± 0.00	1.00 ± 0.23	0.07 ± 0.02	0.00 ± 0.00	0.12 ± 0.04
Estate 37	3	2002-2004	224.0 ± 2.3	0.16 ± 0.01	0.09 ± 0.02	0.25 ± 0.02	0.04 ± 0.01	0.00 ± 0.00	0
Estate 38	14	1988-2003	122.7 ± 17.6	0.11 ± 0.03	0.02 ± 0.01	0.27 ± 0.04	0.07 ± 0.02	0.04 ± 0.01	0.00 ± 0.00
Estate 39	26	1979-2004	243.2 ± 16.2	0.72 ± 0.08	0.07 ± 0.01	0.85 ± 0.08	0.22 ± 0.02	0.34 ± 0.04	0.00 ± 0.00
Estate 40	24	1981-2004	68.7 ± 4.5	0.33 ± 0.05	0.01 ± 0.00	0.23 ± 0.03	0.07 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Estate 41	3	1996-1998	388.0 ± 74.2	0.07 ± 0.02	0.03 ± 0.01	0.69 ± 0.15	0.09 ± 0.08	0.00 ± 0.00	0.31 ± 0.07
Estate 42	5	1997-2004	405.0 ± 27.0	1.96 ± 0.76	0.18 ± 0.07	1.69 ± 0.46	0.25 ± 0.08	0.05 ± 0.02	0.02 ± 0.01
Estate 43	31	1973-2004	277.2 ± 5.5	0.12 ± 0.01	0.07 ± 0.01	0.10 ± 0.01	0.04 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
Estate 44	7	1998-2004	116.7 ± 3.4	0.36 ± 0.10	0.11 ± 0.03	0.61 ± 0.08	0.06 ± 0.03	0.05 ± 0.02	0.36 ± 0.13
Estate 45	6	1998-2004	63.0 ± 7.3	4.77 ± 1.73	0.83 ± 0.20	2.32 ± 0.69	1.04 ± 0.26	0.12 ± 0.06	0.01 ± 0.01