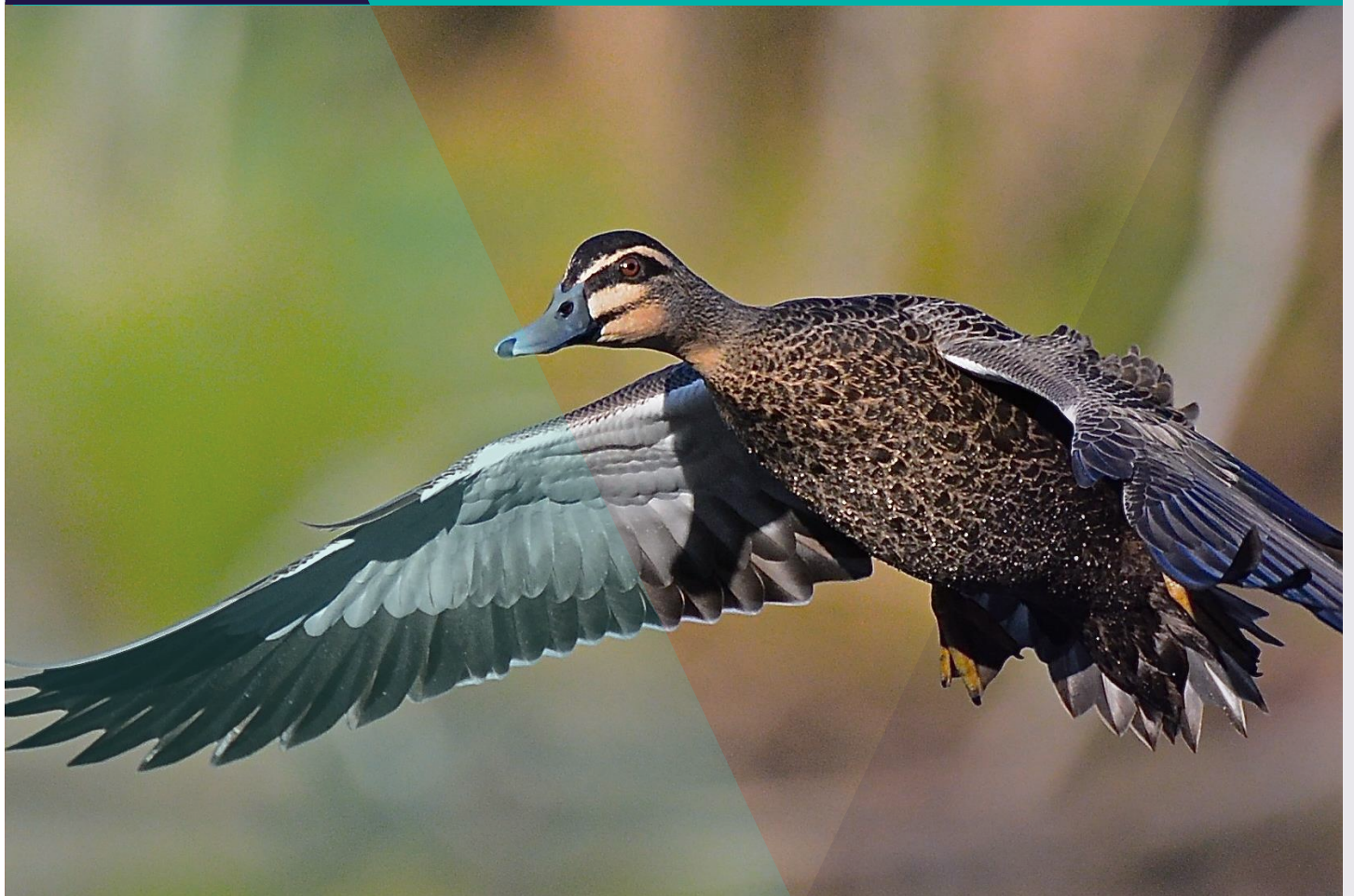


Estimate of duck and Stubble Quail harvest in Victoria for 2019

Results from surveys of Victorian Game
Licence holders in 2019

P. D. Moloney and Z. Powell

November 2019



Arthur Rylah Institute for Environmental Research
Unpublished Client Report

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.



Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.ari.vic.gov.au

Citation: Moloney, P.D. and Powell, Z. (2019). *Estimate of duck and Stubble Quail harvest in Victoria for 2019: Results from surveys of Victorian Game Licence holders in 2019*. Unpublished Client Report for the Game Management Authority. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: Pacific Black Duck in flight (Game Management Authority).

© The State of Victoria Department of Environment, Land, Water and Planning 2019

Edited by Organic Editing

Disclaimer

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Estimate of duck and Stubble Quail harvest in Victoria for 2019

**Results from surveys of Victorian Game Licence holders in
2019**

Paul D. Moloney and Zachary Powell

¹Arthur Rylah Institute for Environmental Research
123 Brown Street, Heidelberg, Victoria 3084

²Game Management Authority
121 Exhibition Street, Melbourne, Victoria 3000

Arthur Rylah Institute for Environmental Research
**Unpublished Client Report for the Game Management
Authority,
Department of Environment, Land, Water and Planning**

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
Heidelberg, Victoria

Acknowledgements

This report was commissioned by the Game Management Authority, and data analysis undertaken by the Arthur Rylah Institute for Environmental Research. We thank the Game Licence holders who gave their time to participate in the surveys, which were conducted by Marketing Skill Pty Ltd (Mt Eliza, Victoria). We would also like to thank Louise Durkin and Katie Howard for making valuable comments on drafts of this report.

Contents

Acknowledgements	ii
Summary	6
Context:	6
Aims:	6
Methods:	6
Results:	6
Conclusions and implications:	6
1 Introduction	7
2 Methods	8
2.1 General methodology	8
2.2 Duck	9
2.3 Stubble Quail	9
3 Results	10
3.1 Duck	10
3.2 Stubble Quail	16
4 Discussion	21
4.1 Duck	21
4.2 Stubble Quail	23
4.3 Locations with the most hunting days	24
4.4 Assumptions	25
References	26
Appendix 1 Additional method details	28
Appendix 2 Boxplot explanation	30

Tables

Table 1: Summary of responses for duck surveys in 2019.	10
Table 2: Proportion and corresponding total number of duck licence holders who hunted in each survey period in 2019.	10
Table 3: Average harvest of ducks per hunter (Game Licence holders who hunted) for each survey period in 2019.	11
Table 4: Estimates of the total duck harvest in Victoria in 2019 by holders of a Game Licence endorsed for duck.	12
Table 5: Estimates of average harvest of ducks per Game Licence holder in each survey period in 2019. ..	12
Table 6: Reported numbers of ducks harvested by hunters, proportions of the total harvest, and estimates of total 2019 harvest for each duck species.	13
Table 7: Days on which ducks were hunted per Game Licence holder for 2019.	14
Table 8: Percentage of days hunted and associated duck harvest by land tenure in 2019.	14
Table 9: Summary of responses for Stubble Quail surveys in 2019.	16
Table 10: Proportion and corresponding total number of Game Licence holders endorsed to hunt Stubble Quail who hunted in each survey period in 2019.	16
Table 11: Average harvest of Stubble Quail per hunter (Game Licence holders who hunted) for each survey period in 2019.	17
Table 12: Estimates of the total Stubble Quail harvest in Victoria in 2019 by holders of a Game Licence endorsed for Stubble Quail.	18
Table 13: Estimates of the average harvest of Stubble Quail per Game Licence holder endorsed to hunt Stubble Quail in each survey period in 2019.	18
Table 14: Days on which Stubble Quail were hunted per Game Licence holder endorsed to hunt Stubble Quail for 2019.	19
Table 15: Percentage of days hunted and associated Stubble Quail harvest by land tenure and dog usage in 2019.	19
Table 16: Percentage of hunting days and associated Stubble Quail harvest per grassland type in 2019. ...	20
Table 17: Comparison of duck harvests of 2009 to 2019.	22
Table 18: Comparison of Stubble Quail harvests of 2009 to 2019.	24

Figures

Figure 1: Boxplot of the number of ducks reported harvested by individual hunters for each survey period in 2019.....	11
Figure 2: Estimates of total duck harvest in 2019 by CMA region.	15
Figure 3: Boxplot of the number of quail reported harvested by individual hunters for each survey period in 2019.....	17
Figure 4: Estimates of total Stubble Quail harvest in 2019 by CMA region.	20
Figure 5: Estimates of total duck harvests (in thousands) from 2009 to 2019.	21
Figure 6: Estimates of total Stubble Quail harvests (in thousands) from 2009 to 2019.	23
Figure A2.1. Example boxplot, with labels.....	30

Summary

Context:

To effectively manage game species, it is important to quantify the numbers harvested. Since 2009, the Victorian State Government game management agency has commissioned a series of regular telephone surveys of randomly selected Game Licence holders. Each year, three sets of telephone surveys are conducted during the various game harvest seasons for deer, duck and Stubble Quail (*Coturnix pectoralis*). This report focuses only on the duck and Stubble Quail harvests for 2019.

Aims:

The aim of this report is to provide estimates of the total harvest of duck and Stubble Quail by Victorian hunters during the 2019 hunting seasons for each game type.

Methods:

Game Licence holders for each game type were randomly sampled and interviewed by telephone at intervals during their respective game seasons. In all surveys, respondents were asked whether they had hunted during the period for which the survey applied, and (if applicable) the number and species of birds harvested. Additional information was obtained on hunting methods and locations.

Results:

Each holder of a Victorian Game Licence endorsed for duck hunted on an average of approximately 3.3 days during the 2019 duck hunting season, and there was an average season harvest of 9.6 ducks for each Game Licence holder. Based on the total number of Game Licence holders, this equates to an estimated 238,666 ducks being harvested during the 2019 duck hunting season in Victoria [95% confidence interval (CI) = 205,075–277,760]. The three most commonly harvested species were Pacific Black Duck (*Anas superciliosa*) (which comprised 35% of the total harvest), Grey Teal (*Anas gracilis*) (27%) and Australian Wood Duck (*Chenonetta jubata*) (24%). The remaining ducks harvested were Chestnut Teal (*Anas castanea*) (6%), Mountain Duck (*Tadorna tadornoides*) (4%), Pink-eared Duck (*Malacorhynchus membranaceus*) (1%) and Hardhead (*Aythya australis*) (<1%). Hunting of Blue-winged Shoveler (*Anas rhynchos*) was prohibited for the 2019 season.

Each holder of a Game Licence endorsed for Stubble Quail hunted on approximately 0.9 days during the 2019 quail-hunting season, with an average season harvest of 6.7 Stubble Quail per Game Licence holder. Using the total number of Game Licence holders endorsed to hunt Stubble Quail, this yielded an estimate of 188,015 Stubble Quail being harvested during the 2019 Stubble Quail hunting season in Victoria (95% CI = 137,168–257,710).

Conclusions and implications:

For duck, the total number of hunter days during the 2019 duck hunting season was estimated to be 81,023 (95% CI = 68,841–95,362); for Stubble Quail, the total number of hunter days was estimated to be 25,358 (95% CI = 18,342–35,056).

The approach used here explicitly accounts for the possibility that not every holder of a Game Licence will hunt during every survey period. The total number of Game Licence holders who hunted ('active hunters') was estimated for each survey period and combined with the harvest per active hunter to derive the total harvest for each survey period.

The methodology of performing telephone surveys throughout the season is likely to minimise memory bias and non-response bias, compared with the earlier end-of-year postal surveys. However, sources of bias will remain (due to over- and under-reporting), and the estimates of total harvest must be interpreted with care.

1 Introduction

To effectively manage game species, it is important to quantify the numbers harvested. Since 2009, the State Government game management agency has commissioned a series of regular telephone surveys of randomly selected Game Licence holders. Three sets of telephone surveys were conducted during the various game harvest seasons for deer, duck and Stubble Quail. However, this report focuses only on the duck and Stubble Quail harvests.

In response to sustained dry conditions and low abundance of game ducks the 2019 duck hunting season was reduced from the usual 12 weeks to 9 weeks, from 16 March to 19 May (Game Management Authority 2019). Seven species could legally be hunted in 2019: Pacific Black Duck (*Anas superciliosa*), Australian Wood Duck¹ (*Chenonetta jubata*), Mountain Duck² (*Tadorna tadornoides*), Grey Teal (*Anas gracilis*), Chestnut Teal (*Anas castanea*), Pink-eared Duck (*Malacorhynchus membranaceus*) and Hardhead³ (*Aythya australis*). Hunting of Blue-winged Shoveler⁴ (*Anas rhynchotis*, a declared game species) was prohibited for the 2019 season due to continued low numbers. For 2019, the daily bag limit was also reduced from the usual ten birds per day to four game ducks per hunter per day for the opening weekend (Saturday and Sunday) and five game ducks per day for the rest of the season.

The 2019 duck hunting survey used the same methods (i.e. telephone surveys) as those used during the 2005, 2006 and 2009 to 2018 duck hunting seasons (Barker 2006; Gormley and Turnbull 2009, 2010, 2011; Moloney and Turnbull 2012, 2013, 2014, 2015, 2016, 2017, 2018).

The 2019 Stubble Quail (*Coturnix pectoralis*) hunting season lasted 12 weeks, from 8 April to 30 June (Game Management Authority 2019). The daily bag limit for the 2019 season was 20 Stubble Quail per hunter.

The 2019 Stubble Quail hunting survey used the same methods (i.e. telephone surveys) as those used during the 2009 to 2015 and 2017 to 2018 Stubble Quail hunting seasons (Gormley 2009; Gormley and Turnbull 2009, 2010, 2011; Moloney and Turnbull 2012, 2013, 2014, 2015, 2017, 2018). Due to a clerical error, the 2016 Stubble Quail hunting survey used a slightly different method (Moloney and Turnbull 2016).

¹ Australian Wood Duck is also referred to as Wood Duck, Maned Duck and Maned Goose.

² Mountain Duck is also referred to as Australian Shelduck.

³ Hardhead is also referred to as White-eyed Duck.

⁴ Blue-winged Shoveler is also referred to as Australasian Shoveler.

2 Methods

2.1 General methodology

Slightly different methodology was used for estimating duck and Stubble Quail harvests. All surveys were conducted by the telephone survey company Marketing Skill Pty Ltd (Mt Eliza, Victoria) on behalf of the Game Management Authority. Estimates of total harvest by Game Licence holders were based on the hunting activities reported by the survey respondents.

For duck, surveys were performed for the opening weekend and then every fortnight thereafter throughout the season. For Stubble Quail, surveys were performed for the opening weekend and then every month thereafter throughout the season. Each survey involved telephoning a random sample of Game Licence holders and asking them to report their hunting activities for the periods covered by that survey only. Therefore, although a respondent⁵ may have hunted during the periods covered by Surveys 2 and 3, if they were contacted as part of Survey 3, then only information pertaining to the period covered by Survey 3 was collected. An additional random sample of 400 Game Licence holders were surveyed immediately after the conclusion of the duck and Stubble Quail hunting season. They were asked whether they had hunted at any stage during the season. The numbers of active hunters of duck and Stubble Quail were estimated based on responses to the final survey (specifically, to the question regarding whether they had hunted at any stage of the 2019 duck season and Stubble Quail season, respectively).

Survey responses were used to generate estimates of hunting data for the whole population of Game Licence holders for each game type. Estimates of harvest were determined for each of the survey periods, and these estimates were summed to give an estimate of the total season harvest. For each survey period, the proportion of respondents who hunted was used as an estimate of the proportion of Game Licence holders who hunted. The proportion of the Game Licence holders surveyed who had hunted during each survey period was multiplied by the total number of Game Licence holders, yielding the estimated total number of hunters for that survey period.

For each survey period, the average harvest per hunter⁶ was estimated from the total reported harvest divided by the number of respondents who hunted. The total harvest for each survey period was estimated by multiplying the average harvest per hunter by the previously estimated total number of hunters for that survey period. Finally, the total season harvest was estimated from the sum of the survey-specific total harvests.

The season harvest per Game Licence holder was also estimated. For each survey period, the average harvest per survey respondent was estimated by multiplying the average harvest per hunter by the proportion of respondents who hunted. The sum of these estimates across the season provided an estimate of the total season harvest per Game Licence holder.

Respondents who hunted were also asked to provide information on whether hunting was conducted on private land or public land (such as State Game Reserves), the name of the town nearest to where they hunted, and the number of days on which they hunted during the survey period. Regional harvest estimates were calculated by summing the reported harvest for each town, then aggregating these for the corresponding Victorian Catchment Management Authority (CMA) region.

There were differences between the number and length of the duck and Stubble Quail surveys, as indicated in the following sections. Additional details of the methods, as well as examples of the calculations, are provided in Appendix 1. Information describing and interpreting boxplots is provided in Appendix 2.

⁵ Respondent refers to a Game Licence holder who was contacted and agreed to take part in the survey.

⁶ Hunter refers to a Game Licence holder who actually went out and hunted (successfully or unsuccessfully) at some point during the period with which the survey was concerned.

2.2 Duck

Samples were drawn from hunters who held a Game Licence endorsed to hunt ducks during the 2019 season. A random sample of 200 licence holders was interviewed by telephone immediately after opening weekend (Duck Survey 1), and this was followed up by surveys of independent random samples of licence holders at 2-week intervals for the remainder of the duck season (Duck Surveys 2–6). Respondents were also asked to report the number of each species harvested. An additional random sample of 400 Game Licence holders endorsed to hunt ducks were surveyed immediately after the conclusion of the duck hunting season. They were asked if they had hunted duck at any stage during the season.

2.3 Stubble Quail

Samples were drawn from hunters who held a Game Licence to hunt Stubble Quail during the 2019 season. A random sample of 300 licence holders was interviewed by telephone immediately after the opening weekend (Survey 1), and further random samples, each of 300 licence holders, were interviewed in April (excluding opening weekend; Survey 2), May (Survey 3) and June (Survey 4). Respondents were asked to report the number of Stubble Quail harvested, the type of grassland where hunting occurred (native, stubble or introduced) and whether or not dogs were used. An additional random sample of 400 Game Licence holders endorsed to hunt Stubble Quail were surveyed immediately after the conclusion of the Stubble Quail hunting season. They were asked if they had hunted at any stage during the season.

When a Game Licence holder is endorsed for duck, they are automatically endorsed for Stubble Quail (you can be endorsed for Stubble Quail only without a duck endorsement). Therefore, the number of Game Licence holders endorsed to hunt Stubble Quail is not representative of the number of self-reported Stubble Quail hunters⁷. In the 2018 Stubble Quail hunter survey, all respondents were asked whether they ever hunt quail. This information was used to increase the precision of the estimates of the Stubble Quail harvest and of the number of hunting days. Unfortunately, in 2019 this question was not asked in the opening weekend survey and therefore the precision could not be increased in 2019. Future surveys will rectify this.

⁷ Self-reported Stubble Quail hunters are Game Licence holders endorsed to hunt Stubble Quail who say that they may actually hunt Stubble Quail, regardless of whether they hunted Stubble Quail this season.

3 Results

3.1 Duck

The number of Game Licence holders endorsed to hunt ducks remained relatively constant throughout the season, increasing from 24,690 at opening weekend to 24,925 at the end of the season (Table 1). In order to achieve the required sample size of respondents, slightly more than 200 licence holders were contacted each survey, with an average of 98% of those contacted being willing to take part.

Table 1: Summary of responses for duck surveys in 2019.

Duck survey	Period	Licence holders	Respondents	Respondents who hunted	Days hunted ⁸	Ducks harvested ⁹
1	16–17 Mar	24,690	200	85	128	370
2	18–31 Mar	24,690	200	47	106	268
3	1–14 Apr	24,747	199	46	129	374
4	15–28 Apr	24,863	200	48	131	369
5	29 Apr – 12 May	24,905	200	26	66	232
6	13–19 May	24,925	200	43	93	310

The proportion of duck Game Licence holders who hunted in each survey period varied throughout the season. During opening weekend, 42% of licence holders hunted, corresponding to approximately 10,493 hunters (Table 2). The proportion of licence holders who hunted during other survey periods varied from 13% to 24% (3238 to 5967 duck hunters) (Table 2).

Table 2: Proportion and corresponding total number of Game Licence holders endorsed for duck who hunted in each survey period in 2019.

Period	Proportion	SE	Lower	Upper	Total hunters	SE	95% CI	
							Lower	Upper
16–17 Mar	0.42	0.035	0.36	0.50	10,493	863	8,933	12,325
18–31 Mar	0.24	0.030	0.18	0.30	5,802	740	4,523	7,443
1–14 Apr	0.23	0.030	0.18	0.30	5,720	740	4,445	7,362
15–28 Apr	0.24	0.030	0.19	0.31	5,967	751	4,667	7,629
29 Apr – 12 May	0.13	0.024	0.09	0.19	3,238	592	2,269	4,620
13–19 May	0.22	0.029	0.17	0.28	5,359	724	4,117	6,975

⁸ Days hunted indicates the combined number of days on which duck hunting took place by respondents.

⁹ Ducks harvested indicates total number of ducks harvested by respondents.

Within each survey period, there was large variation in the reported harvest of ducks per hunter (i.e. per Game Licence holder who hunted). Some hunters harvested more than 20 ducks in a survey period, whereas some did not harvest any ducks (Figure 1). The average number of ducks per hunter varied throughout the season (Table 3). The average harvest per hunter was 4.4 ducks on opening weekend (Saturday and Sunday), which was smaller than the average harvest per hunter for most other survey period. The greatest average harvest per hunter was 8.9 ducks (in the fifth survey period). The last survey period only lasted 1 week but had an average harvest per hunter not too much smaller than the 2-week surveys.

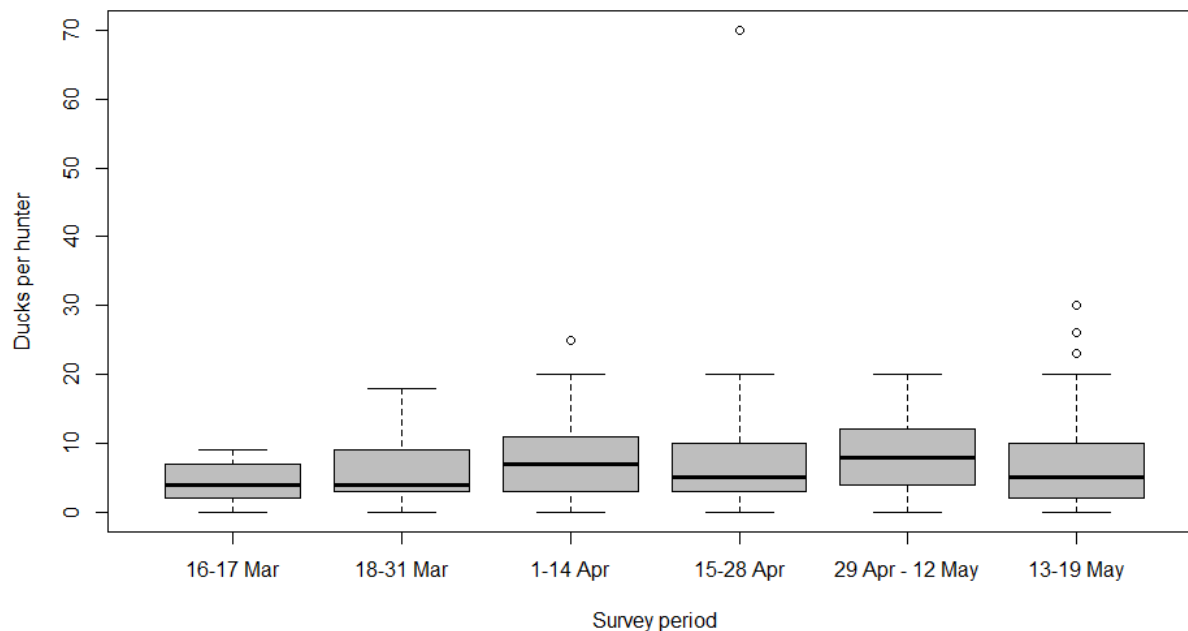


Figure 1: Boxplot of the number of ducks reported harvested by individual hunters for each survey period in 2019.

The bottom and top of each 'box' indicate the 25th and 75th percentiles, respectively, and the black horizontal line indicates the median (50th percentile) reported value.

Table 3: Average harvest of ducks per hunter (Game Licence holders who hunted) for each survey period in 2019.

Period	Average harvest per hunter ¹⁰	SE	95% CI	
			Lower	Upper
16–17 Mar	4.35	0.28	3.83	4.95
18–31 Mar	5.70	0.68	4.52	7.19
1–14 Apr	8.13	0.93	6.49	10.18
15–28 Apr	7.69	1.51	5.25	11.25
29 Apr – 12 May	8.92	1.15	6.94	11.48
13–19 May	7.21	1.10	5.36	9.70

¹⁰ Average harvest per hunter = Ducks harvested divided by Respondents who hunted (Table 1).

There were an estimated 45,676 ducks harvested during opening weekend (95% CI = 37,189–56,101), which constituted 19% of the total seasonal harvest (Table 4). The harvest throughout the remainder of the season varied between survey periods, with fortnightly estimates ranging from 28,890 to 46,509 ducks harvested. The total season harvest estimate was 238,666 (95% CI = 205,075–277,760; Table 4).

Table 4: Estimates of the total duck harvest in Victoria in 2019 by holders of a Game Licence endorsed for duck.

Period	Total harvest ¹¹	SE	95% CI	
			Lower	Upper
16–17 Mar	45,676	4,804	37,189	56,101
18–31 Mar	33,085	5,786	23,544	46,492
1–14 Apr	46,509	8,077	33,176	65,203
15–28 Apr	45,872	10,755	29,150	72,187
29 Apr – 12 May	28,890	6,501	18,688	44,660
13–19 May	38,634	7,906	25,976	57,460
Total	238,666	18,499	205,075	277,760

The total average season harvest per licence holder was estimated to be 9.6 birds (95% CI = 8.3–11.2; Table 5). Note that, for each survey period, the average duck harvest per Game Licence holder was lower than the average duck harvest per hunter (Table 3), because the former includes those respondents who did not hunt during the survey period, whereas the latter includes only those who hunted.

Table 5: Estimates of average harvest of ducks per Game Licence holder in each survey period in 2019.

Period	Average harvest ¹²	SE	95% CI	
			Lower	Upper
16–17 Mar	1.85	0.19	1.51	2.27
18–31 Mar	1.34	0.23	0.95	1.88
1–14 Apr	1.88	0.33	1.34	2.63
15–28 Apr	1.84	0.43	1.17	2.90
29 Apr – 12 May	1.16	0.26	0.75	1.79
13–19 May	1.55	0.32	1.04	2.31
Total	9.62	0.75	8.27	11.20

¹¹ Average harvest per hunter = Ducks harvested divided by Respondents who hunted (Table 1).

¹² Average harvest per licence holder = Ducks harvested divided by Respondents who hunted (Table 1).

Using a telephone survey immediately after the 2019 duck season ended, it was estimated that 22% (95% CI = 19–24%) of Game Licence holders actually hunted for ducks during the 2019 duck season. That equates to an estimate of 5401 (95% CI = 4801–6075) active duck hunters in the 2019 duck season. The average duck harvest per active duck hunter was estimated to be 44.2 (95% CI = 36.5–53.5). The average number of duck hunting days per active duck hunter was estimated to be 15.0 (95% CI = 12.3–18.3).

The total harvest was estimated for each species by multiplying the total estimated duck harvest by the percentage of the total harvest for that species (Table 6). The most frequently harvested species was Pacific Black Duck, comprising 35% of the total reported harvest, followed by Grey Teal (27%) and Australian Wood Duck (24%). The remaining four species comprised 11% of the total harvest.

Table 6: Reported numbers of ducks harvested by hunters, proportions of the total harvest, and estimates of total 2019 harvest for each duck species.

Species	Reported harvest	Proportion of harvest	SE	Estimated harvest	SE	95% CI	
						Lower	Upper
Australian Wood Duck	464	0.24	0.010	57,588	5,035	32,651	101,569
Blue-winged Shoveler ¹³	0	NA	NA	NA	NA	NA	NA
Chestnut Teal	109	0.06	0.005	13,528	1,638	6,974	26,243
Grey Teal	511	0.27	0.010	63,421	5,472	36,087	111,459
Hardhead	5	0.00	0.001	621	281	187	2,057
Mountain Duck	70	0.04	0.004	8,688	1,222	4,267	17,688
Pacific Black Duck	669	0.35	0.011	83,031	6,938	47,654	144,670
Pink-eared Duck	25	0.01	0.003	3,103	662	1,311	7,346

Each Game Licence holder hunted an average of 3.3 days during the 2019 duck-hunting season (Table 7). When multiplied by the total number of Game Licence holders in each survey period, this equalled a total of 81,023 hunter days (95% CI = 68,841–95,362).

¹³ Game Licence holders were not permitted to harvest Blue-winged Shoveler (*Anas rhynchos*), also referred to as Australasian Shoveler, in 2019.

Table 7: Days on which ducks were hunted per Game Licence holder for 2019.

Period	Days hunted	SE	95% CI	
			Lower	Upper
16–17 Mar	0.64	0.06	0.54	0.76
18 Mar – 1 Apr	0.53	0.08	0.39	0.72
2–15 Apr	0.65	0.10	0.48	0.88
16–29 Apr	0.66	0.11	0.47	0.91
30 Apr – 13 May	0.33	0.07	0.22	0.50
14–19 May	0.46	0.08	0.33	0.65
Total per licence holder	3.27	0.21	2.88	3.71
Total hunting days	81,023	6,747	68,841	95,362

Greater duck hunting effort was expended on public (47.3%) than on private land (45.8%), with a greater proportion of ducks being harvested solely on private land (47.8%) compared with public land (43.7%) (Table 8).

Table 8: Percentage of days hunted and associated duck harvest by land tenure in 2019.

Land tenure	Days (%)	Duck harvest (%)
Private land only	45.8	47.8
Public land only	47.3	43.7
Both	6.4	8.1
Total	99.5	99.7

Total harvest was estimated to be greatest in the West Gippsland CMA, followed by the Corangamite CMA and the North Central CMA (Figure 2). The top five towns for the total reported number of ducks harvested were (in descending order) Sale, Geelong, Ballarat, Shepparton and Horsham. The top five towns for the total number of reported duck hunting days were (in descending order) Sale, Geelong, Ballarat, Shepparton and Horsham.

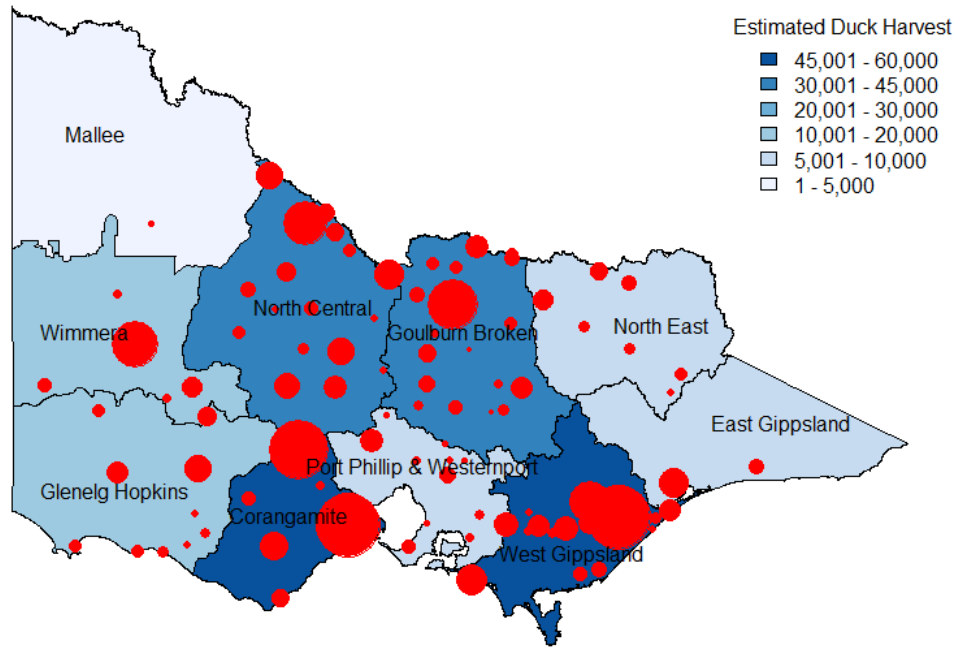


Figure 2: Estimates of total duck harvest in 2019 by CMA region.

Red circles indicate the nearest town to harvest locations, with symbol size proportional to reported harvest.

3.2 Stubble Quail

The number of Game Licence holders endorsed to hunt Stubble Quail remained relatively constant throughout the season, increasing from 27,862 at opening weekend to 28,400 at the end of the season (Table 9). In order to achieve the required sample size of respondents, slightly more than 300 licence holders were contacted each survey, with an average of 99.3% of those contacted being willing to take part.

Table 9: Summary of responses for Stubble Quail surveys in 2019.

Stubble Quail survey	Period	Licence holders	Respondents	Respondents who hunted	Days hunted ¹⁴	Quail harvested ¹⁵
1	Opening weekend	27,862	300	12	15	191
2	April ¹⁶	28,077	300	20	53	318
3	May	28,303	299	24	89	522
4	June	28,400	300	29	80	558

The proportion of Game Licence holders endorsed to hunt Stubble Quail who hunted Stubble Quail in each survey period varied throughout the season. During opening weekend, 4% of Game Licence holders hunted, corresponding to approximately 1114 hunters (Table 10). The proportion who hunted during the remainder of the season was higher, increasing to 10% in June (Table 10).

Table 10: Proportion and corresponding total number of Game Licence holders endorsed to hunt Stubble Quail who hunted in each survey period in 2019.

Period	Proportion	SE	95% CI		Total hunters	SE	95% CI	
			Lower	Upper			Lower	Upper
Opening weekend	0.04	0.011	0.02	0.07	1,114	315	647	1,920
April	0.07	0.014	0.04	0.10	1,872	404	1,232	2,845
May	0.08	0.016	0.05	0.12	2,272	445	1,553	3,322
June	0.10	0.017	0.07	0.14	2,745	485	1,948	3,870

Within each survey period, there was large variation in the reported harvest of Stubble Quail per hunter (i.e. per Game Licence holder who hunted). Some hunters harvested more than 40 Stubble Quail in a

¹⁴ Days hunted indicates the combined number of days on which Stubble Quail hunting took place by respondents.

¹⁵ Stubble Quail harvested indicates total number of Stubble Quail harvested by respondents.

¹⁶ April after the opening weekend.

survey period, whereas some did not harvest any Stubble Quail (Figure 3). The average number of Stubble Quail harvested per hunter varied throughout the season (Table 11). The average harvest per hunter was 15.9 Stubble Quail on the opening weekend (Saturday and Sunday), which was similar to the average harvest per hunter for the remainder of April. The largest average harvest per hunter was 21.8 Stubble Quail (in May).

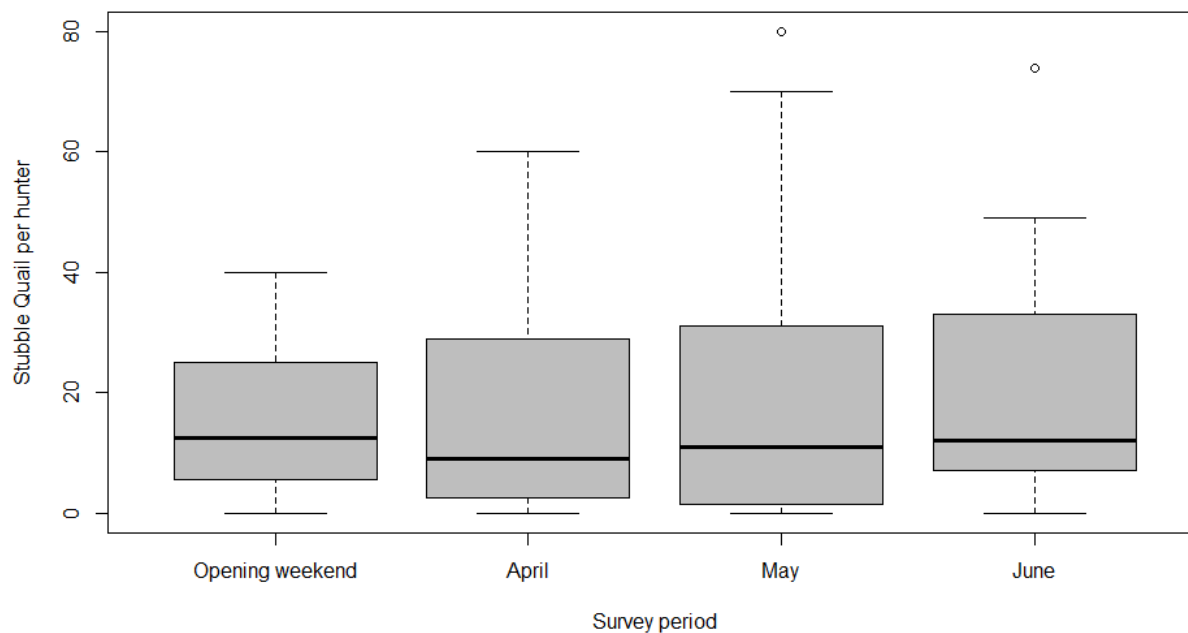


Figure 3: Boxplot of the number of quail reported harvested by individual hunters for each survey period in 2019.

The bottom and top of each 'box' indicate the 25th and 75th percentiles, respectively, and the black horizontal lines indicate the median (50th percentile) reported value.

Table 11: Average harvest of Stubble Quail per hunter (Game Licence holders who hunted) for each survey period in 2019.

Period	Average harvest per hunter ¹⁷	SE	95% CI	
			Lower	Upper
Opening weekend	15.92	4.04	9.75	25.99
April	15.90	3.98	9.80	25.79
May	21.75	5.27	13.62	34.73
June	19.24	3.33	13.74	26.94

¹⁷ Average harvest per hunter = Stubble Quail harvested divided by Respondents who hunted (Table 9).

There were an estimated 149,736 Stubble Quail harvested by all holders of a Game Licence for Stubble Quail during the 2019 Stubble Quail season (95% CI = 110,001–203,826). The opening weekend Stubble Quail harvest was approximately a third of that during the May and June periods. Including the opening weekend, the April harvest total was similar to the May and June harvest totals (Table 12).

Table 12: Estimates of the total Stubble Quail harvest in Victoria in 2019 by holders of a Game Licence endorsed for Stubble Quail.

Period	Total harvest ¹⁸	SE	95% CI	
			Lower	Upper
Opening weekend	17,739	6,864	8,530	36,887
April ¹⁹	29,762	9,977	15,699	56,423
May	49,412	15,568	27,037	90,304
June	52,824	13,151	32,665	85,423
Total	149,736	23,706	110,001	203,826

The total average season harvest per Game Licence holder was estimated to be 5.3 birds (95% CI = 3.9–7.2; Table 13). Note that, for each survey period, the average Stubble Quail harvest per Game Licence holder was lower than the average Stubble Quail harvest per hunter (Table 11), as the former includes those respondents who did not hunt during the survey period, whereas the latter includes only those who hunted.

Table 13: Estimates of the average harvest of Stubble Quail per Game Licence holder endorsed to hunt Stubble Quail in each survey period in 2019.

Period	Harvest per respondent ²⁰	SE	95% CI	
			Lower	Upper
Opening weekend	0.64	0.25	0.31	1.32
April	1.06	0.36	0.56	2.01
May	1.75	0.55	0.96	3.19
June	1.86	0.46	1.15	3.01
Total	5.30	0.84	3.90	7.22

¹⁸ Total harvest = Harvest per hunter (Table 11) × Total hunters (Table 10). Numbers may differ slightly due to rounding of average harvest per hunter.

¹⁹ April after the opening weekend.

²⁰ Average harvest per Game Licence holder = Stubble Quail harvested divided by Respondents (Table 9).

Using a telephone survey immediately after the 2019 Stubble Quail season ended, it was estimated that 8% (95% CI = 6–9%) of Game Licence holders endorsed to hunt Stubble Quail, actually hunted for Stubble Quail during the 2019 Stubble Quail season. The estimate of active Stubble Quail hunters in the 2019 Stubble Quail season is 2157 (95% CI = 1726–2695). The average Stubble Quail harvest per active Stubble Quail hunter was estimated to be 69.4 (95% CI = 47.5–101.4).

Table 14: Days on which Stubble Quail were hunted per Game Licence holder endorsed to hunt Stubble Quail for 2019.

Period	Days hunted	SE	95% CI	
			Lower	Upper
Opening weekend	0.05	0.02	0.03	0.09
April	0.18	0.05	0.11	0.29
May	0.30	0.08	0.18	0.49
June	0.27	0.07	0.16	0.43
Total per licence holder	0.79	0.11	0.60	1.04
Total hunting days	22,351	4037	15,732	31,755

Most Stubble Quail hunting was conducted on private land (94.1% of the hunting days and 93.8% of the harvested Stubble Quail) (Table 15). A very small proportion of hunting was conducted on public land (State Game Reserves) (5.5% of days and 5% of the harvested Stubble Quail), with less than 1% of reported hunting being conducted on both private land and State Game Reserves during the same hunting trip. The percentage of Stubble Quail hunting days on which dogs were used (32.5%) was similar to the percentage of Stubble Quail harvested using dogs (33.6%, Table 15). More Stubble Quail hunting and Stubble Quail harvesting took place on stubble (27.9% and 36.0%, respectively) than on other individual grassland types or combinations of grasslands (Table 16).

Table 15: Percentage of days hunted and associated Stubble Quail harvest by land tenure and dog usage in 2019.

Land tenure	Days (%)			Harvest		
	No dogs	Dogs	Total	No dogs	Dogs	Total
Private land only	8.4	30.4	94.1	8.0	31.5	93.8
State Game Reserves only	1.3	1.7	5.5	1.6	0.9	5.0
Both	0.0	0.4	0.4	0.0	1.1	1.1
Total	9.7	32.5	100.0	9.6	33.6	100.0

Table 16: Percentage of hunting days and associated Stubble Quail harvest per grassland type in 2019.

Habitat type	Days (%)	Stubble Quail harvest (%)
Introduced grass	23.0	14.2
Native and introduced grass	4.1	7.4
Native grass	25.4	26.6
Stubble	27.9	36.0
Stubble and introduced grass	18.9	14.2
Stubble and native grass	0.8	1.5
Total	100.0	100.0

Total harvest was estimated to be greatest in the Corangamite CMA, followed by the North Central CMA and the Goulburn Broken CMA (Figure 4). The top five towns for the total reported number of Stubble Quail harvested were (in descending order) Ballarat, Lake Bolac, Donald, Seymour and Bendigo. The top five towns for the total number of reported Stubble Quail hunting days were (in descending order) Ballarat, Donald, Kilmore, Bendigo and Colac.

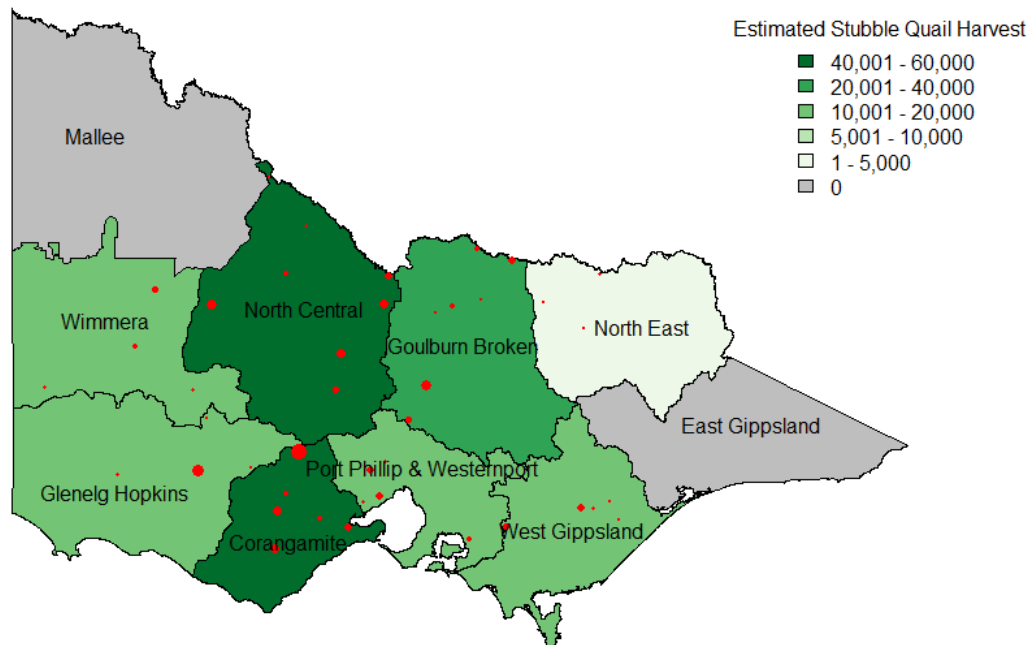


Figure 4: Estimates of total Stubble Quail harvest in 2019 by CMA region.

Red circles indicate the nearest town to harvest locations, with symbol size proportional to reported harvest.

4 Discussion

4.1 Duck

A total of 238,666 ducks were estimated to have been harvested in Victoria during the 2019 season (95% CI = 205,075–277,760), which was smaller than the average estimated harvests from 2009 to 2019 of 373,000 (Table 17 and Figure 5). The estimated harvest of most duck species available to harvest in 2019 were more than 20% lower than their average estimated harvest since 2009. Only Mountain Duck (23% greater than average) was not lower than the average harvest since 2009.

The estimated number of total hunting days and ducks harvested per licence holder were much smaller than average levels (second-lowest and lowest recorded, respectively). Hunter efficiency (ducks harvested per hunting day) was much lower (25%) in 2019 compared with the average from 2009 to 2019.

It was estimated that 22% (95% CI = 19–24%) of Game Licence holders actually hunted for ducks during the 2019 duck season. That equates to an estimate of 5401 (95% CI = 4801–6075) active duck hunters in the 2019 duck season. The average duck harvest per active duck hunter was estimated to be 44.2 (95% CI = 36.5–53.5) over a total of 15.0 hunting days (95% CI = 12.3–18.3).

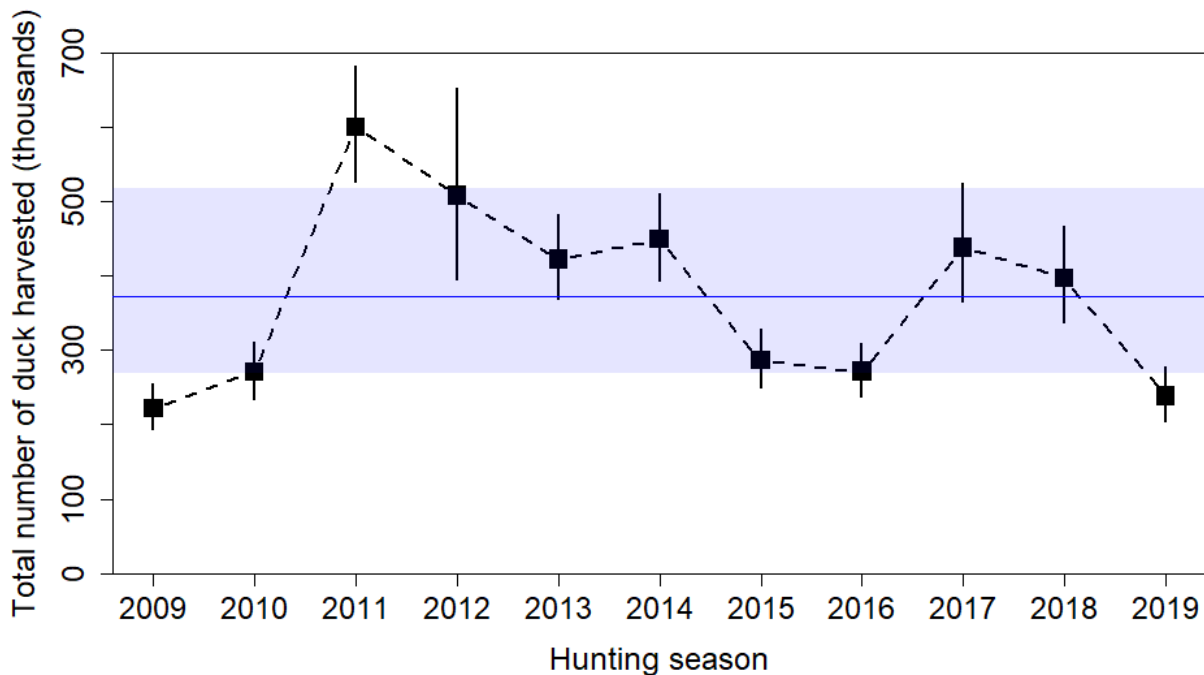


Figure 5: Estimates of total duck harvests (in thousands) from 2009 to 2019.

The squares are the estimated total harvests for each season; the solid vertical lines indicate the 95% confidence intervals; the blue line is the average duck harvest from 2009 to 2019; the shaded area is the 95% confidence interval for the average duck harvest from 2009 to 2019.

Table 17: Comparison of duck harvests of 2009 to 2019.

Year	Australian Wood Duck	Blue-winged Shoveler	Chestnut Teal	Grey Teal	Hardhead	Mountain Duck	Pacific Black Duck	Pink-eared Duck	Total harvest	Hunting days	Ducks per licence holder	Hunting days per licence holder	Ducks per hunting day
2009	131,084	NA	13,176	20,919	NA	2,173	55,150	NA	222,302	76,659	11.10	3.98	2.79
2010	112,390	216	14,354	26,011	324	5,936	96,487	0	270,574	85,801	12.54	3.98	3.15
2011	132,908	4,854	49,812	211,034	25,657	8,090	156,484	12,597	600,739	103,450	26.02	4.48	5.81
2012	150,150	1,319	23,506	110,574	30,222	9,234	160,704	21,587	508,256	109,718	21.19	4.60	4.61
2013	106,553	7,104	39,804	135,947	7,349	2,694	92,714	30,129	422,294	91,748	17.24	3.75	4.60
2014	131,282	4,155	29,866	127,126	6,363	8,440	127,646	14,154	449,320	118,800	17.29	4.57	3.78
2015	80,194	1,497	19,456	79,945	998	6,860	81,940	15,839	286,729	90,634	11.35	3.59	3.16
2016	77,955	NA	18,097	77,069	506	6,454	89,850	1,645	271,576	100,749	10.73	3.98	2.70
2017	90,929	NA	13,639	175,038	8,083	12,124	118,460	20,080	438,353	96,508	17.36	3.83	4.53
2018	89,354	NA	27,123	122,941	4,816	6,971	132,827	12,674	396,708	91,570	15.65	3.62	4.32
2019	57,588	NA	13,528	63,421	621	8,688	83,031	3,103	238,666	81,023	9.62	3.27	2.94
Average	105,490	3,191	23,851	104,548	8,494	7,060	108,663	13,181	373,229	95,151	15.46	3.97	3.90

4.2 Stubble Quail

The total of 149,736 Stubble Quail estimated to have been harvested in Victoria during the 2019 season (95% CI = 110,001–203,826) is consistent with the average estimated harvest from 2009 to 2019 (Figure 6 and Table 18).

It was estimated that 8% (95% CI = 6–9%) of Game Licence holders endorsed to hunt Stubble Quail actually hunted for Stubble Quail during the 2019 Stubble Quail season. That equates to an estimate of 2157 (95% CI = 1726–2695) active Stubble Quail hunters in the 2019 Stubble Quail season. The average Stubble Quail harvest per active Stubble Quail hunter was estimated to be 69.4 (95% CI = 47.5–101.4).

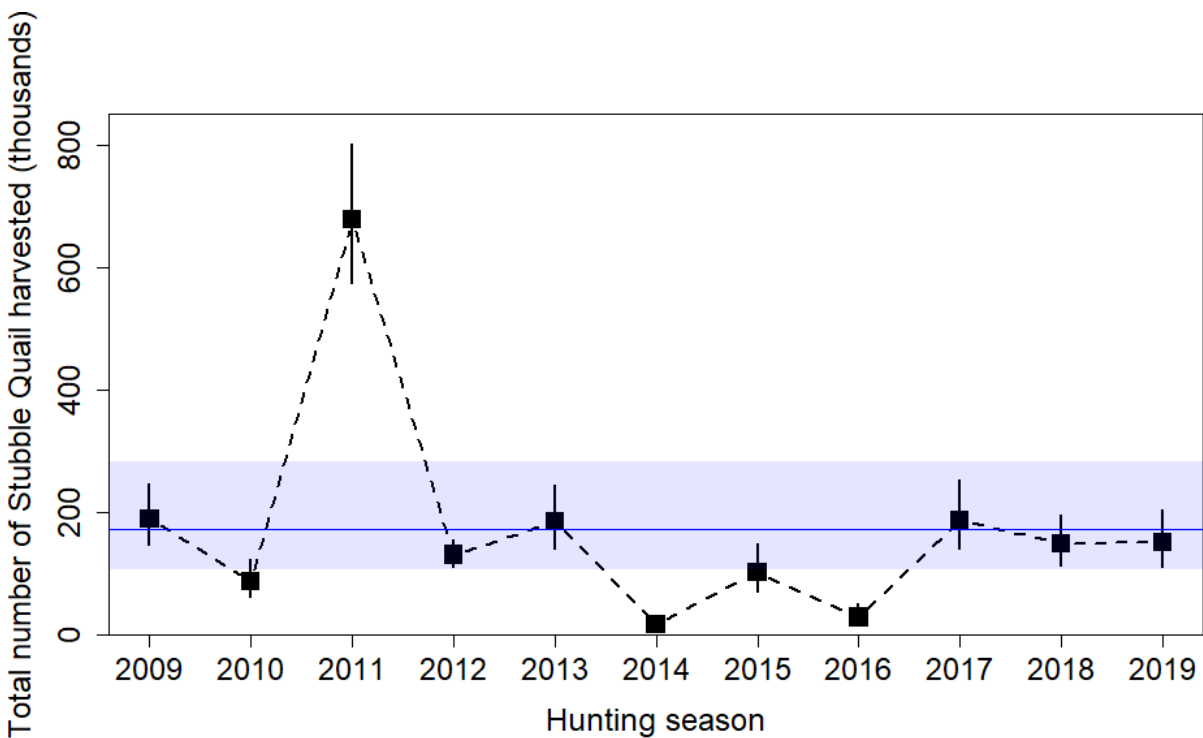


Figure 6: Estimates of total Stubble Quail harvests (in thousands) from 2009 to 2019.

The squares are the estimated total harvests for each season; the solid vertical lines indicate the 95% confidence intervals; the blue line is the average Stubble Quail harvest from 2009 to 2019; the shaded area is the 95% confidence interval for the average Stubble Quail harvest from 2009 to 2019.

Table 18: Comparison of Stubble Quail harvests of 2009 to 2019.

Year	Total harvest	Hunting days	Quail per licence holder	Hunting days per licence holder	Quail per hunting day
2009	189,155	24,648	7.89	1.03	7.97
2010	86,302	24,739	3.59	1.03	3.48
2011	678,431	46,719	26.17	1.80	14.52
2012	129,711	22,262	4.80	0.82	5.81
2013	184,123	21,958	6.69	0.98	8.39
2014	16,243	10,852	0.56	0.38	1.47
2015	101,244	22,432	3.58	0.79	4.51
2016 ²¹	28,043	6,559	1.00	0.23	4.29
2017	186,691	22,052	6.51	0.77	8.45
2018	148,500	17,772	5.19	0.62	8.36
2019	149,736	22,351	5.30	0.79	6.70
Average	172,562	22,031	6.48	0.84	7.71

Due to the structure of Game Licences in Victoria, not every holder of a Game Licence endorsed to hunt Stubble Quail will hunt Stubble Quail. The price of a Game Licence for game birds including duck is the same as a Game Licence for game birds not including duck. Anyone who wants to hunt ducks automatically has Stubble Quail included in their licence. For many hunters, duck hunting will be their primary activity. Hence, a high proportion of Game Licence holders will be permitted to hunt Stubble Quail, even though they may not intend to do so. This does not affect the estimates of Stubble Quail harvest, because the calculations explicitly account for the proportion of Stubble Quail Game Licence holders who did not actually hunt Stubble Quail.

It should be noted that the number of hunting days was only an approximate estimate of total effort: someone who hunted for two hours and someone else who hunted for 12 hours were both recorded as having hunted for one day.

4.3 Locations with the most hunting days

The top five towns for the total number of reported duck hunting days in 2019 were (in descending order) Sale, Geelong, Ballarat, Shepparton and Horsham.

The top five towns for the total number of reported Stubble Quail hunting days in 2019 were (in descending order) Ballarat, Donald, Kilmore, Bendigo and Colac.

Combining duck and Stubble Quail, Sale had the most hunting days during the 2019 hunting seasons, followed by Ballarat, Geelong, Shepparton and Horsham. This assumed that all hunting days were equal in length, even though the time spent hunting on any particular day could vary considerably for each respondent, and for game species.

²¹ The 2016 Stubble Quail surveys were conducted after the season rather than each month of the season. It is assumed that the change in methodology will produce only minor differences.

4.4 Assumptions

The estimates of harvest for each game type were derived based on the assumption that the samples of respondents were representative of the entire population of Victorian Game Licence holders. This assumption may have been violated due to several factors, such as the reasons for non-response [exceeded bag limit, or (conversely) did not harvest anything], memory recall (respondents not remembering their harvest), and deliberate over- or under-reporting (reported numbers knowingly being reported incorrectly). Any bias due to non-response is likely to have been negligible, because the response rate for all surveys was generally above 95% (i.e. very high). Memory bias can inflate estimates of total harvest, in some cases by as much as 40% (Wright 1978; Barker 1991). It is likely, however, that the sampling strategy of the telephone interviews (after each 2-week period in the case of ducks) would have ensured that both memory bias and non-response bias were kept low (compared with postal surveys and end-of-season surveys (Barker 1991; Barker et al. 1992). Nevertheless, some bias likely remains, and the estimates of total harvest should be interpreted with caution.

It needs to be noted that due to a clerical error, the 2016 telephone Stubble Quail survey did not follow the standard methodology, as all surveys happened at the end of the season. That means the results of the 2016 telephone Stubble Quail survey may have increased memory bias and may not be strictly comparable with those of other years.

It is important to note that the methodology explicitly accounts for the possibility that not every Game Licence holder hunts in every survey period (see Gormley and Turnbull 2010). Therefore, the estimate of total season bag per Game Licence holder is the sum of the 'harvest per Game Licence holder', not the sum of the 'harvest per hunter'.

The uncertainty in the estimates of total harvest (as indicated by the confidence intervals) was due to two factors. First, there was variation in the reported numbers of animals harvested between respondents who had hunted (see Figure 1 and Figure 3). For example, within a given survey period for duck hunting, some respondents indicated that they hunted unsuccessfully, whereas others had undertaken multiple trips and indicated a total harvest of more than 50 ducks during the same period. The second source of uncertainty was due to sampling the hunters, rather than taking a complete census. However, the degree of sampling uncertainty was reduced by having sample sizes of 200 respondents per survey for ducks and 300 respondents per survey for Stubble Quail. Statistically, these sample sizes were considered adequate for providing reasonable estimates.

The spatial distributions of the duck and Stubble Quail harvest should also be interpreted with caution. Grouping the harvest for a relatively large region (CMA) provides a broad-scale view of the distribution of the harvest. Grouping by smaller regions would provide a finer-scale representation, but this would come at the cost of increased bias in many regions. Because the data are from a sample of Game Licence holders rather than a complete census, it is likely that some areas that were actually hunted are shown as having a zero harvest if no respondents that hunted those areas were contacted. This would be increasingly likely at finer spatial scales. Furthermore, respondents were only asked to report the nearest town to where they hunted, not the actual location. It is, therefore, possible that the nearest town was in a different CMA than the hunting location.

References

- Barker, R.J. (1991). Nonresponse bias in New Zealand waterfowl harvest surveys. *Journal of Wildlife Management* **55** (1), 126–131. <https://doi.org/10.2307/3809249>
- Barker, R.J. (2006). *Survey of waterfowl hunting in victoria by victorian licence holders 2006*. Report for the Game Management Unit, Department of Sustainability and Environment, Victoria.
- Barker, R.J., Geissler, P.H. and Hoover, B.A. (1992). Sources of nonresponse to the federal waterfowl hunter questionnaire survey. *Journal of Wildlife Management*, 337–343. doi: [10.2307/3808832](https://doi.org/10.2307/3808832)
- Game Management Authority. (2018). *Game Hunting in Victoria. A Manual for Responsible and Sustainable Hunting*. Game Management Authority and Kalkomey Enterprises, LLC, Melbourne, Victoria. www.gma.vic.gov.au
- Game Management Authority. (2019). *2019 duck season arrangements*, <https://www.gma.vic.gov.au/hunting/duck/arrangements-for-duck-season>, accessed 5/8/2019.
- Gormley, A.M. (2009). *Survey of quail hunting in Victoria by Victorian Licence holders 2008*. Report for the Game Management Unit, DSE. Arthur Rylah Institute for Environmental Research, Department of Sustainability; Environment.
- Gormley, A.M. and Turnbull, J.D. (2009). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2009*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 196. Department of Sustainability and Environment, Heidelberg, Victoria.
- Gormley, A.M. and Turnbull, J.D. (2010). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2010*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 210. Department of Sustainability and Environment, Heidelberg, Victoria.
- Gormley, A.M. and Turnbull, J.D. (2011). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2011*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 224. Department of Sustainability and Environment, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2012). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2012*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 239. Department of Sustainability and Environment, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2013). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2013*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 251. Department of Environment and Primary Industries, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2014). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2014*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Game Management Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2015). *Estimates of harvest for duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2015*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Game Management Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2016). *Estimates of harvest for duck and quail in Victoria: results from surveys of Victorian Game Licence holders in 2016*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Game Management Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P.D. and Turnbull, J.D. (2017). *Estimates of duck and Stubble Quail harvest in Victoria: results from surveys of Victorian Game Licence holders in 2017*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Game Management Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

- Moloney, P.D. and Turnbull, J.D. (2018). *Estimates of duck and Stubble Quail harvest in Victoria: results from surveys of Victorian Game Licence holders in 2018*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Game Management Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Wright, V.L. (1978). Causes and effects of biases on waterfowl harvest estimates. *Journal of Wildlife Management* **42**, 251–262. doi:[10.2307/3800262](https://doi.org/10.2307/3800262)

Appendix 1 Additional method details

Common definitions used

SD = standard deviation of the data. SD represents the variation in the numbers reported.

SE = standard error of the mean. SE represents the variation in the estimated mean.

CV = coefficient of variation. CV is calculated as: $CV = SE \div \text{mean}$. This provides an indication as to how much uncertainty is in the estimate relative to the mean.

Calculations

For each survey j , we surveyed n_j respondents, of which h_j had hunted. The proportion of respondents p who hunted in each period j is given by:

$$p_j = \frac{h_j}{n_j}$$

E.g. for Duck Survey 3, we obtained: $\frac{34}{200} = 0.170$.

The total number of hunters for each survey period (H_j) was estimated by multiplying the total number of licence holders (L) by the proportion of respondents who reported having hunted during that survey period (p_j), as found previously:

$$H_j = p_j L$$

E.g. for Duck Survey 3, we obtained: $0.17 \times 25\,418 = 4,321$.

The estimated average harvest per hunter (w_j) is the total reported harvest for survey j (y_j) divided by the total number of respondents who hunted (h_j):

$$w_j = \frac{y_j}{h_j}$$

E.g. for Duck Survey 3, we obtained: $\frac{290}{34} = 8.53$.

The total harvest for each survey period (W_j) was estimated by multiplying the average harvest per hunter (w_j) by the total number of hunters (H_j):

$$W_j = w_j H_j$$

E.g. for Duck Survey 3, we obtained: $8.53 \times 4,321 = 36,856$.

The estimate of the total harvest was calculated as the sum of the estimated harvest for each survey period:

$$W_{TOT} = W_1 + W_2 + W_3 + W_4 + W_5 + W_6 + W_7$$

Standard errors (SEs) for the proportion of respondents who hunted are given by:

$$SE(p_j) = \sqrt{\frac{p_j(1-p_j)}{n_j}}$$

E.g. for Duck Survey 3, we obtained: $\sqrt{\frac{0.17 \times 0.83}{200}} = 0.027$.

Standard errors (SEs) for the average harvest per hunter are given by:

$$SE(w_j) = \frac{SD(w_j)}{\sqrt{h_j}}$$

E.g. for Duck Survey 3, we obtained: $\frac{9.196}{\sqrt{34}} = 1.58$.

The standard error for the total estimated harvest per survey period (W_j) was found by determining the coefficient of variation (CV) of p_j and w_j and then adding their sums of squares to find the combined CV (assuming independence).

$$CV(w_j) = \frac{SE(w_j)}{w_j}, \text{ and } CV(p_j) = \frac{SE(p_j)}{p_j}$$

$$CV(W_j) = \sqrt{(CV(w_j))^2 \times (CV(p_j))^2 + (CV(w_j))^2 + (CV(p_j))^2}$$

$$SE(W_j) = CV(W_j) \times W_j.$$

The standard error of the total harvest was calculated by:

$$SE(W_{TOT}) = \sqrt{(SE(W_1))^2 + (SE(W_2))^2 + \dots + (SE(W_7))^2}.$$

Confidence intervals were computed on the natural logarithm scale and back-transformed to ensure that lower limits were ≥ 0 . A consequence is that the confidence intervals were asymmetric and cannot be reported as the estimate plus or minus a fixed value. In general, for some estimates denoted as \hat{X} , 95% confidence interval limits were calculated using:

$$\text{upper limit} = \hat{X} \times r$$

$$\text{lower limit} = \hat{X} \div r, \quad \text{where:}$$

$$r = \exp\left(1.96 \times \sqrt{\ln(1 + CV^2)}\right).$$

E.g. for the total duck harvest we have

$$CV = \frac{20,286}{286,729} = 0.071$$

$$r = \exp\left(1.96 \times \sqrt{\ln(1 + 0.071^2)}\right) = 1.15.$$

Therefore, upper and lower confidence intervals are given by:

$$UL = 286,729 \times 1.15 = 329,321$$

$$LL = 286,729 \div 1.15 = 249,645.$$

Appendix 2 Boxplot explanation

A boxplot is a way of displaying key points of the data and is especially good for comparing groups of data. It is sometimes referred to as a box-and-whisker plot. A boxplot shows the following key points:

outliers, signified by hollow circles;

minimum, signified by the horizontal line below the box (smallest value, excluding outliers);

lower quartile (Q1), signified by the horizontal line at the bottom of the box (25% of the data is at this point or below);

median, signified by the thick horizontal line in the box (50% of the data is at this point or below);

upper quartile (Q3), signified by the horizontal line at the top of the box (75% of the data is at this point or below);

maximum, signified by the horizontal line above the box (largest value, excluding outliers);

interquartile range or IQR (difference between the upper and lower quartiles);

whiskers—the lines that go from the minimum or maximum to the box.

Outliers are values that are very large (or small) compared with the rest of the data. Formally, an outlier is any point that is either below $Q1 - 1.5 \times IQR$ or above $Q3 + 1.5 \times IQR$, which means that any point that lies more than one-and-a-half times the length of the box outside the box is an outlier.

The boxplot indicates the spread of the data. The data is broken into quarters: 25% of the data are in each whisker and between the edge of the box and the median line. Approximately half the data are contained within the box. Any unusual data are highlighted as outliers. As an example, Figure A2.1 shows a boxplot indicating that most hunters harvested between 5 and 13 ducks, and a quarter harvested more than about 27 ducks, including one who harvested over 50 ducks. Sometimes there are no whiskers because the minimum (or maximum) is the same as the lower (or upper) quartile (see Figure 3, where at least 25% of licence holders who hunted were unsuccessful).

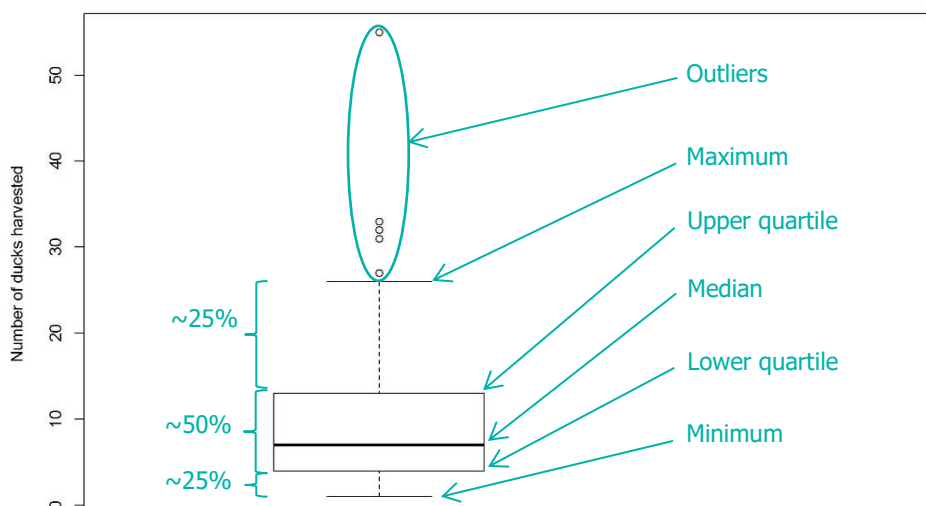


Figure A2.1. Example boxplot, with labels.

www.delwp.vic.gov.au

www.ari.vic.gov.au