Differences in Hunter Harvest Metrics by Survey Modes

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Abstract: We analyzed a three-year consolidated sample of Louisiana hunters' responses to the Louisiana Game Harvest Surveys (LAGHS) distributed via email and mail in May following the 2016–2017, 2017–2018, and 2018–2019 hunting seasons. To determine whether the distribution modes produced different results, both modes asked identical questions about hunting effort, harvest, and age. We used generalized linear mixed models to test hypotheses about hunters' days hunted, harvest, representation of age classes, and effect of age-weighting (i.e., weighting responses based on the difference in proportion between individual age classes in the response sample and the original license population) across survey modes. We compared days spent hunting and species harvested across distribution modes. We received 42,346 qualified email responses with a qualified response rate of 19.3%, and 6387 qualified mail responses with a qualified response rate of 14.1%. We calculated the cost of distribution modes and found email distribution costs (US$50,315 total; $1.19 per qualified email response) to be 87% less than mail distribution ($58,417 total; $9.15 per qualified mail response). Email respondents reported harvesting more game in 7 of 11 individual harvest metrics. Email respondents did not hunt more days than mail respondents according to 11 of 12 metrics. We evaluated whether age-weighting would improve model fit for days hunted and for harvest, but Bayesian analysis results indicated there were no meaningful differences in age-weighted and unweighted models. Email responses provided better overall coverage of age classes, as mail responses differed from the population of licensed hunters across age classes ($P=0.04$) and email responses did not ($P=0.68$). Based on these results, email surveys provided a more representative sample of Louisiana hunters' effort and harvest.

Key words: age class, age-weighting, survey cost, representative sample

Journal of the Southeastern Association of Fish and Wildlife Agencies 10:92–99

Wildlife managers increasingly seek input from their stakeholders as part of the natural resources management process (Riley et al. 2002). Wildlife agencies are compelled by statute, legal tradition (i.e., The Public Trust Doctrine), and policy to facilitate engagement of stakeholders (Sax 1970, Smith 2011, Decker et al. 2014). Formal comment periods regarding proposed management changes are one way of engaging stakeholders and often are required, but may be an inefficient method to fully measure the diverse range of stakeholder perspectives (AFWA and TWMI 2019). Such comment periods provide information that may not be useful for management objectives or may require additional qualitative analyses and interpretation before being useful to decision-makers. Riley et al. (2002) ranked scientifically designed random surveys as their most important technique for obtaining stakeholder opinions for wildlife management because quantitative survey data are readily integrated into management frameworks, such as adaptive impact management.

Given the importance of survey data to management frameworks, selecting the most appropriate survey mode requires care. Mail surveys have declining response rates, take longer to complete, and cost more than internet-based surveys (Sterrett et al. 2017, Daikeler et al. 2020). Wildlife managers have limited time and money available, which explains an increased interest in internet-based surveys (Vaske 2008, Fieberg et al. 2010). Internet surveys are normally faster to complete, easier, and cheaper for data management and processing than mail, phone, or interpersonal interview surveys, and provide flexibility for respondents in completion time (Campbell et al. 2018, Loomis and Paterson 2018).

Despite the increasing popularity of internet surveys, there is no standard optimal internet-based survey mode that functions best

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in terms of quality data, speed, ease, coverage, and cost. Therefore, some researchers and agency staff may be hesitant to completely shift to a stand-alone internet survey mode to assess stakeholder preferences (e.g., Daikeler et al. 2020). Further, critics of this data collection mode raise legitimate concerns regarding multiple biases (Duda and Nobile 2010, Gigliotti 2011, Vaske 2011, Loomis and Paterson 2018). For example, when a portion of the target population is not given the opportunity to participate (e.g., hunters without internet access), a coverage error can arise (Dillman et al. 2009). From surveys of Louisiana waterfowl hunters during 2010–2014, Laborde (2014) found 10% of respondents did not have access to the internet, mirroring the non-access rate documented in the U.S population as of 15 October 2020 (Pew Research Center 2022). Another bias common in internet-based surveys is non-response error (i.e., data from the survey may not be generalizable to non-respondents); online respondents are disproportionately younger, wealthier, and likely to be more educated, urban, of European descent, and male (Dillman et al. 2009, Duda and Nobile 2010, Graefe et al. 2011, Laborde 2014, Loomis and Paterson 2018, Daikeler et al. 2020). Low response rates also increase the possibility of non-response error, and response rates to internet surveys are, on average, 11% lower than responses from other survey types (Dillman et al. 2010, Laborde 2014, Daikeler et al. 2020). Internet surveys may also produce poor results due to incorrect e-mail addresses, e-mail spam filters, software incompatibility, or system crashes (Vaske 2008, Dillman et al. 2009, Gigliotti 2011, Laborde 2014). However, in wildlife-related studies, low response rates do not always mean poor quality data (Gigliotti et al. 2019).

Mail and internet-based survey modes individually each have potential weaknesses. However, email surveys can provide an efficient, inexpensive means of investigating attitudes as a supplement to random mail surveys, if the survey objective is to establish an index of effort and success (Laborde 2014, Daikeler et al. 2020). Across disciplines, surveys with mixed delivery modes have been recommended to improve coverage, cost, and efficiency, and to attract different user profiles which would increase response rates (Dillman et al. 2009, Dillman et al. 2010, Stern et al. 2014). Therefore, despite the concerns expressed by some authors (Duda and Nobile 2010, Gigliotti 2011, Vaske 2011, Loomis and Paterson 2018) and depending on specific research goals, email-only and mixed-mode surveys may provide quality data.

Since 2010, seven post-season, mixed-mode surveys assessing wildlife harvest and harvest effort in Louisiana have been performed, each employing identical and concurrent survey instruments using combinations of web, random mail, and mixed-mode surveys with a stratified random sample (stratified by age class) for one mode and a complete census of the remaining hunters by the second mode. Age classes were determined prior to the 2010 survey based on age distributions in the license sale data and on life stages (i.e., students, early career, mid-career, late career, and retired) because of concerns over recruitment of younger hunters and retention of older hunters. For these surveys, contact information was obtained for Louisiana Department of Wildlife and Fisheries (LDWF) licensed hunters and Mandatory Harvest Information Program registered waterfowl hunters. Emails sent to respondents included a link to an online form to complete the survey. The Louisiana Game Harvest Surveys (LAGHS) effort has evolved from its original 1967 random mail format focusing only on white-tailed deer (*Odocoileus virginianus)* harvest (J. P. Duguay, Louisiana Department of Wildlife and Fisheries, unpublished data) into surveys of harvest and effort for all game species in Louisiana using more cost-effective and modern survey approaches (e.g., Dillman et al. 2009, Rübsamen et al. 2017, Schonlau and Couper 2017, Loomis and Paterson 2018, Daikeler et al. 2020). The LAGHS was delivered to LDWF licensed resident hunters via random mail and email sampling methods (i.e., mixed-mode) following the 2016–17, 2017–18, and 2018–19 Louisiana hunting seasons. The sampling included a 17 question/item email survey and a 15 question/item mail survey, which included species-specific game harvest questions, and constructs on hunter effort, demographics, license type, and perspectives on Louisiana wildlife populations. The email survey appeared to respondents to be two questions longer but the difference was only due to formatting, with two items subdivided in the email survey but combined for analyses.

We sought to improve game harvest surveys by comparing the effectiveness of email and mail delivery modes in providing adequate coverage of the target population and collecting unbiased harvest data. Additionally, we evaluated the effect of post-hoc weighting of age classes in the survey response data to better reflect the age classes in the licensed population. Age-weighting is a commonly used correction technique to compensate for sampling coverage issues among groups within the population of interest (Vaske et al. 2011), and age-class data has been consistently reported in LAGHS, unlike geographic information that is often not provided by respondents or income, which is not included in these surveys. Specifically, we were interested in whether email surveys alone could provide the same information. We designed the survey instrument to assess hunter motivations and constraints to address five objectives using a multifaceted-discrepancy model (Manfredo et al. 1995). For evaluating whether email respondents hunted more days (Objective 1) and harvested more game (Objective 2) than mail respondents, as observed among Louisiana waterfowl hunters (Laborde et al. 2014), we applied an avidity construct comprised of survey items measuring frequency of hunting and harvest. Objective 3 examined whether mail surveys represented the age-class distributions of the license population more closely than email surveys. Random mail surveys have been reported to provide better sample coverage; but as a fundamental premise, sample surveys require a statistical assessment for coverage error among the respondents within the sampled frame (Dillman et al. 2009, Gigliotti 2011, Graefe et al. 2011). The last two objectives were to determine whether age-weighting (i.e., adjusting the age-class distributions of email and mail respondents to reflect the age-class distributions in the license population) would result in differences in response variables between modes. Thus, we tested whether age-weighting would result in better-fitting survey responses for days hunted (Objective 4) and harvest (Objective 5). We expected that age-weighting would increase precision of our days hunted and harvest estimates compared with unweighted data by reducing variability from over- and underrepresentation of age classes in the survey data.

Methods

We obtained a consolidated dataset of Louisiana licensed hunters' responses to the LAGHS distributed via email (LSU Public Policy Research Lab) and mail (LDWF) in May following the 2016–2017, 2017–2018, and 2018–2019 hunting seasons. A random sample of 6% ($n = 49{,}169$) of all Louisiana licensed resident hunters who had a valid physical mailing address in their LDWF license profile was selected to be surveyed by mail during the three-year sampling period. The email sampling frame included 234,325 remaining Louisiana licensed resident hunters who had a valid email in their LDWF license profile during the three-year sampling periods, which did not include any hunters selected for the mail survey. The email included a link to an online survey instrument (Qualtrics XM, Provo, Utah). For both modes, the number of surveys sent was approximately evenly distributed among the three survey periods and no respondent was surveyed more than once (email = 72,098, 71,703, and 90,524; mail = 17,086, 16,089, and 15,994 respondents in 2017–2019, respectively). Survey protocols ensured informed consent, anonymity, and confidentiality of responses, and were approved by the LSU AgCenter Institutional Review Board (IRB Protocol Number HE-17-06 [2017 and 2018] and HE-19-05 [2019]).

We assessed response data following quality-control procedures (e.g., we excluded responses where days hunted and game harvested exceeded legal limits), producing an electronic database for use in the LDWF decision-making process for hunting regulations, in public meetings, and/or in popular and scientific publications. We calculated response rates based on deliverable email and mail count and qualified responses by eliminating all respondents reporting that they did not hunt, who were under 16 years old, who failed to report at least one game species hunted during the season, or who did not answer more than five questions. These latter respondents were determined to be unqualified; therefore, a standardized cooperation response rate was based on complete and partial responses and non-contacts (AAPOR 2016) after these unqualified individuals were removed. We calculated average costs per qualified responses based on the total costs of the three-year sampling period, which was the sum of labor and distribution costs. For mail surveys, labor included costs to develop instrument, data entry, and analyses. Distribution costs included paper, printing, and postage. For email surveys, labor (same categories as above) was the primary expense. Costs for software licenses were not included, as free, open-source options exist.

We post-hoc weighted survey responses in the three-year consolidated dataset using two steps. We determined the differences among proportions of email respondents, mail respondents, and original license population across age classes by using email and mail as independent, fixed variables and days hunted by hunting type, harvest by hunting type, and age classes as response variables in generalized linear models (logit link, binomial distribution; PROC GLIMMIX in SAS 9.3 (SAS Institute 2019). This model provided standardized parameter estimates that were used to weight the respondent responses positively or negatively, such that the age classes in the age-weighted data more closely resembled the original license population.

We used generalized linear mixed models for hypotheses testing (Objectives 1–2). Each model had a single response variable and a single fixed method effect. For each response variable, several link function and probability combinations were possible (e.g., log link with Poisson distribution, log link-negative binomial distribution; inverse link with Gamma distribution), resulting in multiple models for each response variable. The best fitting model for each response variable was selected by Pearson X^2/df. For each response variable, the best fitting model was then used to identify the significance of each variable. For all models, survey period was the random effect. For these analyses, we initially set the significance threshold at $\alpha = 0.05$ (Dillman et al. 2009, Vaske 2019). However, we applied the Dunn-Šidák correction for a familywise adjusted $\alpha = 0.01$ for Objectives 1–2 because multiple analyses were conducted across several variables.

To statistically assess coverage error (Objective 3), we calculated the distributions of qualified responses by age class (16–25, 26–35, 36–45, 46–55, 56–65, and >65 years old), and compared them to the age-class distribution of the three-year license population of potential hunters (i.e., those that actively hunt or have hunted and may hunt again; $n = 234{,}325$) using a logit link and beta distribution

(PROC GLIMMIX in SAS 9.3; SAS Institute 2019). This analysis also included *a priori* comparisons between methods within each age class. For age-weighting comparisons (Objectives 4–5), we compared Pearson X^2/df to determine whether age-weighting improved fit and precision) and Bayesian credible intervals (Gelman et al. 2013) to determine if estimates meaningfully differed, based on generalized linear models with distribution mode, survey period, and their interaction as fixed effects and appropriate link transformations and probability distributions (PROC GENMOD; SAS Institute 2019). Bayesian credible intervals were generated based on a noninformative independent normal prior distribution with zero mean and variance for each parameter of 10^6. This approach was an adaptation of the analysis of credible intervals described by Matthews (2019). These methods were chosen due to concerns about combining age-weighted and unweighted estimates into a single model, which could have led to spurious statistical significance from large sample sizes, and the impracticality of model selection between these models.

Results

Response Rate and Cost per Survey Mode

The overall response rate for the three-year consolidated email LAGHS was 24.0%. Adjustment for undeliverable emails and elimination of inapplicable responses produced 42,346 qualified email responses, and a standardized cooperation rate of 19.3%. The overall response rate for mail surveys was 23.4%; adjustment for undeliverable mail and elimination of unusable responses produced 6387 qualified mail responses, and a standardized cooperation rate of 14.1%. The average cost of email and mail distribution per qualified response was US$1.19 ($50,315.30 total cost / 42,346) and $9.15 ($58,416.71/6387), respectively.

Days Hunted and Game Harvested

Email survey respondents did not hunt more days than mail survey respondents (Table 1). We observed statistically significant differences in only 3 of 12 variables tested between email and mail respondents for days hunted by game type (Table 2). These results indicated that email respondents hunted white-tailed deer more days than mail respondents. Conversely, email respondents hunted squirrels (*Sciurus* spp.) and rabbits (*Sylvilagus* spp.) fewer days than mail respondents. We found no significant difference between email and mail respondents in total days hunted, days spent still-hunting deer with modern firearms, deer with primitive firearms, archery hunting deer, wild turkey (*Meleagris gallopavo*), feral hogs (*Sus scrofa*) during the day, mourning dove (*Zenaida macroura*), ducks (order *Anseriformes*), and geese (order *Anseriformes*) (Table 2).

Table 1. Descriptive results of total days hunted for all game species analyzed in the 2016–2017, 2017–2018, and 2018–2019 Louisiana Game Harvest Surveys.

	Email			Mail		
Response variable	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**
All days hunted	35.32	37.05	24	38.00	39.16	26
Deer, modern firearm—still hunt	14.94	11.89	12	15.17	12.95	12
Deer, primitive firearm	5.40	5.13	4	5.53	5.48	4
Deer, bow and arrow	13.09	12.56	10	12.07	12.02	10
Deer, total	22.02	17.55	18	19.07	16.82	15
Hogs (times hunted during the day)	12.96	16.31	6	12.20	16.05	5.5
Turkey	5.60	4.94	4	5.87	5.15	4
Squirrel	6.16	7.42	4	7.67	9.41	4
Rabbit	5.34	8.06	3	6.78	10.52	3
Mourning dove	3.48	3.77	2	3.62	4.90	2
Duck	11.56	11.65	8	10.48	11.48	6
Geese	9.65	12.53	4	8.55	11.57	4

Table 2. Results of generalized linear mixed models on 12 unweighted response variables (days hunted or times hunted [hogs]) testing whether email respondents in Louisiana Game Harvest Surveys hunted more days on average than mail respondents. Parameter estimate (β) and effect size indicate differences between modes, email – mail. NSD = no statistical differences. $\hat{c}$ = Pearson X^2/df.

Response variable	$\hat{c}$	*F* (df[b])	Type III *P*	β (SE)	Effect Size (SE)
Deer, total[a]	14.19	1424.62 (19,312)	< 0.01	0.14 (0.01)	3.09 (0.01)
Deer, primitive firearm[a]	1.68	4.75 (3977)	0.03	NSD	
Deer, modern firearm—still hunt[a]	1.09	0.38 (10,339)	0.54	NSD	
Deer, bow and arrow[a]	1.28	2.98 (2500)	0.08	NSD	
Hogs (times hunted during the day[a]	1.76	1.07 (3921)	0.30	NSD	
Turkey[a]	4.52	1.07 (1270)	0.03	NSD	
Squirrel	10.04	190.73 (898)	<0.01	−0.20 (0.01)	2.04 (0.01)
Rabbit	13.63	159.19 (1776)	<0.01	−0.20 (0.01)	1.91 (0.04)
Mourning dove	4.57	11.38 (2033)	<0.01	NSD	
Duck	11.89	2.26 (6755)	<0.01	NSD	
Geese[a]	15.99	0.90 (1331)	0.34	NSD	

a. Modeled with negative binomial distribution (log link); all others modeled with Poisson distribution (log link).

b. Denominator df is listed; numerator df = 1 for all *F* statistics.

Email respondents harvested more game on average than mail respondents (Table 3, Table 4). We observed significant differences for game harvested in 7 of 11 variables tested between email and mail respondents, and results from 6 of the 7 significant variables indicated that email respondents harvested more game than mail respondents. Email respondents harvested more deer while still-hunting with modern firearms, with primitive firearms, with bow and arrow, and in total harvest than mail respondents. Email respondents also harvested more hogs during the day than mail respondents. Email respondents harvested more geese than mail respondents. In contrast, mail respondents harvested fewer squirrels than mail respondents, and, although not statistically significant, fewer turkeys than mail respondents. Our results indicated no significant difference in average harvest of rabbits, mourning doves, and ducks between email and mail respondents (Table 4).

Age-Class Distribution

Overall, across age classes, email respondents were not significantly different than the active and potential license population of Louisiana hunters (Table 5) and were more representative of the license population. Mail respondents differed significantly from the active and potential license population. Examination of *a priori* comparisons of age class identified important differences in specific age groups (Table 5, Table 6). Email respondents were over-represented from ages 26–55 of the active and potential population of Louisiana hunters, whereas mail respondents were over-represented for ages ≥56. In the 16–25-year-old age class, both email and mail respondents were under-represented; however, mail respondents of this age class were represented less than email respondents. Survey age classes were not statistically different from active and

Table 4. Results of generalized linear mixed models on 11 unweighted response variables (number harvested, killed during day [hogs], or bagged [ducks]) for data from Louisiana Game Harvest Surveys, testing whether email respondents harvested more game on average than mail respondents. Parameter estimate (β) and effect size indicate differences between modes, email—mail. NSD = no statistical differences. $\hat{c}$ = Pearson X^2/df.

Response variable	$\hat{c}$	F (df[b])	Type III *P*	β (SE)	Effect Size (SE)
Deer, modern firearm—still hunt	1.44	40.56 (9161)	<0.01	0.23 (0.04)	0.02 (0.004
Deer, primitive firearm	1.25	16.68 (10114)	<0.01	0.22 (0.05)	0.02 (0.01)
Deer, bow and arrow	1.80	58.54 (6205)	<0.01	0.66 (0.09)	0.08 (0.01)
Deer, total	1.68	107.77 (16361)	<0.01	0.21 (0.02)	0.14 (0.003)
Hogs killed during the day	27.21	118.59 (3909)	<0.01	0.35 (0.03)	0.08 (0.01)
Geese[a]	2.08	8.49 (1245)	<0.01	0.38 (0.13)	0.74 (0.09)
Squirrel	33.54	267.71 (4719)	<0.01	−0.16 (0.01)	0.10 (0.05)
Turkey	1.20	5.35 (1270)	0.02	NSD	
Rabbits[a]	2.02	0.11 (1776)	0.74	NSD	
Mourning dove[a]	1.44	0.74 (1920)	0.77	NSD	
Ducks (bagged)[a]	1.25	1.39 (6755)	0.24	NSD	

a. Modeled with negative binomial distribution (log link); all others modeled with Poisson distribution (log link).
b. Denominator df is listed; numerator df = 1 for all *F* statistics.

Table 3. Descriptive results of total game harvested for all game species analyzed in the 2016–2017, 2017–2018, and 2018–2019 Louisiana Game Harvest Surveys.

	Email			Mail		
Response variable	Mean	SD	Median	Mean	SD	Median
All days hunted	0.76	1.03	0	0.63	0.97	0
Deer, modern firearm—still hunt	0.29	0.59	0	0.23	0.57	0
Deer, primitive firearm	0.31	0.75	0	0.16	0.55	0
Deer, bow and arrow	0.88	1.22	0	0.68	1.16	0
Deer, total	3.93	1.24	1	3.16	1.16	0
Hogs killed during the day	0.22	12.00	2	0.24	11.85	1
Turkey	13.38	0.50	0	14.69	0.51	0
Squirrel	6.20	19.12	8	5.58	24.94	8
Rabbit	15.97	11.76	3	15.37	9.41	3
Mourning dove	29.22	21.58	10	25.05	23.76	10
Duck	10.02	44.06	12	4.77	38.07	12
Geese	0.76	1.03	0	0.63	0.97	0

Table 5. Results of a generalized linear mixed model comparing representation of age classes among survey method in Louisiana Game Harvest Surveys, with a random effect of survey year, which tested whether mail respondents were more representative of the actual population of Louisiana hunters than email respondents. Estimates are differences between each age class against the population and scaled to be directly comparable.

	Percentage	β (SE)		Type III *P* (*t* statistic[a])	
Response variable	Population / Email / Mail	Email	Mail	Email	Mail
All age classes		0.02 (0.05)	−0.11 (0.05)	0.68 (0.41)	0.04 (−2.08)
16–25	13 / 7 / 6	−0.64 (0.15)	−0.91 (0.16)	<0.01 (−4.19)	<0.01 (−5.55)
26–35	13 / 18 / 7	0.38 (0.12)	−0.74 (0.16)	<0.01 (3.11)	<0.01 (−4.73)
36–45	13 / 21 / 17	0.63 (0.12)	−0.30 (0.14)	<0.01 (5.17)	0.04 (−2.15)
46–55	14 / 21 / 16	0.63 (0.12)	0.19 (0.13)	<0.01 (4.71)	0.15 (1.48)
56–65	25 / 22 / 32	−0.15 (0.11)	0.36 (0.10)	0.16 (−1.42)	<0.01 (3.67)
Over 65	18 / 10 / 31	−0.66 (0.12)	0.72 (0.11)	<0.01 (−4.96)	<0.01 (6.80)

a. df = 34 for all *t* statistics.

Table 6. Age-class distribution between survey types in Louisiana Game Harvest Surveys and across game harvested. Percentages are number of respondents hunting at least one day for each game type within each age class.

	White-tailed deer (*n* = 32,440)		Wild hogs (*n* = 11,938)		Wild turkey (*n* = 3363)		Squirrels (*n* = 12,175)		Rabbit (*n* = 3990)		Any small game (*n* = 22,382)		Ducks (*n* = 16,440)		Geese (*n* = 3352)	
Age class	Email	Mail	Email	Mail	Email	Mail	Email	Mail	Email	Mail	Email	Mail	Email	Mail	Email	Mail
16–25	6.6	5.7	7.9	5.9	7.6	5.6	8.5	6.4	9.0	7.8	9.1	7.6	11.5	11.0	12.1	12.5
26–35	18.2	7.1	19.0	8.8	20.2	6.6	20.2	6.3	21.1	11.2	20.7	8.3	23.8	11.5	25.5	13.8
36–45	23.2	11.4	21.5	13.4	20.7	9.0	21.2	11.1	23.6	8.7	21.4	11.2	20.4	12.5	19.5	12.9
46–55	23.4	18.4	22.2	18.5	21.1	15.1	20.7	16.6	21.2	10.4	20.9	17.8	19.6	19.1	18.1	16.0
56–65	20.7	30.8	21.0	30.7	20.4	32.4	20.8	31.2	18.3	10.3	19.8	30.0	17.8	28.0	18.0	27.6
Over 65	7.9	26.6	8.4	23.6	10.0	31.2	8.5	28.4	6.8	9.9	8.1	25.1	6.8	26.6	6.9	17.2

potential license population for 46–55-year-old mail respondents and 56–65-year-old email respondents (Table 5).

Age-Weighting Days Hunted and Game Harvested

When comparing the effect of age-weighting on fit of the days hunted variables, six unweighted days hunted variables resulted in a better fit than the age-weighted days hunted variables: deer with modern firearm, deer with bow and arrow, total deer, turkeys, squirrels, and ducks (Table 7). The all days hunted variable had a better fit in the age-weighted model. The model fit for analyses of rabbit days hunted was unchanged by age-weighting. Results indicated that the other four age-weighted days hunted variables had a better fit than the unweighted days hunted variables: deer with primitive firearm, hogs during the day, mourning doves, and geese. Despite improved fit, we found no significant differences in the Bayesian credible intervals for any of the 12 days hunted variables (Table 7).

Table 7. Comparison of 12 variables measuring effect of age-weighting on days hunted in Louisiana Game Harvest Surveys analysis. A $\hat{c}$ value for Pearson X^2/df of 1.0 indicates the best possible fit. Bayesian credible interval estimates of days hunted determined if estimates meaningfully differed, based on generalized linear models with distribution channel, survey period, and their interaction as fixed effects. The fit for all variables followed a Negative Binomial distribution with a log link function.

Response variable	*n*	$\hat{c}$ weighted / unweighted	Bayesian posterior interval weighted / unweighted
Deer days hunted modern firearm—still hunt	28,900	1.14 / 1.09	–0.5–0.02 / –0.08–0.01
Deer days hunted—primitive firearm	11,536	1.65 / 1.68	–0.05–0.03 / –0.08–0.06
Deer days hunted—bow and arrow	6847	1.37 / 1.28	0.09–0.20 / 0.1–0.29
Deer days hunted total	19,241	1.50 / 1.76	–0.08– –0.02 / –0.16–0.06
Number of times hunted hogs during the day	11,165	1.50 / 1.76	–0.08– –0.2 / –0.16–0.06
Turkey days hunted	3213	1.25 / 1.19	–0.05– –0.06 / –0.25–0.06
Squirrel days hunted	3743	1.75 / 1.71	–0.25– –0.14 / –0.50–0.14
Rabbit days hunted	4885	2.13 / 2.13	–0.50– –0.14 / –0.50– –0.14
Mourning dove days hunted	15,803	1.67 / 1.78	0.03–0.31 / 0.03–0.31
Duck days hunted	3225	1.26 / 1.15	0.12–0.31 / 0.11–0.30
Geese days hunted	41,546	1.48 / 1.49	0.20–0.77 / 0.20–0.77
All days hunted	3743	1.09 / 1.22	0.02–0.16 / 0.02–0.16

Table 8. Comparison of 11 variables measuring effect of age-weighting on harvest (number harvested) in the of Louisiana Game Harvest Surveys analysis. A $\hat{c}$ value for Pearson X^2/df of 1.0 indicates the best possible fit. Bayesian credible intervals determine if estimates meaningfully differed, based on generalized linear models with distribution channel, survey period, and their interaction as fixed effects.

Response variable	*n*	$\hat{c}$ weighted / unweighted	Bayesian posterior interval weighted / unweighted
Deer harvested modern firearm—still hunt	28,063	0.95 / 1.44	0.09–0.23 / 0.09–0.23
Deer harvested—primitive firearm	10,071	0.67 / 0.28	0.22–0.56 / 0.22–0.56
Deer harvested—bow and arrow	6162	0.94 / 0.94	0.99–1.61 / 0.99–1.61
Deer harvested total	17,134	1.24 / 0.73	0.04–0.17 / 0.04–0.17
Number of hogs killed during the day[a]	11,387	5.08 / 5.61	0.13–0.42 / 0.22–0.33
Turkey harvested	3219	0.55 / 1.20	–0.28–0.51 / –0.28–0.51
Squirrel harvested[a]	11,482	1.61 / 1.82	–0.11–0.10 / –0.03–0.02
Rabbit harvested[a]	3760	2.21 / 2.02	–0.33–0.14 / –0.16– –0.02
Mourning dove harvested[a]	5152	1.44 / 1.44	–1.90–1.48 / –0.4–0.60
Duck harvested[a]	15,873	1.53 / 1.25	0.18–0.26 / 0.05–0.38
Geese harvested[a]	3619	9.84 / 2.08	0.01–0.41 / 0.25–0.30

a. Modeled with negative binomial distribution (log link); all others modeled with Poisson distribution (log link).

Based on our data, age-weighting resulted in better model fit for game harvested. Focusing on harvest of individual species, 6 of 11 age-weighted variables produced a better model fit than the unweighted variables, suggesting a difference in age-weighted harvest in email and mail respondents (Table 8). Most age-weighted harvest variables had a better fit than the unweighted harvest variables: deer with modern firearm, deer with primitive firearm, deer with bow and arrow, total deer, hogs during the day, and squirrels. However, after the Bayesian analysis, we found no meaningful differences (i.e., the Bayesian credible intervals overlapped between the two modes) generated in 10 of the 11 harvest variables, the exception being harvest of mourning doves (Table 8).

Discussion

Our comparison of modes to deliver game harvest surveys illustrated few differences in relevant management variables and similar coverage between modes. Email respondents reported harvesting more game, and email responses provided better overall coverage of age classes, supporting our expectations. Email respondents did not hunt more days, and age-weighting did not improve model fit for days hunted or for harvest. Therefore, email surveys using all available email addresses may better represent age classes and harvest of Louisiana hunters. Mail surveys provided better estimates for days hunted for more types of individual game species; however, survey mode selection should be based on which mode provides better estimates for species of interest.

Where differences were detected, email responses were likely better for understanding harvest. Email respondents reported harvesting more animals for most species hunted, thus email responses may represent a better estimate of harvest than by mail or may represent a more liberal estimate, potentially due to more avid and efficient hunters among the email respondents. Mail respondents reported higher average harvest than email respondents only for squirrel and turkey. This was expected, as previous LAGHS surveys indicated that email respondents spent fewer days hunting for squirrel and turkey. Schroeder et al. (2018) and Frawley (2019) reported that the average age of squirrel and turkey hunters was greater than 50 years old. In this study, more than 60% of turkey and squirrel hunters were 36–65 years old, with only 35% of turkey hunters and 26% of squirrel hunters under age 35. Combined with greater representation of these age groups in the mail responses, these differences could be the result of age-related biases in the survey data, if data are pooled. However, comparison of model fit for age-weighting only supported this interpretation for squirrel hunters. Differences in turkey harvest may arise from other factors, such as the spring-only season in Louisiana, whereas most states offer spring and fall seasons, providing more opportunities for hunters to harvest turkeys. The disparity of hunting opportunities between states may also skew the age composition, as our data showed that Louisiana turkey hunters were an older demographic whereas other states hunters' age composition is more evenly dispersed (Alpizar-Jara 2001).

Our analyses found that email hunters reported fewer days hunted, however, the same hunters reported harvesting more game. These results reinforce other research indicating that the association between more days hunted and more game harvested may be inconsistent and that reported success in harvest could not be solely determined from days hunted (Brunke and Hunt 2007, Schroeder et al. 2017, Bradshaw et al. 2019, Gruntorad et al. 2020). In summary, these results provide support that the number of days spent hunting reflects the level of harvest in most (6 of 11 variables) but not all hunting types (5 of 11 variables). Given that harvest surveys are widely conducted across harvested species and regions, future research should be conducted to determine a metric that could perhaps transform total game and fish harvested data into statistically testable indices.

If only a single method is to be selected, email surveys provide better coverage of Louisiana hunters. These results support that, based upon age classes, email respondents were more representative of the active and potential hunter population than mail respondents with a caveat that neither method well represented the youngest respondents. Email provided a closer estimate to the population in four of six age classes. Both methods under-represented ages 16–25; email surveys over-represented ages 26–55, and under-represented the over-65 age class. We suspect that as internet access and email use become more prevalent, and as non-users age out of hunting, email distribution will become even more representative of the actual population of Louisiana hunters. However, our research team's experience with young people (<21 years old) in the university and educational settings suggests that email may be inefficient in reaching these hunters. Email surveys have good representation of many ages and have biases primarily in the youngest and oldest groups.

We suggest that thoughtful consideration is needed to link survey method to targeted age classes, including potentially adding other methods to a broad email survey. The findings of this study support the current literature indicating decreased response rates to mail surveys and that internet surveys are cheaper, faster to complete, and have better coverage of the population, but can promote several biases (Dillman et al. 2009, Duda and Nobile 2010, Campbell et al. 2018, Daikeler et al. 2020). Early implementation of internet-based methods, whether email or web, generated valid criticisms and concerns with errors associated with coverage and non-response bias (Duda and Nobile 2010, Gigliotti 2011, Vaske 2011, Graefe et al. 2011). Mixing survey delivery modes to target specific groups that researchers are interested in has been recommended to improve coverage, cost, and efficiency, and to attract different user profiles which would increase response rates (Dillman et al. 2009, Dillman et al. 2010, Stern et al. 2014). Based on these results and other recent analyses, greater access to broadband internet and the ubiquity of smartphones appears to have addressed the earlier concerns, at least for many age classes (Campbell et al. 2018, Daikeler et al. 2020). Candidly, if respondents over 65 years old prefer mail surveys, managers could send supplemental mail surveys to that age class, and if 16–25-year-old respondents prefer text messages or surveys via social media, researchers should investigate implementation of these methods. Further research is needed to understand how to effectively reach the 16–25-year-old age class, which is a highly important group of hunters, as they are the future of hunting in Louisiana.

Acknowledgments

These studies were cooperative efforts between the LSU AgCenter, and the Louisiana Department of Wildlife and Fisheries. We thank LSU School of Renewable Natural Resources alumni Kailyn Avery, Jessica Bonin, Jenna Cheramie, H. Nash Jackson, Collette Pansini, Anne Weaver, and Anna West for their tireless efforts in data scrubbing. We thank hunters who took time to complete the survey. This study was supported in part by the USDA National Institute of Food and Agriculture, McIntire-Stennis Cooperative Forestry Program as Project Number LAB-94335. This manuscript was approved for publication by the Director of the Louisiana Agricultural Experiment Station as MS 2022-241-38299.

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