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A preliminary assessment of shorebird harvest in coastal Guyana

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Shorebirds have been harvested for centuries on Caribbean islands and along the northern coast of South America. Although the magnitude of modern harvest pressure on shorebirds within this region is incompletely quantified, accumulating evidence indicates that harvest could limit the growth of certain shorebird populations. Central to understanding the effect of harvest on shorebird populations is the need for current quantitative assessments of harvest. To begin filling this need, we determined the number of sites where harvest occurred along the coast of Guyana in 2017 and 2018 and compared that to surveys conducted in 2001–2002. During fall 2020, we estimated the number of shorebirds harvested at two coastal sites and sold in one community market. We also conducted periodic shorebird surveys to characterize the phenology and species composition of the post-breeding migration. Although the occurrence of harvest at coastal sites has likely declined over the last two decades, we estimated that approximately 37,000 shorebirds were harvested at two sites and sold in one market during the post-breeding period of 2020. Given the limited scale of our study, the total harvest along the country's entire coast was undoubtedly greater. Small *Calidris* sandpipers dominated the post-breeding migratory shorebird assemblage and, along with the Semipalmated Plover *Charadrius semipalmatus*, were most abundant in the harvest. Shorebird harvest in Guyana exceeded that of all Caribbean islands combined where harvest estimates were available. The lack of a national policy to regulate the harvest of migratory shorebirds poses a significant challenge to achieving a sustainable shorebird harvest in Guyana and ultimately across the region. A more complete characterization of the social aspects of the harvest, including the economic impact, is needed to support the development of strategies to promote shorebird conservation that are acceptable to the local harvesters, commercial vendors, and conservation stakeholders.

Keywords

Americas
Calidris
hunting
management
shorebirds
waders

INTRODUCTION

Shorebirds have been harvested for centuries on Caribbean islands and along the northern coast of South America. Although the practice has disappeared or been regulated in many jurisdictions, modern hunting pressure on shorebirds in the Caribbean and northern South America has been largely unknown, with limited information provided by isolated reports spread across decades (e.g., Trull 1983, Hutt 1991, Ottema & Spaans 2008). In 2010, the Canadian Wildlife Service and BirdLife International began working with the Barbados Wildfowlers Association to obtain logbooks of shooting swamps, with the purpose of providing a current estimate of shorebird harvest on the island (Reed 2012). Concurrently, the non-governmental organization BirdsCaribbean (formerly the Society for the Conservation and Study of Caribbean Birds) developed an online SurveyMonkey® questionnaire to solicit information on shorebird harvest (defined as shorebirds that are intentionally wounded or killed using firearms, nets, traps, or other methods) from their members throughout the Caribbean Basin. The results of this survey indicated that substantial harvest was still occurring in Barbados, northern Brazil, France's Overseas Departments and Territories (French Guiana, Guadeloupe, Martinique, and Saint Martin), Guyana, Suriname, and perhaps Trinidad and Tobago (Andres 2011).

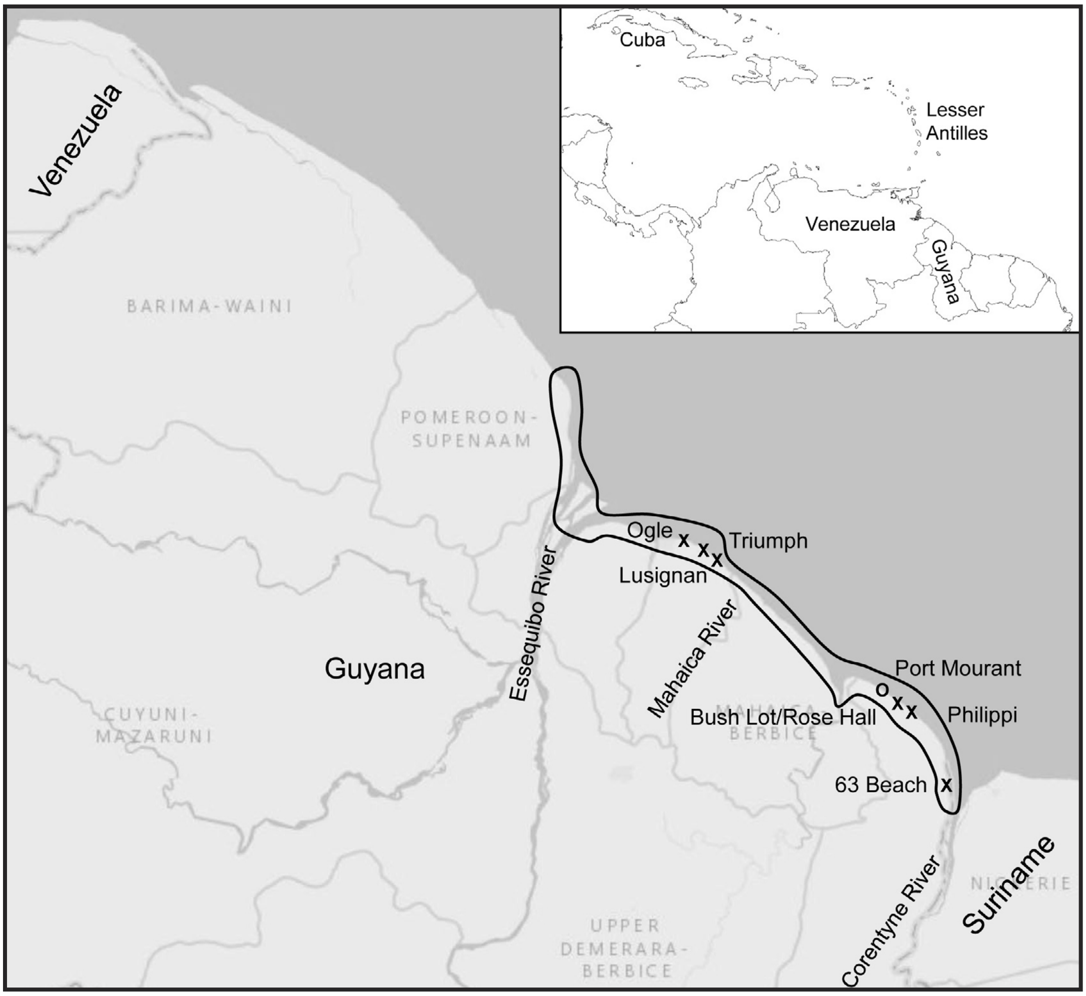

Fig. 1. Coast of Guyana where shorebird counts and harvest surveys were conducted August–November 2017, 2018, and 2020 (outlined) and locations of shoreline shorebird harvest sites (X) and commercial market (O).

The accumulating evidence on the scope of shorebird harvest was considered in the development of the Atlantic Flyway Shorebird Initiative (AFSI) Business Plan (AFSI 2015), where harvest was identified as a primary anthropogenic threat to shorebirds. Under the auspices of the AFSI, a Harvest Working Group, consisting of government agencies, non-governmental organizations, and stakeholder hunting groups, was formed to address the threat of unsustainable shorebird harvest in the Caribbean and northern South America. The group identified that robust assessments of the biological and social components of shorebird harvest would be a critical first step in determining whether other conservation strategies should be implemented, such as developing hunting policies or strengthening law enforcement (AFSI Harvest Working Group 2016, Watts & Turrin 2016).

Although preliminary harvest estimates now exist, or are being generated, for many of the jurisdictions identified in 2011 (AFSI Harvest Working Group 2017, 2020), harvest levels in Guyana remain unknown. Since 1877, the government of Guyana (formerly British Guiana) has provided protection for some birds through the Wild Birds Ordinance (Ordinance No. 14 of 1877), which was transformed into the Wild Birds Protection Act (act 31) in 1919 and was subsequently amended several times through 1997. The original act and subsequent amendments focused primarily on resident species and did not provide any protections for migratory shorebirds (families Charadriidae and Scolopacidae). At this time, killing and selling migratory shorebirds is legal in Guyana year-round and there are no regulations in place to limit the amount of harvest.

Trull (1983) first alerted the international conservation community about the use of 'choking' wires for harvesting shorebirds in Guyana. Bayney (2005) confirmed the continued use of choking wires and provided an overview of their use. In brief, a 12- to 15-meter length of stiff wire is attached to a short length of stick that is inserted into the sand or mud. As a flock of birds skims the surface of the sand or mud, the wire is pulled taut cutting into the flock. The tension of the wire removes heads, wings, and sometimes feet in the process of killing the birds. Bayney & Da Silva (2005) reported a substantial harvest of shorebirds and other waterbirds by this method along Guyana's eastern coast. They also documented commercial selling of shorebirds in several communities but did not provide an estimate of total shorebird harvest. 'Shocking' is the current local term for the use of choking wires to harvest waterbirds, and we use the terms 'shocking' to describe the harvest method and 'shockers' to describe harvesters who use this method.

Here, we present initial work to describe harvest of shorebirds in Guyana. We surveyed the 55 harvest sites identified by Bayney (2005) to determine whether shorebird harvest has continued and to count the shorebirds using the site. We also intensively monitored two shocking sites and one market to quantify the number and species composition of shorebirds harvested there. Our objectives were to (1) provide an initial assessment of the current prevalence and the magnitude of harvest and commercial selling of migratory shorebirds along the coast of Guyana and (2) compare species composition and harvest levels to other jurisdictions in the region, which contributes to the broader goal of understanding shorebird harvest in the Caribbean and northern South America.

METHODS

Study area

The coastal plain of Guyana occupies <10% of the country's area but supports >90% of its inhabitants (n = 786,559 people in 2020; World Bank Data Catalog: *https://data.worldbank.org/indicator/SP.POP.TOTL?locations=GY*). Local sediment discharges of the Corentyne and Essequibo Rivers are supplemented by those of the Amazon River to form extensive coastal mud banks, which migrate in a northwesterly direction along the coast (Augustinus 1987). The processes of sediment accretion and subsequent erosion create a dynamic coastline. Mangroves are common along the coast (Pastakia 1991), although they have been depleted severely in recent decades (Anthony & Gratiot 2012). The loss of mangroves, construction of seawalls, and rising sea levels have greatly altered the eastern coast of Guyana.

Site surveys

We used Bayney's (2005) list of 55 sites along the accessible coast of eastern Guyana as the spatial basis to assess the persistence of shorebird shocking over the last two decades (Fig. 1). We made six trips to these sites on weekends during August–October 2017 and October–November 2018. At each site, we assessed potential shorebird habitat (e.g., mudflats/sand flats versus mangroves) and checked the shoreline for evidence of shocking. If we did not observe shocking activity, we opportunistically asked local community members about their knowledge of current shocking activity in the area. While conducting surveys along the coast, we added additional sites to our original list if shoreline conditions provided opportunities for shocking or we observed active shocking (n = 6). In 2020, we focused on sites where we documented shocking in 2017 and 2018, with the intent of providing a more robust estimate of harvest. We visited sites every two weeks on Fridays and weekends between 29 August and 7 November 2020, which was the primary post-breeding shorebird migration period (see below). We chose to survey on Fridays and weekends because of the potential sale of shorebirds in markets that operated primarily on weekends.

At sites where shorebird feeding or roosting habitat appeared suitable, as described above, we conducted counts of shorebirds during August–November in 2017, 2018 and 2020. At each site, we observed shorebirds with spotting scopes and counted the numbers of shorebirds present to species, where possible, or groups based on genera. All count data were entered into eBird.

To illustrate the phenology of shorebird migration along the coast of Guyana, we included data only from sites that had at least five surveys during the entire study period. The post-breeding migration season (August–November) was partitioned into six periods of about 10 days. We extrapolated missing values by averaging the counts from the two adjacent periods; if a site was missing data from the first period, we did not derive a count value. If we conducted surveys at an individual site during the same period in multiple years, we averaged the counts across years. Scientific names of all observed shorebird species are provided in Table 1.

Shocker surveys

We adapted a questionnaire used previously to interview shorebird harvesters in Brazil, French Guiana, and Suriname, which included input from a social scientist, for use along Guyana's coast (e.g., Bosi de Almeida *et al.* 2018). When we encountered shockers at a site in 2020, we asked them the following questions: (1) how many weekend and weekdays did they shock in the last two weeks; (2) on average, how many shorebirds did they harvest per day; (3) which species did they harvest; (4) did they consume the birds themselves or sell them; (5) how many other people were present at the site when they were shocking; and (6) what times of year did they harvest shorebirds. In total, we interviewed 10 active shockers at two sites. Respondents remained anonymous and provided informed consent to be interviewed; no personal identifiable information was collected. Some shockers declined to be interviewed, but we did not quantify the number of rejections. Prior to data collection, our study plan was discussed with the Guyana Wildlife Conservation and Management Commission and the Environmental Protection Agency. All shocker and vendor interviews were conducted by Guyanese nationals.

Market surveys

In 2020, we visited one established open-air community market to determine if shorebirds were being sold commercially. We visited the market every two weeks, during their weekend operations, and asked vendors a set of questions similar to those posed to shockers: (1) how many weekend and weekdays did they sell shorebirds in the last two weeks; (2) on average, how many shorebirds did they sell per day; (3) which species did they sell; (4) what times of year did they sell shorebirds; and (5) what was the price they charged for shorebirds. We often had to purchase some shorebirds to obtain information from vendors. We conducted 24 interviews of vendors; individual vendors were not tracked across market dates, and multiple interviews were conducted with some vendors.

Data analysis

For analyses of shocking harvest and vendor selling, we used Bayesian hierarchical models with a data augmentation scheme (Royle & Dorazio 2008) to make predictions about the number of shorebirds harvested at two sampled shoreline sites and the total number of shorebirds sold at one sampled market during the harvest period. The data augmentation strategy allowed us to make predictions about the numbers of shocking groups and the numbers of birds harvested at each site for days when we did not survey the shoreline site. Our predictions are limited to the timeframe of the survey and accounted for the uncertainties of our sampling protocols (Cressie *et al.* 2009).

For the two shoreline sites where we observed shocking, we modelled the harvest of shorebirds from 1 to 30 September 2020 (i.e., 30 days). We chose this time-period because our site surveys indicated that shocking had not begun before 29 August and had ceased by 10 October. First, we modelled the number of groups of shockers at each site *b* for each date *t* using a truncated Poisson distribution as $NShockers_{b,t} \sim Poisson(\lambda_{shockers})$. Based on our observations and interviews with shockers, we limited the possible number of shocking groups on any given date to eight per site. We then modelled the total harvest for each shocking group *g* at each site using a compound Poisson-gamma distribution as a surrogate for the negative binomial distribution (i.e., NB2; Greene 2007), because the expected number of harvested shorebirds showed marked overdispersion. The Poisson-gamma distribution can be expressed as $TotalShock_{b,t,g} \sim Poisson(\lambda_{shock_b} \times \rho_{shock_{b,t,g}})$, where λ_{shock_b} is the expected number of shorebirds shocked at site *b* per shocking group, and ρ_{shock} is the overdispersion term for each observation modelled from a gamma distribution with single parameter $Gamma(\theta_b, \theta_b)$ for each site. Our model included a step function that prevented the model from creating harvested birds when there was no shocking group active at a site on a given day (Sollmann *et al.* 2016, Roy *et al.* 2022). We derived the predicted total numbers of birds shocked each day at each site from the model.

Table 1. Shorebirds observed along the coast of Guyana, their size categorization (large or small), and their frequency of occurrence of being sold by market vendors (n = 18 vendor-days) during August–November 2017, 2018, and 2020.

English name	Scientific name	Size	% occurrence at markets[1]
Black-necked Stilt	*Himantopus mexicanus*	large	16.7
Black-bellied Plover	*Pluvialis squatarola*	large	44.4
Semipalmated Plover	*Charadrius semipalmatus*	small	72.2
Whimbrel	*Numenius phaeopus*	large	38.9
Hudsonian Godwit	*Limosa haemastica*	large	–
Ruddy Turnstone	*Arenaria interpres*	large	5.6
Red Knot	*Calidris canutus*	large	–
Sanderling	*C. alba*	small	44.4
Least Sandpiper	*C. minutilla*	small	11.1
White-rumped Sandpiper	*C. fuscicollis*	small	94.4
Semipalmated Sandpiper	*C. pusilla*	small	94.4
Western Sandpiper	*C. mauri*	small	–
Short-billed Dowitcher	*Limnodromus griseus*	large	–
Spotted Sandpiper	*Actitis macularius*	small	11.1
Solitary Sandpiper	*Tringa solitaria*	large	–
Lesser Yellowlegs	*T. flavipes*	large	88.9
Willet	*T. semipalmata*	large	16.7
Greater Yellowlegs	*T. melanoleuca*	large	44.4

[1]Species not observed in markets but recorded during shorebird counts indicated by '–'.

We modeled the number of market vendors selling shorebirds on a given market date t with a truncated Poisson distribution as $NVendors_t \sim Poisson(\lambda_{vendors})$, where $\lambda_{vendors}$ is the expected number of market vendors selling shorebirds at the market on known market dates from 29 August to 7 November 2020 (i.e., 11 dates); we truncated the distribution at six vendors per date. We then modelled total sale of shorebirds for each date t and market vendor v using a compound Poisson-gamma distribution, given that the observed number of shorebirds sold by each vendor showed marked overdispersion. Our model can be expressed as $TotalSale_{t,v} \sim Poisson(\lambda_{sale} \times \rho_{sale_{t,v}})$, where λ_{sale} is the expected shorebird sales by each vendor, and ρ_{sale} is the overdispersion term modelled from a Gamma distribution with a single parameter $Gamma(\theta_v, \theta_v)$.

During market surveys, we were able to distinguish between large shorebirds and small shorebirds for sale by many, but not all, vendors. Within the market vendor model, we estimated the proportion of large shorebird for sale (r_{large}) by each market vendor with a binomial distribution as $LargeSale_{t,v} \sim Binomial(r_{large}, TotalSale_{t,v})$. Sale of small shorebirds was then derived from the total sale as $SmallSale_{t,s} = TotalSale_{t,v} - LargeSale_{t,v}$.

We also calculated the mean total revenue per vendor by summing the revenue of all vendors across all dates, and calculated the mean revenue of each vendor by dividing the total revenue by total number of vendors selling shorebirds summed across all dates. There were five dates for which we used data augmentation to estimate shorebird sales and six dates during which we had information on shorebirds prices because we had completely surveyed the market. The model included a step function that prevented the model from creating sales by more vendors than were predicted to be active for a given market date. We modeled the price per shorebird with a uniform distribution as $Price_{t,v} \sim Uniform(min, max)$ for large and small shorebirds. We set the price ranges based on the prices that we observed at the market during our surveys. We then calculated $Revenue_{t,v} = Sale_{t,v} \times Price_{t,v}$) for large and small shorebirds.

We processed all data in R v.4.0.3 (R Core Team 2020) and conducted analyses of (1) birds harvested by shockers and (2) birds sold at market and their associated revenues in JAGS v.4.3.0 (Plummer 2003) via the R package *jagsUI* (Kellner 2021). We used non-informative priors for all parameters and ran three chains with randomized initial start values for 220,000 iterations, using the first 20,000 iterations as burn-in and thinning the chains to save every 10th iteration. We present the medians with the 90% Bayesian credible intervals based on the highest density interval (HDI). We opted for HDI because our predictions contained many uncertainties (i.e., the posterior densities are right skewed), and we preferred to present conservative credible intervals (Kruschke 2015).

RESULTS

Site surveys

Based on repeated visits and opportunistic interviews with local residents, we recorded shocking at six of the 60 sites we visited in 2017–2018 (Fig. 1): Ogle Seawall (shocking), Triumph/BV (shocking), Lusignan (shocking), Bush Lot Village (shocking and netting), Philippi Village (shocking) and 63 Beach (shocking and some shooting). Three of these active sites were west of the Mahaica River, and three were east of the river. Thirty-two (53%) of the sites we visited did not provide suitable habitat for shorebirds, and hence shocking activity, due to mangrove forestation, erosion, or sand deposition. In late October 2018, we found a shocking site away from the shoreline in an abandoned rice field currently used to farm shrimp, where flooded fields attracted roosting shorebirds during high tide. This was the only site away from the shoreline that we discovered.

Table 2. Mean annual composition of the post-breeding migratory shorebird assemblage along the coast of Guyana, 2017–2020 (annual mean of n = 101,500 total shorebirds). Scientific names provided in Table 1.

Species/group	Counts	
	Number	%
Small *Calidris* sandpipers (Sanderling, Least, White-rumped, Semipalmated & Western Sandpipers)	93,975	92.6
Solitary Sandpiper/Lesser Yellowlegs/Greater Yellowlegs	3,907	3.8
Semipalmated Plover	1,845	1.8
Black-bellied Plover	654	0.6
Whimbrel	320	0.2
Short-billed Dowitcher	268	0.3
Ruddy Turnstone	180	0.2
Willet	239	0.2
Other species (Hudsonian Godwit, Red Knot, Stilt Sandpiper, Spotted Sandpiper)	112	0.1

Eighteen species of shorebirds were recorded during site surveys (Table 1). Small *Calidris* sandpipers dominated the post-breeding migratory shorebird assemblage, constituting 92.6% of all shorebirds counted at 19 coastal sites (Table 2). Of a sample of small sandpipers that could be identified to species (n = 8,082), 92% were Semipalmated Sandpipers *Calidris pusilla*. *Tringa* sandpipers (Solitary Sandpipers *Tringa solitaria* and Lesser/Greater Yellowlegs *T. flavipes/melanoleuca*; 3.8%) and the Semipalmated Plover *Charadrius semipalmatus* (1.8%) were the only other taxa that exceeded 1% of all counted shorebirds. Of the *Tringa* sandpipers, 96% were Lesser Yellowlegs. Migration of combined shorebird species peaked in the middle of September (Fig. 2).

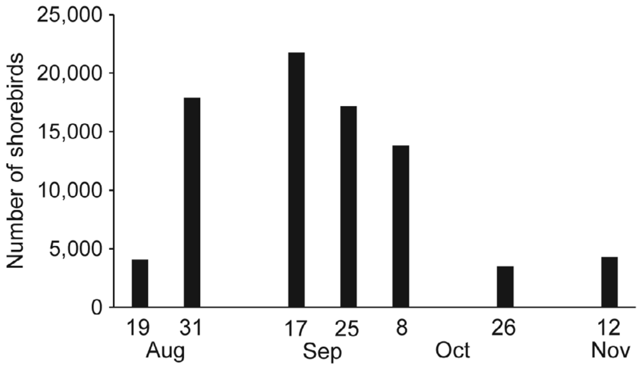

Fig. 2. Estimated numbers of shorebirds at sites with repeated surveys (n = 10) along the coast of Guyana, August–November (mean of 2017, 2018, 2020).

Shocker surveys

During fall of 2020, we observed regular shocking at two sites, 63 Beach and Lusignan. A third site, Ogle Seawall, had much lower levels of shocking in 2020 than in 2017–2018, and we did not conduct interviews of shockers there. All of the 10 shockers interviewed at 63 Beach and Lusignan indicated that they only harvested shorebirds during fall migration. They all also indicated that they used shorebirds for personal consumption. One-third of shockers on 63 Beach indicated they also sold harvested shorebirds directly to local restaurants. Shockers at Lusignan mostly used shorebirds for home consumption or sometimes sold them to other people in the community, occasionally filling individual or family requests. Interviews with shockers at Lusignan and 63 Beach indicated that they did not supply shorebirds to commercial vendors at the Port Mourant market (see below), and shocking occurred throughout the week. All observed shockers were men or boys, and many indicated they were fishermen. Teams of shockers consisted of the wire operator and often 'chasers' who flushed birds toward the shocking wire. Shocking occurred at all tide stages.

Based on observations and interviews with shockers at Lusignan and 63 Beach, we estimated that on any given day in September approximately four groups of shockers ($\lambda_{shockers}$; 90% CI = 2–7) were active at each site, and each group harvested an average of 122 shorebirds (90% CI = 110–134) at Lusignan and 67 shorebirds ($\lambda_{shockers}$; 90% CI = 56–78) at 63 Beach. Between 1 and 30 September 2020, we predicted that 27,991 shorebirds (90% CI = 17,229–38,864; Fig. 3) were harvested at these two sites, with approximately 18,219 birds harvested (90% CI = 11,330–25,651) at Lusignan and 9,711 birds (90% CI = 5,880–14,141) harvested at 63 Beach.

Market surveys

We found shorebirds for sale at weekend markets at Mon Repos and Port Mourant in 2017 and 2018, with up to 1,000 shorebirds being sold on one occasion. In 2020, we focused on the Port Mourant market, where at least 13 species of shorebirds were sold (Table 1). It was not always possible to identify harvested shorebirds to species, but it appeared that Semipalmated and White-rumped Sandpipers *Calidris fuscicollis*, Sanderling *C. alba*, and Semipalmated Plovers were the most abundant shorebirds being harvested and sold. Although large shorebirds were sold in smaller numbers (r_{large} = 9.5%, 90% CI = 8.8–10.3%), vendors frequently sold Lesser Yellowlegs, Greater Yellowlegs, Black-bellied Plovers *Pluvialis squatarola*, and Whimbrels *Numenius phaeopus* (see Table 1 for size designations). Harvested shorebirds were sold either dressed or feathered; sometimes shorebirds on strings were sold alive. We were not able to determine the age of harvested shorebirds. The temporal pattern of sales (Fig. 4a) generally followed the distribution of shorebirds during fall migration (Fig. 2).

From the more intensive market surveys conducted between 29 August and 7 November 2020, we estimated that 8,866 shorebirds (90% CI = 6,328–11,717) were sold at the Port Mourant market (Fig. 4b). On any given day at the market, approximately three vendors (λ_{stalls}; 90% CI = 2–6) sold shorebirds, each selling about 272 shorebirds daily (90% CI = 196–357). Based on our model predictions, we estimated that 840 large shorebird (90% CI = 594–1,115) and 8,023 small shorebirds (90% CI = 5,696–10,527) were sold during this time period. Shorebirds sold at the Port Mourant market were likely coming from the communities of Bush Lot, Rose Hall, or Philippi, where we only rarely observed active shocking and did not obtain any interviews to quantify harvest. Some Port Mourant vendors told us they also sold shorebirds at the Rose Hall market on Mondays.

Interview results from shockers coupled with distances between Port Mourant and the shocking sites of Lusignan (105 km to the northwest) and 63 Beach (40 km to the southeast) indicated that our estimates for the two shocking sites were independent of each other and of shorebirds being sold at the market. Therefore, our combined estimate of harvest by shockers and those sold at the market was 36,990 shorebirds (90% CI = 25,666–47,724).

Both large and small shorebirds were sold in groups, and prices varied among vendors and across the season. Prices for small shorebirds ranged from $7.50 to $20 ($US) per

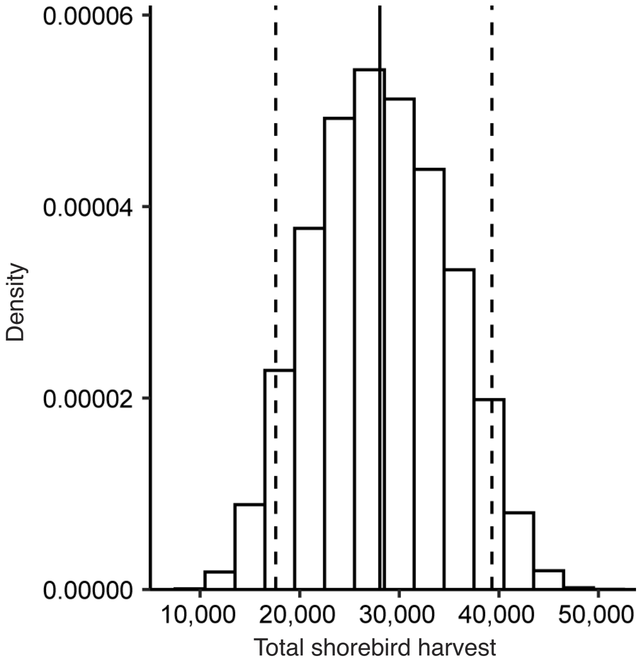

Fig. 3. Posterior distribution of the total shorebirds harvested at 63 Beach and Lusignan in coastal Guyana during September 2020. The solid line indicates the median and the dashed lines represent the 90% CIs.

20–25 individuals. Prices for larger shorebirds ranged from \$10 for 12 individuals to \$20 for four individuals. At an average price of \$0.64 (90% CI = \$0.15–1.58) for each small shorebird and \$2.60 (90% CI = \$0.70–4.62) for each large shorebird, we estimate that shorebird sales at the Port Mourant market generated approximately \$7,928 (90% CI = \$4,888–11,258; Fig. 4c) between 29 August and 7 November 2020. Each vendor generated approximately \$240 (90% CI = \$177–311) per day of sale.

DISCUSSION

The occurrence of shorebird harvesting, using shocking wires and occasionally other methods, at sites we sampled along the coast of eastern Guyana in 2017–2018 likely decreased since 2001–2002 (Bayney & Da Silva 2005). We recorded shocking at 10% of the 60 sites we visited, whereas Bayney (2005) determined that shocking occurred at 40 of 55 sites (73%). Almost all of the sites Bayney (2005) visited east of the Mahaica River (96%, n = 27) had some shocking taking place in the early 2000s. Survey methods differed between the two periods, which makes direct comparison tenuous. Bayney & Da Silva (2005) interviewed at least four people about shocking activity at each site, whereas we made repeated visits, at different times, to the same sites to document shocking activity. Regardless, our informal interviews with coastal residents at sites where shocking previously occurred confirmed that shocking occurrence has decreased, particularly among boys and young men. At a minimum, shocking occurrence has not increased in the last two decades.

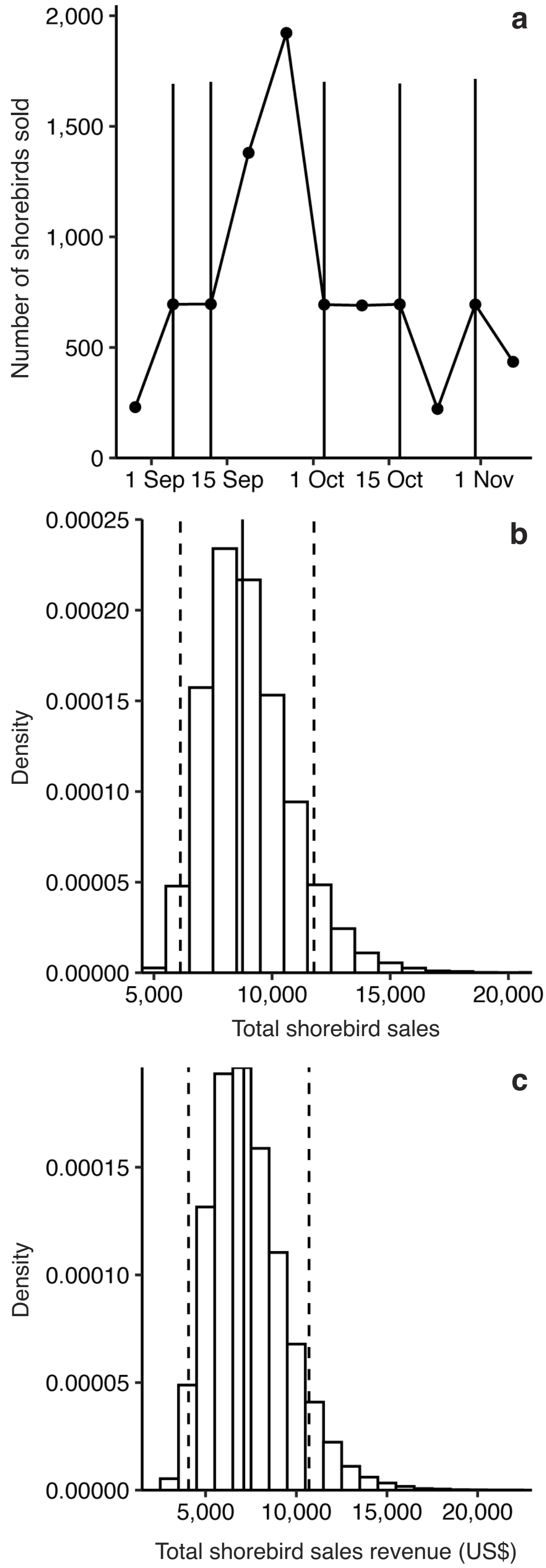

Fig. 4. (a) Observed number of shorebirds for sale at the Port Mourant market in coastal Guyana during August–November 2020, with posterior distributions for estimates of **(b)** total number of shorebirds sold and **(c)** total revenue from shorebird sales during this time-period. In **(a)**, error bars indicate 90% CIs for dates where sales were estimated instead of observed. In **(b)** and **(c)**, solid line indicates the median and dashed lines represent the 90% CIs.

A partial explanation for the observed decline is that the Guyana coastline has changed dramatically in the last decades, due initially to shoreline hardening and mangrove destruction that increased coastal erosion (Anthony & Gratiot 2012). More than half the sites we visited in 2017–2018 were no longer suitable for shorebirds and consequently for their harvest. Socio-economic and cultural factors could have contributed to the decline in harvest occurrence, but those factors have not yet been documented.

Some strings of live birds sold by vendors showed little sign of injury, indicating that they were likely netted at sites where we did not consistently observe harvest activity in 2020. Bayney & Da Silva (2005) found that 9% of the people they interviewed used nets to capture shorebirds. Sale of shorebirds at the Port Mourant market into early November also indicated that harvest occurred at sites where we did not quantify harvest activity, as shocking has ceased by October at the sites we monitored. Harvesters at undocumented sites might consume shorebirds themselves or sell directly to other individuals or restaurants, which would not be included in our market estimates. Because our data from shocker interviews was limited to two sites and was only estimated for September, we interpret our estimate as a minimum harvest of shorebirds along the Guyana coast during post-breeding migration.

Our preliminary estimate of the harvest of 37,000 shorebirds is the first assessment of the harvest of migratory shorebirds for Guyana. Due to survey data constraints, we assumed that daily harvest on the beaches did not vary throughout the week (i.e., that our weekend surveys were representative of weekday shocking) and that there were no seasonal trends in either beach shocking or market sales. Because many shockers were fishermen and may have shocked during poor fishing conditions rather than on a specific day of the week, biases may have been introduced by these assumptions. However, the magnitude of the harvest at our limited number of sites along the coast of Guyana exceeds the combined harvest on all Caribbean islands, where the current combined estimate for Barbados, Guadeloupe, and Martinique ranges from 20,000 to 28,000 shorebirds (AFSI Harvest Working Group 2020). Recent work has indicated that shorebird harvest on Trinidad and Tobago is minimal (Gebauer 2018). The magnitude of harvest in Guyana is second only to Suriname, where at least 73,500–182,100 shorebirds were harvested annually (New Jersey Audubon Society 2017, AFSI Harvest Working Group 2020). Our minimum estimate of an annual harvest of 37,000 individuals therefore indicates that Guyana may account for a substantial portion of the annual harvest mortality of shorebirds in the Caribbean and northern South America.

The preponderance of small *Calidris* sandpipers in the harvest reflects the composition of species in the post-breeding migratory shorebird assemblage along the Guyana coast, as we ascertained through counts. As a method, shocking is indiscriminate relative to shorebird size; for example, Bayney (2005) documented shocking mortality of terns and herons. In contrast, small sandpipers (and *Charadrius* plovers) are less often harvested on Caribbean islands due to differences in harvest regulations and harvest practices, including the use of firearms for harvesting shorebirds (AFSI Harvest Working Group 2020). On Barbados and Guadeloupe, Lesser Yellowlegs constitute about two-thirds of the shorebird harvest (Reed 2012, B. Andres unpubl. data). If the percentage of small shorebirds harvested by shoreline shockers is similar to that of shorebirds sold in markets (90.5%) and there is no species-specific harvest selectivity for small sandpipers, then 82% of all shorebirds harvested in Guyana may be Semipalmated Sandpipers. Our minimum estimate of harvest mortality in Guyana would therefore be approximately 44% of the maximum sustainable mortality for the central and eastern populations of the Semipalmated Sandpiper (Watts *et al.* 2015). This sandpiper is also harvested in substantial numbers in Suriname (Ottema & Spaans 2008, New Jersey Audubon Society 2017), and combined harvest mortality for this species in Guyana and Suriname could be approaching maximum sustainable limits (Watts *et al*. 2015). Although shorebird hunting on the Caribbean islands and along the northern coast of South America might have been sustainable in the past, current harvest levels seem to be incompatible with the current size and trajectory of shorebird populations and likely contribute to observed declines in shorebird abundance in the Atlantic Americas Flyway (e.g., Morrison *et al*. 2012).

In 2020, the average daily wage in Guyana was $25 ($US; *https://www.statista.com/statistics/1070071/gross-national-income-per-capita-guyana/*), and minimum wage jobs provided a daily wage of less than $10 (*https://wageindicator.org/salary/minimum-wage/guyana*). Given the daily market revenue of $240, capturing and selling shorebirds represents a substantial economic opportunity. However, this economic opportunity is limited to the main fall migration period of September through mid-November, which makes shorebird harvest unlikely to be a sole source of income.

The lack of a national policy to regulate the harvest of migratory shorebirds poses a significant challenge for achieving a sustainable shorebird harvest in Guyana and ultimately throughout the Caribbean and northern South America. The high level of harvest we estimated likely underestimates total harvest in the country and elevates the need for policies and tools to implement a sustainable shorebird harvest in Guyana. In sharing our results with the Guyana Wildlife Commission, we hope to support such efforts. An expanded effort is needed to determine how additional netting and shocking sites might be contributing to the overall harvest. Engagement with the local harvest and commercial communities through a thorough study of the social aspects of the harvest, including the economic impact, would contribute to the co-development of culturally acceptable strategies to support sustainable harvest and promote shorebird conservation in Guyana.

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