Production and use of *Sagittaria platyphylla* tubers in a managed impoundment at Yazoo National Wildlife Refuge, Mississippi

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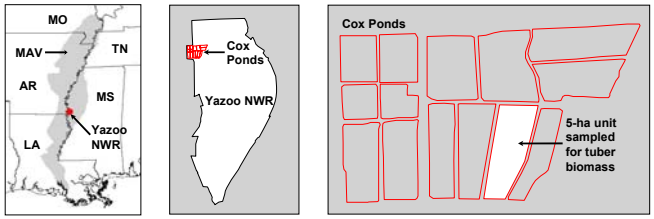
INTRODUCTION

Most research on seasonally flooded impoundments has concentrated on the production and use of moist-soil plant seeds as food for waterfowl. Less effort has been made to understand the potential for tuber production by selected plant species. Tubers produced by *Sagittaria* and certain other species are rich in carbohydrates and important foods of many waterfowl. Studies done in coastal Louisiana indicated tuber production by delta arrowhead (*Sagittaria platyphylla*) can equal or exceed seed production by moist-soil plants. However, the extent to which tuber production in managed impoundments in the Mississippi Alluvial Valley (MAV) reaches levels observed in coastal sites is unknown. Further, there is no information on the use of impoundments managed for delta arrowhead as foraging habitat by waterfowl. Finally, understanding relations between selected variables (e.g. plants, water, soil) and tuber production could provide managers with a simple technique for assessing tuber production, similar to methods currently used for estimating seed production by moist-soil plants.

The objectives of our study were to 1) estimate biomass of delta arrowhead tubers in early and late winter, 2) determine the extent to which waterfowl exploit tubers during winter, and 3) determine the extent to which tuber production can be predicted from measurements of plants, water, and soil.

STUDY AREA

We conducted our study at Yazoo National Wildlife Refuge (NWR) in the MAV of westcentral Mississippi. We sampled a 5-ha impoundment within the Cox Ponds Wetland Complex at Yazoo NWR during the autumn and winter of 2002-2003.

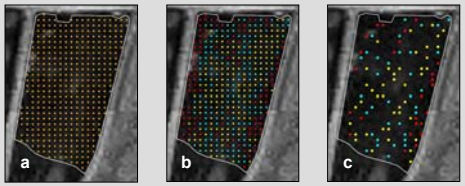


METHODS

OBJECTIVE 1

We used 'double-sampling for stratification' to increase precision of tuber biomass estimates over that attainable with simple random sampling. To apply this sampling design, we first selected a large systematic sample (n_1 = 396) of 1-m^2 plots (Fig. 1a). In September, we located plots using GPS and, based on presence, stem density, and leaf width of delta arrowhead, we assigned each plot to 1 of 3 strata (low, medium, high) differing in expected tuber density. We used data from the first sample of plots (n_1 = 396) to estimate stratum sizes as proportions (Fig. 1b). For the second sample, we selected a random subsample (n = 100) from the first sample and allocated plots proportional to stratum sizes (Fig. 1c). We visited each plot in the second sample twice, once in early winter and once in late winter. During each visit, we collected 10-cm diameter soil cores to a depth of 15 cm. We recovered tubers from soil cores by washing samples with water over a sieve. Tubers retained by the sieve were counted, dried, and weighed to the nearest 0.1 mg.

Figure 1. A large systematic sample of 1-m^2 plots (Fig. 1a; orange dots) was selected for the first sample and assigned to strata (Fig. 1b; red = high, blue = medium, yellow = low) differing in expected tuber density. A second sample of 100 plots (Fig. 1c) was selected by subsampling the first sample and allocating plots to strata proportional to estimated stratum area.



OBJECTIVE 2

In early winter, we placed exclosures (0.25 m^2) at 25 of 100 plots selected for the second sample. After installing exclosures, we collected 4 soil cores immediately adjacent to the plot. In late winter, we returned to each exclosure and collected 4 soil cores on the opposite (i.e. unprotected) side of the plot. Then, after removing the exclosure, we took 4 additional soil cores from the area protected by the exclosure.

OBJECTIVE 3

Before *Sagittaria* senesced, we collected measurements of: 1) stem density, 2) stem length, 3) leaf width, 4) soil penetration depth, and 5) water depth at 30 of 100 plots selected for the second sample. In early winter, after plants senesced, we returned to the 30 plots and collected 4 soil cores from the marked sites where we collected measurements of potential explanatory variables. We developed *a priori* models for predicting tuber biomass from general ecological principles. We expected tuber biomass to increase with increases in stem density, stem length, leaf width, and soil penetration depth, whereas we expected tuber biomass to decrease with increases in water depth. We used Akaike's Information Criterion (AIC_c) to select the best approximating model(s) and make inferences on variables predicting tuber biomass.

RESULTS

OBJECTIVE 1

In early winter, mean biomass of delta arrowhead tubers was 437 ± 46 (SE) kg/ha and ranged from 240 ± 67 kg/ha in the low density stratum to 803 ± 101 kg/ha in the high density stratum. By late winter, mean tuber biomass decreased to 264 ± 46 kg/ha, suggesting tubers were exploited by waterfowl or decomposed during winter.

OBJECTIVE 2

The rate of tuber depletion estimated from soil cores collected inside exclosures was low, and the confidence interval of the estimate included zero (Table 1). Thus, loss of tubers was minimal in the absence of foraging. In contrast, tuber biomass of samples exposed to foraging decreased by 173 kg/ha, and the confidence interval excluded zero (Table 1). Thus, decreases in tuber biomass during winter resulted primarily from foraging by waterfowl.

Differences in mean tuber biomass among strata were similar in early and late winter (Fig. 2). Thus, waterfowl did not exploit tubers in the positively density-dependent manner predicted by some models of patch use. Lack of experience or inability to obtain information about variation in tuber density may have caused waterfowl to exploit tubers with a relatively inefficient fixed-time strategy.

OBJECTIVE 3

Among 21 candidates, the best model for predicting tuber biomass was one in which tuber biomass was directly proportional to stem density (Table 2). Stem density clearly was an important predictor of tuber biomass because it was included in each of the 8 most plausible models ($AIC_c \leq 4$; Table 2).

Measuring stem density provides a simple method for managers in the MAV to estimate production of delta arrowhead tubers. Means predicted by the best model had coefficients of variation of 0.15, and confidence intervals for hypothetical means predicted at 100 and 200 stems/0.25 m^2 did not overlap (270 kg/ha [192, 349] vs. 541 kg/ha [383, 698]).

Table 1. Rates of tuber depletion (kg/ha) inside and outside exclosures at Yazoo NWR, Mississippi in winter 2002-2003.

Location	n	$\bar{x}$	SE	95% LCL	95% UCL
Inside (no feeding)	25	25	65	-105	155
Outside (feeding)	100	173	62	49	298

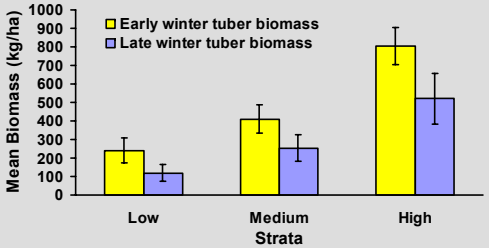


Figure 2. Mean tuber biomass (kg/ha) in 3 sampling strata in early and late winter 2002-2003 at Yazoo NWR, Mississippi. Error bars represent ± 1 SE.

Table 2. The most plausible models (ranked by AIC_c) for predicting tuber biomass (kg/ha) in early winter 2002 at Yazoo NWR, Mississippi.

Model	K	AIC_c	Δ_i	w_i
stems	2	347.85	0.00	0.28
stems + soil	3	349.20	1.35	0.14
Intercept + stems + soil	4	349.67	1.82	0.11
stems + water	3	350.06	2.21	0.09
Intercept + stems	3	350.11	2.25	0.09
stems + width + soil	4	351.04	3.19	0.06
Intercept + stems + width + soil	5	351.20	3.35	0.05
stems + width + water	4	351.24	3.39	0.05

CONCLUSIONS

Mean biomass of delta arrowhead tubers in an impoundment at Yazoo NWR was less than previous estimates from the Gulf Coast region. In coastal Louisiana, production of delta arrowhead tubers averaged >1,000 kg/ha. Tuber production in coastal Louisiana may have been greater than at Yazoo NWR because of longer growing seasons, greater nutrient subsidies, and more favorable soils. However, biomass of delta arrowhead tubers at Yazoo NWR was similar to and competitive with production of moist-soil seeds in managed impoundments.

Waterfowl were primarily responsible for decreases in tuber biomass during winter at Yazoo NWR, but exploitation of tubers was independent of available biomass. The pattern of exploitation we observed suggested waterfowl used a fixed-time exploitation strategy and may have lacked information necessary to employ a more efficient density-dependent strategy. In contrast, studies of rice fields in the MAV suggest ducks are capable of exploiting rice seeds in a density-dependent manner.

Stem density was the best variable for predicting tuber biomass, and measuring stem density can provide a simple method for estimating tuber production. Wetland managers in the MAV can estimate production of delta arrowhead tubers in a managed impoundment by multiplying 2.704 times the number of stems/0.25 m^2.

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