mallard *Anas platyrhynchos platyrhynchos* and their relationship to environmental changes. J. Zool. (London) 183:377–395.
RAVELING, D. G. 1968. Weights of *Branta canadensis interior* during winter. J. Wildl. Manage. 32:412–414.
ROGERS, D. T., AND E. P. ODUM. 1964. Effects of age, sex, and level of fat deposition on major body components of some wood warblers. Auk 81:505–513.
WISHART, R. A. 1979. Indices of structural size and condition of American wigeon (*Anas americana*). Can. J. Zool. 57:2369–2374.
WOODALL, P. F. 1978. Omental fat: a condition index for redbilled teal. J. Wildl. Manage. 42:188–190.

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GUT MORPHOLOGY OF GADWALLS IN LOUISIANA IN WINTER

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Gut size in gallinaceous birds and waterfowl is influenced by diet quality (Moss 1972, Miller 1975) and quantity (Ankney 1977). Moss (1972) suggested that the gut, especially the ceca, could be a useful index of food habits in gallinaceous birds. Miller (1974) found that captive gadwalls (*Anas strepera*) and other species of *Anas* exhibited rapid accomodation of the gut to changes in diet quality. As a consequence, he suggested that gut measurements were not useful in indexing food habits of ducks due to potential daily variability in diet. Paulus (1980) reported that during the nonhunting season, wintering gadwalls usually remained in specific areas and fed on only 1 or 2 different food items for periods of several days or more. The objectives of this study were to examine the adaptability of the gut to diets of varying quality, determine if gut morphology measurements could serve as an index to food habits, and measure seasonal changes in gut measurements in gadwalls in winter.

STUDY AREA AND METHODS

This study was conducted in southwestern coastal Louisiana on Rockefeller and Marsh Island State Wildlife refuges, Sabine National Wildlife Refuge (NWR), and on privately owned lands within 13 km of the western and northern boundaries of Rockefeller Refuge. Detailed descriptions of the study areas were presented by Paulus (1982).

Eighty-two adult gadwalls were collected by shooting on Rockefeller and Marsh Island refuges from November through March, 1977–78. Digestive organs from an additional 112 gadwalls were obtained from hunters on Sabine NWR and marshes adjacent to Rockefeller Refuge, from November through early January, 1977–78.

Digestive organs from hunter-killed birds were removed intact within 1–6 hours after birds were killed and were frozen for later analysis. The carcasses, including digestive organs, of gadwalls collected on Rockefeller and Marsh Island refuges, were frozen within 3 hours after collection. Carcasses were thawed and digestive organs removed intact for analysis. Analysis was limited only to organs not damaged by collection procedures.

Digestive organs of all gadwalls were disjoined and the attached mesenteric fat was removed. Both ceca were disjoined and measured as a unit, including the short section of intestine between them. Gizzards were weighed with and without

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Table 1. Protein, fiber, and gross energy content of selected gadwall foods collected in southwest Louisiana during winter 1977–78.[a]

		Protein (%)[b]		Fiber (%)		Gross energy (kcal/g)	
Foods	N	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Ruppia maritima	7	16.9	1.2	41.1	0.9	3.58	0.65
Eleocharis parvula	11	12.1	1.6	41.9	5.2	3.44	0.37
Myriophyllum spicatum	6	16.9	2.1	50.1	3.9	3.20	0.24
Algae	4	14.4	0.5	17.8	0.7	3.22	0.98

[a] Determined from above-ground portion of plant, except for *Eleocharis parvula*, in which rhizomes were included in analysis.
[b] All percentages based on dry weight.

contents and contents were preserved in 80% ethyl alcohol for food habits analysis (Paulus 1982). Length, empty, net (full minus empty) wet weight, and net volume (Miller 1975) were recorded for intestines and ceca. Volume was measured to the nearest 1.0 ml for small intestines and 0.1 ml for the ceca and large intestine in a graduated cylinder. Weights were determined to the nearest 0.01 g on a Mettler balance and lengths to the nearest 1.0 mm with care taken not to noticeably stretch or compress organs.

Diets were determined from esophageal and gizzard contents (Paulus 1982) and these data were used to test for relationships between gut size and foods consumed. As gadwall diets at time of collection often consisted of several food items (Paulus 1982), the weight given to each food item in influencing gut morphology was proportioned to percent volumetric contribution of each food item in the diet using a SPSS (Nie et al. 1975: 129) weighting procedure. Thus, gut measurements were analyzed so that foods comprising the bulk of the diet were considered having more influence on gut size than foods consumed in lesser quantities. Statistical analysis reflected this weighting procedure.

Monthly comparisions of gut morphology measurements and comparisons among foods for each sex were examined by ANOVA and Scheffe's tests (Snedecor and Cochran 1976:271), whereas Mann-Whitney U tests (Siegel 1956:116–127) were used to determine differences in gut morphology between sexes for each food item. For comparisons between sexes, gut measurements were recalculated as percent of total body weight to reduce the effect of differences in organ size related to body size (Miller 1974). Due to the infrequent occurrence of several foods, only gut morphology measurements of gadwalls consuming common widgeonweed (*Ruppia maritima*), dwarf spikerush (*Eleocharis parvula*), algae, baby pondweed (*Potamogeton pusillus*), and spiked watermilfoil (*Myriophyllum spicatum*), were used for food comparisons.

Aquatic vascular plants and algae were identified from Fassett (1940), Smith (1950), and Beal (1977). Methods of analysis of foods (except pondweed) for crude protein, fiber, and gross energy content were reported by Paulus (1982) (Table 1).

RESULTS

Most gut morphology measurements increased from November through February and then declined in March (Table 2). However, few differences ($P < 0.05$) were found in comparisons between months. For males, measurements of the ceca were greater ($P < 0.01$) in January than November and empty weight of the gizzard was greater ($P < 0.05$) in Febru-

Table 2. Gut morphology measurements of adult gadwalls collected in southwestern Louisiana during winter 1977–78.

Organ measurement	Nov			Dec			Jan			Feb			Mar		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Gizzard															
Empty weight, g															
Male	36	47.6	7.3	41	47.2	6.0	20	47.8	9.5	9	54.8	9.6A[a]	12	43.7	8.8A
Female	30	43.3	6.0	25	43.3	5.7	8	47.2	10.5	7	52.8	10.4	8	42.2	9.9
Small intestine															
Length, cm															
Male	29	220.5	20.4	23	227.6	27.2	12	233.2	34.6	9	241.7	15.8	12	242.5	13.6
Female	25	217.5	19.0	20	239.0	30.4	6	226.1	23.1	7	237.5	12.0	8	226.1	18.6
Empty weight, g															
Male	29	25.5	5.6	23	27.7	6.2	12	26.9	6.2	9	23.6	7.7	12	22.4	9.5
Female	23	23.9	5.3	20	25.7	5.5	6	23.2	5.6	7	22.5	3.9	8	21.5	3.5
Net volume, ml															
Male	27	116	56	23	145	74	12	141	89	9	160	44	12	164	30
Female	23	126	49	17	126	72	6	132	85	7	177	27	8	148	27
Large intestine															
Length, cm															
Male	29	10.4	1.6	23	11.4	1.6	12	10.8	1.4	9	11.3	8.8	12	10.9	1.3
Female	25	10.5	1.3	21	10.8	1.6	6	10.6	1.8	7	11.7	7.8	8	11.0	2.6
Empty weight, g															
Male	29	3.3	0.6	23	3.7	0.8	12	3.7	1.0	9	3.8	0.8	12	3.9	0.6
Female	26	3.2	0.7A	21	3.2	0.6	6	3.4	0.5	7	4.2	0.8A	8	4.0	1.0
Net volume, ml															
Male	26	5.1	2.9	21	6.7	3.4	12	7.0	5.2	8	8.7	4.5	11	7.1	3.3
Female	24	4.9	2.4	19	6.0	5.1	6	5.8	5.6	7	8.7	3.0	8	6.0	3.1
Ceca															
Length, cm															
Male	29	54.6	6.8AB	23	59.8	8.1	12	64.2	7.4B	9	63.4	6.5A	12	57.2	6.5
Female	26	53.8	5.9	21	57.7	7.9	6	61.1	6.0	7	57.7	4.3	8	52.3	4.8
Empty weight, g															
Male	29	4.5	0.8B	23	5.2	1.4	12	6.2	1.4B	9	5.5	1.2	12	5.1	0.8
Female	25	4.3	0.9A	21	4.7	1.0	6	5.2	0.7	7	5.6	0.5A	8	4.6	0.8
Net volume, ml															
Male	29	18.2	12.1B	23	28.3	14.6	12	43.1	25.4B	8	39.0	14.9	12	36.2	9.9
Female	25	21.4	9.7	19	24.8	13.5	6	24.6	19.3	7	37.4	12.0	8	32.4	8.8

[a] Means sharing letter A differ at $P < 0.05$; B differ at $P < 0.01$.

Table 3. Gut morphology measurements and measurements as percent of total body weight in relation to foods consumed by adult gadwalls in southwestern Louisiana during winter 1977–78.

Organ measurement	*Ruppia maritima*			*Eleocharis parvula*			Algae			*Potamogeton pusillus*			*Myriophyllum spicatum*		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Gizzard															
Empty weight, g															
Male	14	48.6	7.2	18	50.8	8.6	26	46.8	8.4	6	52.9	8.0	4	48.1	2.9
% body wt		5.5	0.8		5.5	0.7[a]		5.0	0.8		5.5	0.6		5.1	0.4
Female	12	44.1	7.6	9	51.3	9.0	20	42.0	7.2	3	45.4	2.7	3	41.9	7.7
% body wt		6.3	0.7		6.3	0.7[a]		5.0	0.7		5.3	0.1		5.6	1.0
Small intestine															
Length, cm															
Male	13	226.1	24.1	18	231.5	22.3A[b]	26	236.8	21.4A	6	210.9	19.9B	4	261.6	6.2B
% body wt		26.0	2.5		25.3	2.9		25.2	3.1		21.9	1.2		27.9	1.5[a]
Female	12	223.1	15.3	9	222.6	22.0	20	233.3	27.0	3	224.6	30.5	2	251.1	45.8
% body wt		28.5	2.9		27.6	1.8		28.1	3.1		25.1	4.2		34.2	0.1[a]
Empty weight, g															
Male	13	26.0	7.4	18	25.7	7.5	26	25.5	8.2	6	26.6	4.4	4	27.4	5.7
% body wt		3.0	0.8		2.8	0.8		2.7	1.0		2.8	0.5		2.9	0.5
Female	11	24.4	5.0	9	24.8	4.7	20	22.9	4.5	2	29.9	7.7	3	23.9	9.1
% body wt		3.0	0.7		3.1	0.7		3.4	0.9		3.4	0.9		3.1	0.8
Net volume, ml															
Male	13	137	67C	18	145	72C	26	137	62	5	82	53A	4	253	42A
% body wt		16	8		16	7		14	6		8	5		27	4
Female	10	152	55	9	139	58	19	148	54	2	117	111	2	197	62
% body wt		19	7		17	7		18	6		13	13		27	4
Large intestine															
Length, cm															
Male	13	10.0	1.4AC	18	11.2	0.9D	26	10.9	1.3CD	6	9.8	1.4	4	12.5	1.6A
% body wt		1.2	0.2		1.2	0.1		1.2	0.2[a]		1.0	0.2		1.3	0.2
Female	12	10.2	1.6	9	10.9	1.2	20	10.8	1.7	3	10.6	1.7	3	11.6	0.6
% body wt		1.3	0.2		1.4	0.1		1.3	0.2[a]		1.1	0.1		1.6	0.2
Empty weight, g															
Male	13	3.2	0.6	18	3.6	0.5	26	3.9	0.7	6	3.3	1.0	4	3.3	1.0
% body wt		0.4	0.1		0.4	0.1		0.4	0.1		0.3	0.1		0.3	0.1
Female	12	3.3	0.6	9	3.5	0.9	20	3.6	0.8	3	3.0	0.6	3	2.9	0.5
% body wt		0.4	0.1		0.4	0.1		0.4	0.1		0.3	0.0		0.4	0.0

Table 3. Continued.

Organ measurement	*Ruppia maritima*			*Eleocharis parvula*			Algae			*Potamogeton pusillus*			*Myriophyllum spicatum*		
	N	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*	$\bar{x}$	SD
Net volume, ml															
Male	12	5.5	3.1	18	7.4	3.4	23	6.3	4.1	6	4.9	3.6	3	8.1	2.0
% body wt		0.6	0.4		0.8	0.4		0.7	0.4		0.5	0.4		0.9	0.3
Female	12	5.1	3.3	9	6.8	3.9	19	6.7	5.3	3	5.8	2.8	2	7.9	1.5
% body wt		0.7	0.4		0.8	0.4		0.8	0.6		0.5	0.3		1.1	0.4
Ceca															
Length, cm															
Male	13	57.5	6.2	18	57.2	7.9	26	60.6	7.9	6	56.0	12.7	4	62.7	6.1
% body wt		6.6	0.8		6.2	0.9		6.5	1.1		5.8	1.2		6.7	0.8
Female	12	53.8	5.1	9	56.1	7.0	20	58.1	7.4	3	59.2	5.9	3	60.4	10.2
% body wt		6.7	0.8		7.0	0.8		7.0	0.9		6.5	0.9		8.1	1.4
Empty weight, g															
Male	13	4.9	0.9	18	5.1	1.0	26	5.5	1.3	6	5.2	2.5	4	4.9	0.5
% body wt		0.6	0.1		0.5	0.1		0.6	0.2		0.5	0.2		0.5	0.0
Female	11	4.5	0.9	9	4.5	0.9	20	4.9	1.1	3	5.0	0.5	3	4.0	1.2
% body wt		0.5	0.1		0.6	0.1		0.6	0.1		0.5	0.0		0.5	0.1
Net volume, ml															
Male	13	23.2	14.2	18	26.4	13.8E	26	34.1	18.3E	6	16.3	23.9	4	38.8	13.8
% body wt		2.7	1.6		2.8	1.5		3.6	1.9		1.6	2.2		4.2	1.7
Female	10	23.4	11.9	9	30.0	17.3	20	32.8	12.9	3	12.4	7.5	2	30.0	6.7
% body wt		2.7	1.7		3.6	2.0		4.0	1.5		1.4	1.2		4.1	0.2

[a] Difference ($P < 0.05$) between sexes, same food.
[b] Means sharing letter A or B differ at $P < 0.05$, C or D differ at $P < 0.01$, or E differ at $P < 0.001$, among foods, same sex.

ary than March. Empty weight of the large intestine and ceca were greater ($P < 0.05$) in February than November for females. Empty weight of the gut declined 7% in males and 3% in females from November through March, despite an increase in total body weight of 8 and 6% in males and females, respectively (Paulus 1980).

Significant differences in gut morphology among foods of males occurred in only 4 of 10 measurements (Table 3). However, the mean in 7 of 10 measurements was largest in males consuming spiked watermilfoil and was smallest in 6 of 10 measurements when pondweed was consumed. None of these measurements varied significantly among foods for females; the mean of 5 measurements was largest and 2 were smallest when females consumed spiked watermilfoil and pondweed, respectively.

Gut morphology of males was larger in most comparisions between sexes for each food involving untransformed measurements (Table 3). However, when gut measurements were recalculated as percentage of total body weight, few significant differences were found between sexes consuming the same food (Table 3).

DISCUSSION

Gadwall food habits reflected nutritive value and quantity with preference of foods and diets varying seasonally (Paulus 1982). Since the primary metabolic requirement of wintering gadwalls was to develop sufficient metabolic reserves for winter survival and spring migration, variability in intestinal morphology was probably an adaptation that improved energy absorption from foods of variable quality.

Consumption of lower quality diets may necessitate greater time spent feeding in waterfowl and gallinaceous birds (Pendergast and Boag 1971, Miller 1975, Dvorak and Bray 1978). Ankney (1977) related gut length to quantities of food ingested by breeding snow geese (*Chen caerulescens*) and noted a reduction in gizzard and large intestine size during periods of limited food intake. Miller (1975) noted a correlation between crude fiber content of diets and gut enlargement in mallards (*Anas platyrhynchos*).

Several gut morphology measurements were significantly greater in midwinter than November. Although consumption rates of foods were not determined in this study, mean time spent feeding in winter by gadwalls increased from 44.3% in October to 64.8% in February, in part due to a decline in quality and quantity of foods used by gadwalls (Paulus 1980, 1982). In mid-February, gadwalls shifted to diets consisting predominately of algae (Paulus 1982). Although time spent feeding increased to 70.5% in March (Paulus 1980), declines in most gut measurements from February to March probably reflected change in diet and indicated that rate of feeding activity does not entirely account for changes in gut size.

Comparison of gut morphology measurements among foods for each sex indicated that the gut was usually largest when birds consumed spiked watermilfoil and smallest in those using pondweed. Analysis of foods (excluding pondweed) for crude fiber, gross energy, and protein content showed that watermilfoil was highest in fiber and lowest in gross energy content of the foods analyzed. Although algae was of similar gross energy content as watermilfoil, it contained less crude fiber. Smaller gut size associated with algae probably indicated that crude fiber in the diet was more important than gross energy in modifying gut morphology.

Miller (1974) found that gut size in mallards was greater in females than males on similar diets and suggested that females may have a greater adaptibility to diet. In wintering gadwalls, gut morphology measurements were similar between sexes, suggesting a similar gut response to diet.

It was apparent that the gut was responsive to diet and, in most instances, gut measurements were related to diet quality. However, variability in response between sexes, absence of several specific measurements indicative of diet quality for both sexes, and a limited understanding of the effect of consumption rate on gut size, discourage using gut morphology as an indicator of food habits of wintering gadwalls, at this time.

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LITERATURE CITED

ANKNEY, C. D. 1977. Feeding and digestive organ size in breeding lesser snow geese. Auk 94:275–282.

BEAL, E. O. 1977. A manual of marsh and aquatic vascular plants of North Carolina. North Carolina Agric. Exp. Stn. Tech. Bull. 247. 298pp.

DVORAK, R. A., AND D. J. BRAY. 1978. Influence of cellulose and ambient temperature on feed intake and growth of chicks. Poultry Sci. 57:1351–1354.

FASSETT, N. C. 1940. A manual of aquatic plants. McGraw-Hill Book Co., New York, N.Y. 382pp.

MILLER, M. R. 1974. Digestive capabilities, gut morphology, and cecal fermentation in wild waterfowl (genus *Anas*) fed various diets. M.S. Thesis. Univ. California, Davis. 87pp.

———. 1975. Gut morphology of mallards in relation to diet quality. J. Wildl. Manage. 39:168–173.

MOSS, R. 1972. Effects of captivity on gut lengths in red grouse. J. Wildl. Manage. 36:99–104.

NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BENT. 1975. Statistical package for the social sciences. McGraw-Hill Book Co., New York, N.Y. 675pp.

PAULUS, S. L. 1980. The winter ecology of the gadwall in Louisiana. M.S. Thesis. Univ. North Dakota, Grand Forks. 357pp.

———. 1982. Feeding ecology of gadwalls in Louisiana in winter. J. Wildl. Manage. 46:71–79.

PENDERGAST, B. A., AND D. A. BOAG. 1971. Nutritional aspects of the diet of spruce grouse in central Alberta. Condor 73:437–443.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York, N.Y. 719pp.

SMITH, G. M. 1950. The fresh-water algae of the United States. McGraw-Hill Book Co., New York, N.Y. 719pp.

SNEDECOR, G. W., AND W. G. COCHRAN. 1976. Statistical methods. Iowa State College Press, Ames. 593pp.

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