BREEDING BIOLOGY AND FOOD HABITS OF THE MUSK DUCK (BIZIURA LOBATA)

BY

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I. INTRODUCTION

The objective of this study was to investigate the breeding biology and food habits of the Australian musk duck (*Biziura lobata*) to provide information necessary in planning programs of conservation or control, should the need for these arise.

The musk duck was first discovered in 1791 near King George's Sound in Western Australia by Archibald Menzies, on a voyage from England to what is now Vancouver, Canada (Whittell, 1954). Since that time little planned research on the species has been published, and today much of its ecology remains unknown. Undoubtedly a major reason for this is that the musk duck has virtually no economic or recreational value. It is loath to fly during daylight hours and is therefore of little interest to shooters. Also, many hunters believe (erroneously) that the musky odour, from which the species gets its common name, renders the meat unfit for consumption.

Although the musk duck has little economic importance today, during the 1930's it was utilized for food in the Mandurah district of Western Australia (Serventy, 1938); and in the early

1900's inhabitants of Flinders Island in Bass Strait collected lobes from male musk ducks, dried them, and placed them among their stored clothing. The odour of the dried lobe was considered pleasing and served as a perfume and a fumigant (Alec Ross, personal communication).

While the musk duck has been little studied, its size, possession of a submandibular lobe and musky odour, and atypical breeding display characterize it as certainly the most unique and interesting member of the Oxyurini, and perhaps the most unique species in the Anatidae.

II. THE STUDY AREA

Barrenbox Swamp, approximately 8,000 acres in size, is located 16 miles north-west of Griffith, New South Wales, in the Murrumbidgee Irrigation Area.

The swamp is presently used as a storage basin for excess irrigation water, which may later be utilized during dry periods. Consequently, water levels are usually highest in winter and lowest in summer, and such fluctuations may exceed those normally caused by rainfall. The maximum change in water level for the period from September 1962 through October 1964 was 3.3 feet. A reduction in water level of 2.1 feet in the summer of 1962-63 resulted in the water's edge receding approximately 100-300 feet. This change caused a negligible reduction in area of the swamp and had no overall effect on the swamp vegetation except in areas exposed by the receding water.

Emersed vegetation in the interior of the swamp consists almost exclusively of cumbungi (*Typha angustifolia*). Other emergents, occurring in shallow water around the edges, include *Polygonum*, *Ludwigia*, *Juncus*, and *Scirpus*. Large numbers of dead trees (*Eucalyptus* sp.) are also present. Submersed vegetation includes *Potamogeton*, *Vallisneria*, *Chara*, *Nitella* and *Myriophyllum*.

Much of the land immediately adjacent to the swamp is used for grazing of sheep and cattle. Surrounding agricultural lands produce rice and various other grain crops which are utilized heavily at times by resident and visitant waterfowl populations (excluding the musk duck).

III. BREEDING

(a) Methods

This investigation was based on a shot sample of musk ducks collected monthly from September 1962 through October 1964, and on field observations made during this same period. A nesting study was not undertaken because of a lack of available manpower and the secretive habits of the nesting female. The shot-sample goal was ten adult males and ten adult females per month, plus any juveniles that could be collected. Numbers of adults in each sample varied due to a combination of limited field time and difficulty in locating birds during some seasons.

Each day's collection was processed in the field. Standard measurements and weight of each bird and presence or absence of the characteristic musky odour were recorded. Testes were removed from males, length and breadth of each recorded, and liquid-displacement volumes taken. In instances where testis volumes were not recorded, these were later computed from the measurements, using a modification of the formula for the volume of an ellipse ($\frac{4}{3}\ \pi\ \underline{AB}^2$, where $\underline{A}$ = radius of the long axis, $\underline{B}$ = radius of the short axis). A factor of 1.1 was used in the formula instead of $\frac{4}{3}$, as it gave a closer approximation of liquid-displacement volumes recorded for other testes of similar size. Testes of each bird were then preserved, one in Bouin's fixative and one in formol calcium, for later sectioning. The lobe of each adult male was also measured; first from the base of the lower mandible downward to the outer extremity of the lobe, and second at right angles to the first and approximately parallel to the lower mandible. From females, diameters of the three largest oocytes in the ovary and the condition of the oviduct were recorded.

Testis material was prepared for histological analysis at the CSIRO Wildlife Division laboratory in Canberra. Testes preserved in Bouin's fixative were embedded in paraffin, sectioned at 8 μ and 10 μ thicknesses, stained with Ehrlich's hematoxylin and counterstained with eosin. Testes fixed in formol calcium were sectioned on a freezing microtome at 20 μ thicknesses, stained with

Ehrlich's hematoxylin and counterstained with Sudan IV for lipid demonstration. Stage of spermatogenesis, tubule diameter (5 measurements), and a subjective appraisal of quantity of lipid material present in tubules and interstitia were recorded for testis sections from each bird.

(b) Results and Discussion

The breeding season of the musk duck reportedly extends from July or August through December or January (Campbell, 1901; Phillips, 1926; Condon, 1939; Ford, 1958; Delacour, 1959). Breeding biology in this study focussed primarily on sexual cycles, with observational data on breeding behaviour and broods.

(i) Testis Cycle and Breeding Behaviour.—The breeding season was well under way when the study began in September 1962. Mean testis volumes of adult male samples decreased to a low in December, January, and February and started to increase again in March (Fig. 1). Peak months in the 1963 testis cycle were June through October. Greatest testis volumes may have occurred in September, but no sample was collected that month. In 1964, testis volumes began increasing in March and were still rising when the study was terminated in October. Breeding males were collected in every month of the year except December, January, and February in 1962-63 and February in 1964. No collection was made in January 1964.

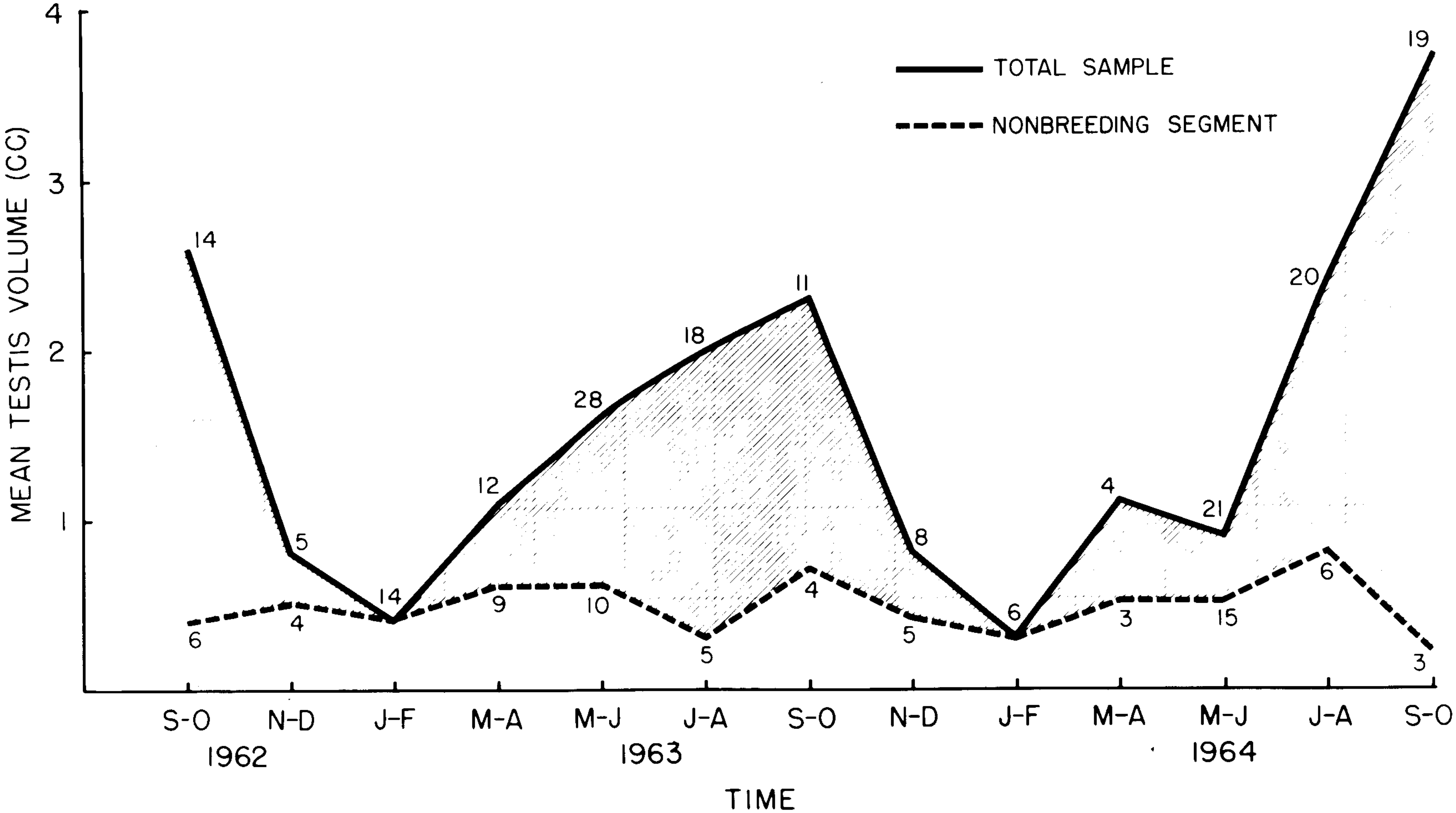

Figure 1. — Mean testis volumes of adult male musk ducks collected at Barrenbox Swamp from September 1962 through October 1964. Numbers indicate sample size. Shaded areas represent differences in mean testis volume caused by breeding males.

Males with large numbers of spermatozoa in their testes were classed as breeding birds; those with none or only a few scattered spermatozoa were classed as non-breeding birds. Mean testis volumes (and 99% confidence limits) were 3.00 $\pm$ 0.43 cc for 89 breeding males and 0.48 $\pm$ 0.07 cc for 90 non-breeding males. The presence of breeding males in the population throughout much of the year apparently also occurs in semi-wild (non-migratory) populations of North American mallards (*Anas platyrhynchos*), in which breeding display and attempted copulation have been observed in fall and winter (C. Southwick, unpubl.) This behaviour (occasionally leading to copulation in fall) has also been observed in North American black ducks (*Anas rubripes*) (Trautman, 1947). Fluctuations in mean testis volumes correlated inversely (P < .01) with temperature for both years of the study (Fig. 2). They did not correlate with day-length cycles or with water-level fluctuations at Barrenbox Swamp.

Oscillations in testis volume generally reflected changes within the testis. Variations in mean tubule diameters of monthly samples coincided closely with changes in testis volume. Mean diameters (and 99% C.L.) of tubules in the testes were 219 $\pm$ 14 μ for 80 breeding males and 104 $\pm$ 8 μ for 89 non-breeding males.

Observations on breeding behaviour support conclusions on the duration of the breeding season suggested by the data on testis volumes. They further suggest that breeding males may have

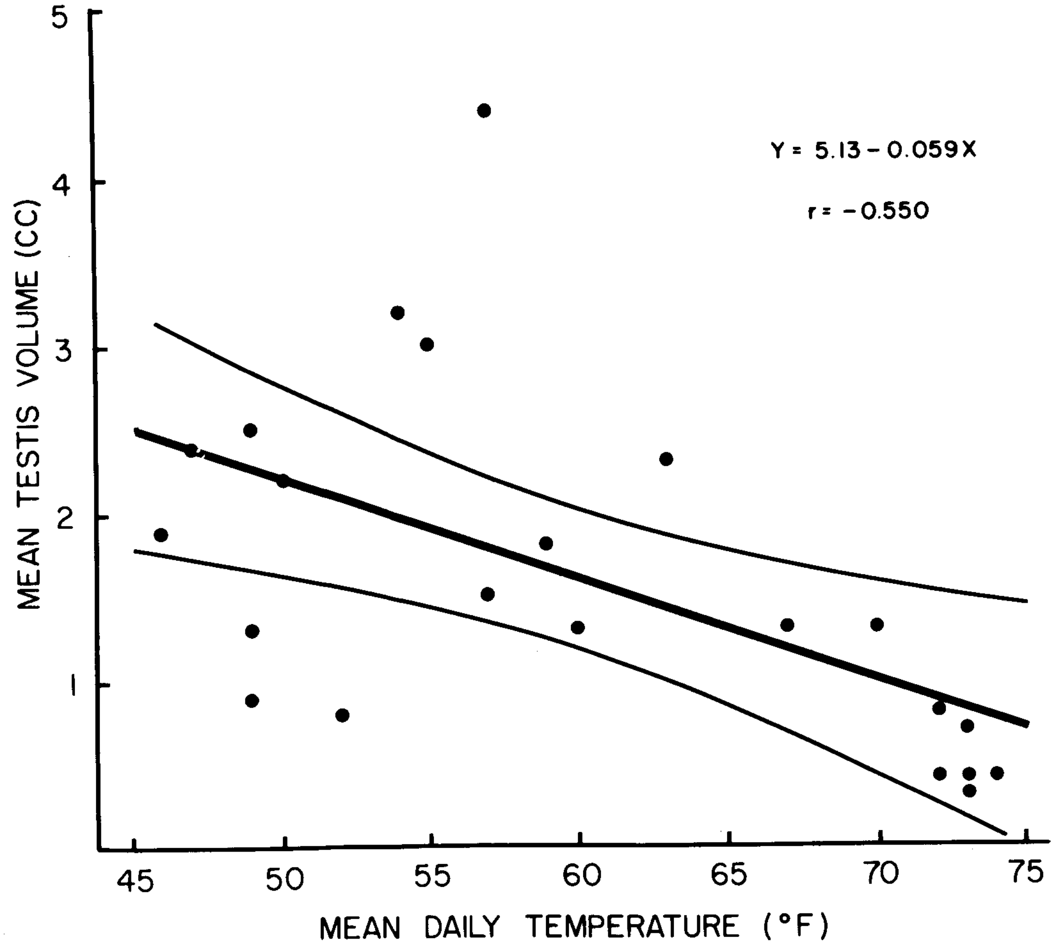

Figure 2. — Correlation of monthly testis volume with monthly temperature for adult male musk ducks collected at Barrenbox Swamp, 1962-64.

been present in the population during periods when none occurred in the samples collected. In January 1963, although I collected no breeding males, I frequently observed displays during the 19 days I was at the swamp. In February, I observed displays on two occasions. No display observations were recorded in March. Breeding activity began again during the latter part of April and increased steadily through June, after which I returned to the United States for a year. In 1964, display activity was well advanced when I returned to the study area in June and increased gradually throughout the rest of the winter and spring until the study was terminated in October.

The environmental influence on timing of breeding in birds has been a subject of interest and controversy for many years. The landmark experiments of Rowan (1929) proved that for some species the basic stimulus for breeding is increasing day length. The works of Bissonnette (1931) and Wolfson (1954, 1959) supported Rowan's findings. However, as Marshall (1959) has pointed out, a strict adherence to any one environmental factor as cyclically constant as photoperiod would be disadvantageous to many species (e.g., those inhabiting desert areas). The importance of other aspects of the environment cannot be discounted. There is evidence that temperature acts to modify responses to the basic stimulus of photoperiod (Marshall, 1949; Kluijver, 1951; Engels and Jenner, 1956). Blanchard (1941) concluded that " ... temperature is the most important single factor lying at the ultimate source of annual variations of the gonad cycle" of the Nuttall white-crowned sparrow (Zonotrichia leucophrys nuttalli) on the Pacific seaboard of the United States.

The breeding season of many species of Australian birds is controlled by rainfall and flooding (Serventy and Marshall, 1957; Frith, 1959), and a number of these species demonstrate a remarkably rapid response to these factors. Since the musk duck usually inhabits only permanent water areas and is principally an animal feeder, available water and food are not limiting factors, and its breeding cycle is not (at least at Barrenbox Swamp) affected by increasing water levels. Confidence limits on musk duck monthly mean testis volumes were broad in most cases, due to a combination of small sample size and within-sample variation. Few significant differences between the means existed, therefore, except in extreme months. The testis cycle is several months out of phase with cycles of temperature and day length (Fig. 3). Although the testis cycle correlated inversely (r = -0.550) with temperature, a slight shifting of testis volume means within their respective confidence limits (which might well have occurred with larger monthly samples) could cause the testis cycle to correlate better with day length than with temperature. However, even though the testis volume data are poor, they are nevertheless an index to what is certainly a definite breeding season. Since other obvious

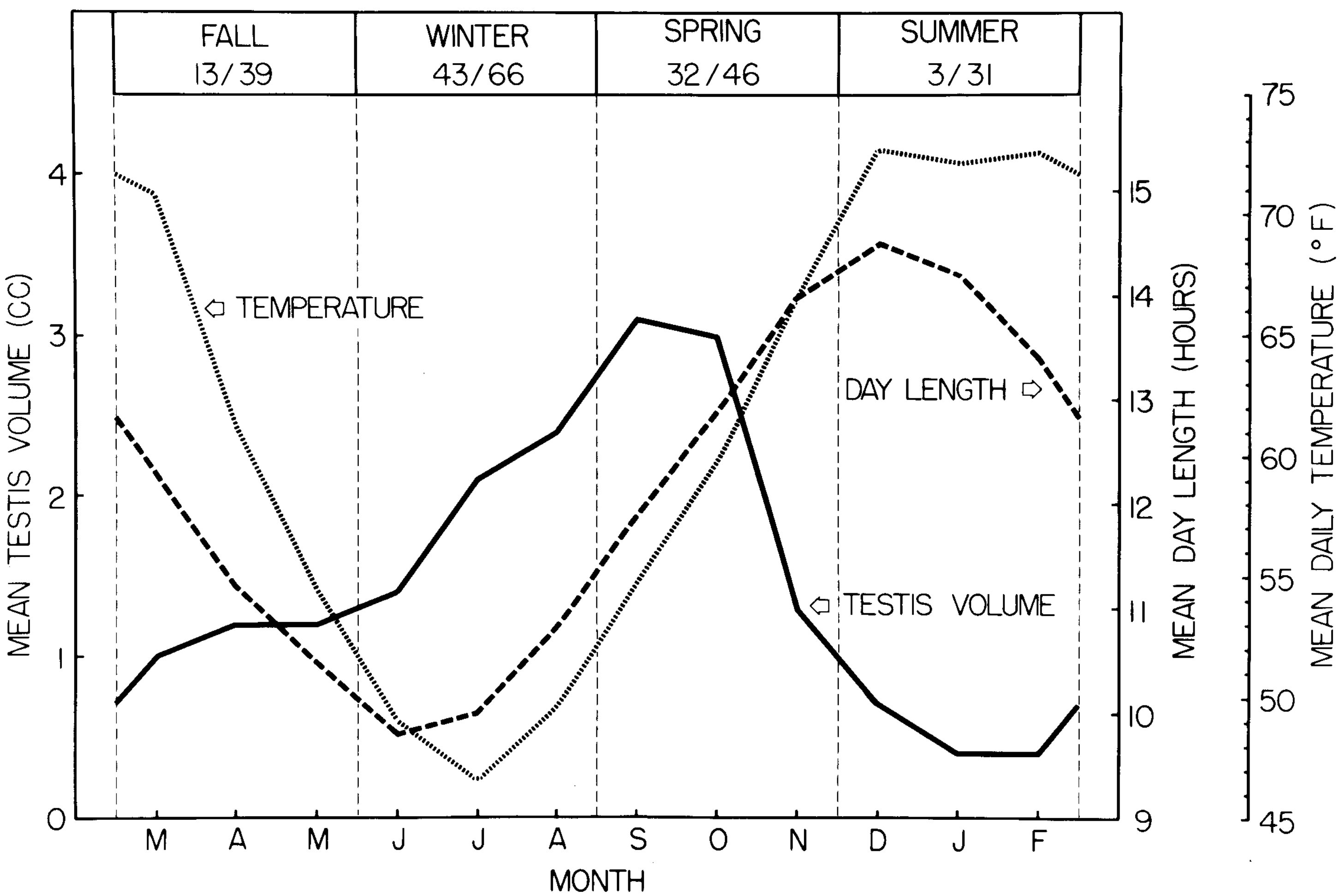

Figure 3. — Cycles of monthly mean day length, temperature, and musk duck testis volume at Barrenbox Swamp for the Period September 1962 to October 1964. Numbers below seasons represent breeding males over the total sample of males.

factors such as available water and food supply are not limiting, environmental influence of breeding is most likely effected by day length, temperature, or a combination of both. The close association of cycles of testis volume, temperature, and day length is indicative of influence by one or a combination of these factors, but further investigation will be necessary to determine fully which is operative.

An interesting gradation in breeding responses to fluctuating water levels can be seen in three species of waterfowl in inland New South Wales. The grey teal (*Anas gibberifrons*), a highly mobile species that prefers habitats of temporary favourability such as floodwaters, responds very quickly to rising water levels which create temporarily favourable breeding conditions (Frith, 1959). The Australian black duck (*Anas superciliosa*), which inhabits water areas of greater permanence, has a more regular breeding cycle but still responds with aberrant breeding to heavy rainfall and flooding (Frith, 1959). The musk duck, with its propensity for permanent water areas, is largely unaffected by shortage of available water and food, breeds with even greater regularity, and does not respond to increases in water level.

(ii) *Size of Submandibular Lobe*.—The black, fleshy lobe beneath the bill of the male musk duck is a unique characteristic of the species. Its exact function is unknown, but it appears to be used as a sight stimulus to the female during the male's breeding display. The lobe is distended basally and turgid throughout the display and the head is raised at frequent intervals, apparently to present the lobe to the female. The size of the lobe differs seasonally and may provide an external indication of breeding condition. Lobes of breeding males were larger than those of non-breeding males. An area approximation of the lobe of each adult male collected was computed from measurements taken in the field. The standard formula for the area of an ellipse ($\pi \underline{AB}$, where $\underline{A}$ = radius of the long axis, $\underline{B}$ = radius of the short axis) was used for the computations. Mean lobe areas (and 99% C.L.) were 42.2 ± 4.9 cm^2 for 90 breeding males and 23.2 ± 2.1 cm^2 for 86 non-breeding males. Lobe areas correlated highly ($\underline{P} < .01$) with testis volumes for a sample of 50 males randomly drawn from the total adult male sample of 182 birds (Fig. 4). The difference in lobe size between breeding and non-breeding males may be a result of distention of the lobe by breeding males during repeated displays, but the close correlation of lobe area and testis volume suggests that the increase in lobe size may have an endocrine origin.

(iii) Musky Odour.—The distinctive musky odour, from which the musk duck gets its common name, occurs only in adult males (Table 1) and the data indicate that it is limited to breeding males. I personally did not examine any of the three non-breeding males on which the odour was detected. None of the 57 non-breeding males that I examined possessed the odour. Of the 82 breeding males examined,

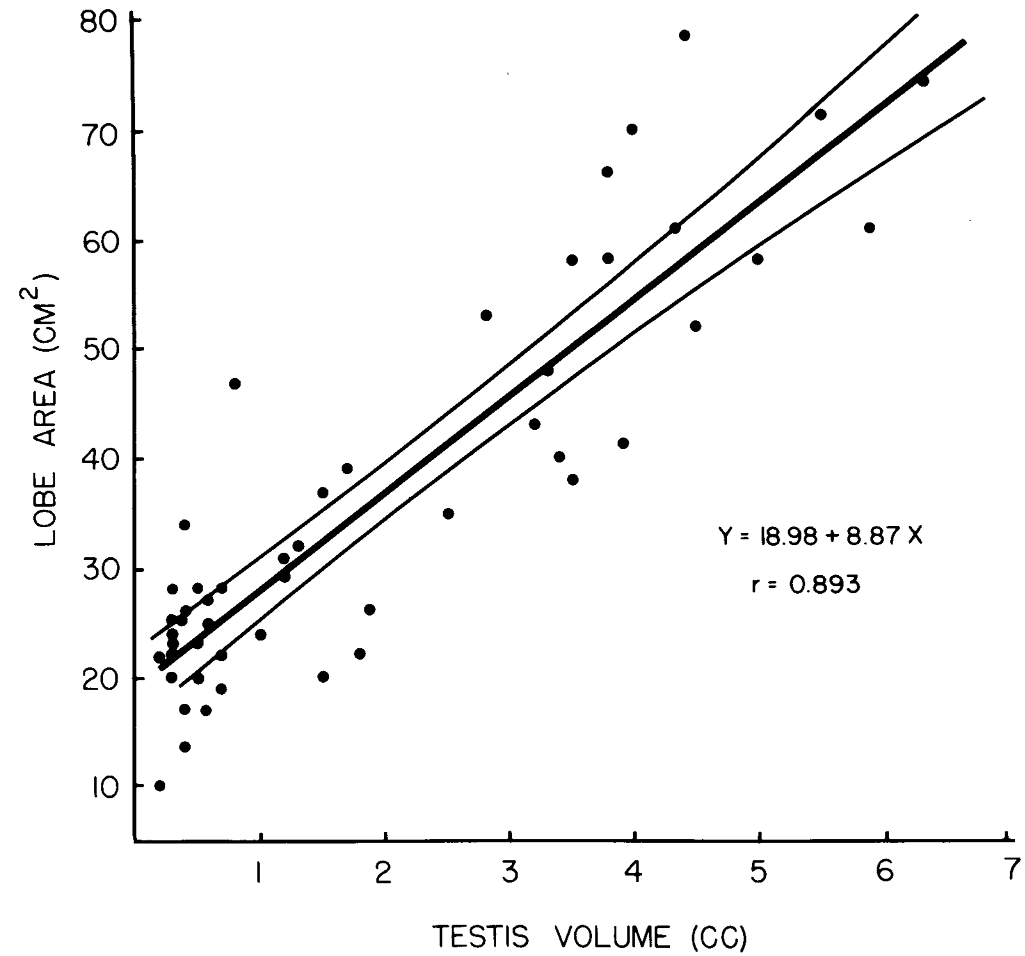

Figure 4. — Correlation of testis volume with lobe area for 50 adult male musk ducks collected at Barrenbox Swamp, 1962-64.

TABLE 1

INCIDENCE OF MUSKY ODOUR IN MUSK DUCKS COLLECTED AT BARRENBOX SWAMP, 1962-64

Class	Number Examined	Musky Odour Present (%)
Males		
Breeding	82	66
Non-breeding	77	4
Females	217	0
Sexual Immatures		
Males	48	0
Females	109	0

53 (65%) were collected at the peak of their breeding cycle, i.e., their testes were past the early stages of sperm production and had large masses of spermatozoa clumped in the centres of the tubules. Incidence of the odour was greatest in this group, occurring in 74% of the 53 birds examined. The function of the odour is unknown. Since it apparently occurs almost exclusively in breeding males, one might suspect that it has a breeding function, perhaps serving as a stimulus to the female. It would not likely act as a deterrent to other males, because it is not detectable at distances greater than 10-15 feet. While the sense of smell in birds is considered by many workers to be virtually non-existent, Portmann (1961), in reviewing the literature pertaining to avian olfaction, concluded that morphological evidence contradicts " ... the simple conclusion that birds are completely anosmatic." Stager (1964) found evidence of a well-developed sense of smell in the American turkey vulture (Cathartes aura). A study of the status of the olfactory apparatus in the musk duck would do much to clarify the true function of the odour.

The source of the musky odour remains unknown. Circumstantial evidence indicates that it may originate from the preen gland at the base of the tail. If the odour were present at all on birds examined, it could always be detected around the opening of this gland. When a strong odour prevailed, it could be detected on any part of the body. If the odour-bearing substance were present in the secretion from the preen gland, it would be spread over the body through the bird's preening. Attempts to determine the chemical composition of the odour through gas chromatography failed. The chemical makeup of the odour is apparently very unstable and breaks down rapidly. Preen glands were collected in the field from males possessing strong musky odours; some were preserved in acetone, others sealed in plastic and frozen, and in one instance an entire carcass was sealed in a plastic bag and frozen. These were then taken to the laboratory in Canberra for analysis. In every case the odour had disappeared completely by the time the material reached the laboratory.

(iv) Oocyte Cycle and Nesting.—In females, oocytes enlarged during the winter months (Fig. 5). Because of small samples and within-sample variation in measurements, significant differences in oocyte size were not revealed for shorter periods of time. Fluctuations in mean oocyte diameters generally coincided with those in mean testis volumes, but maximum and minimum diameters occurred earlier. In 1962-63 and again in 1963-64, minimum oocyte diameters occurred in November-December, while lowest testis volumes occurred in January-February. In 1963 maximum oocyte diameters occurred in July-August, while greatest testis volumes came in September-October, but in 1964 both testes and oocytes were still enlarging when the study ended in October. Changes in oocyte size correlated inversely ($P < .01$) with fluctuations in both day length and temperature but more closely with temperature for both years of the study (Fig. 6).

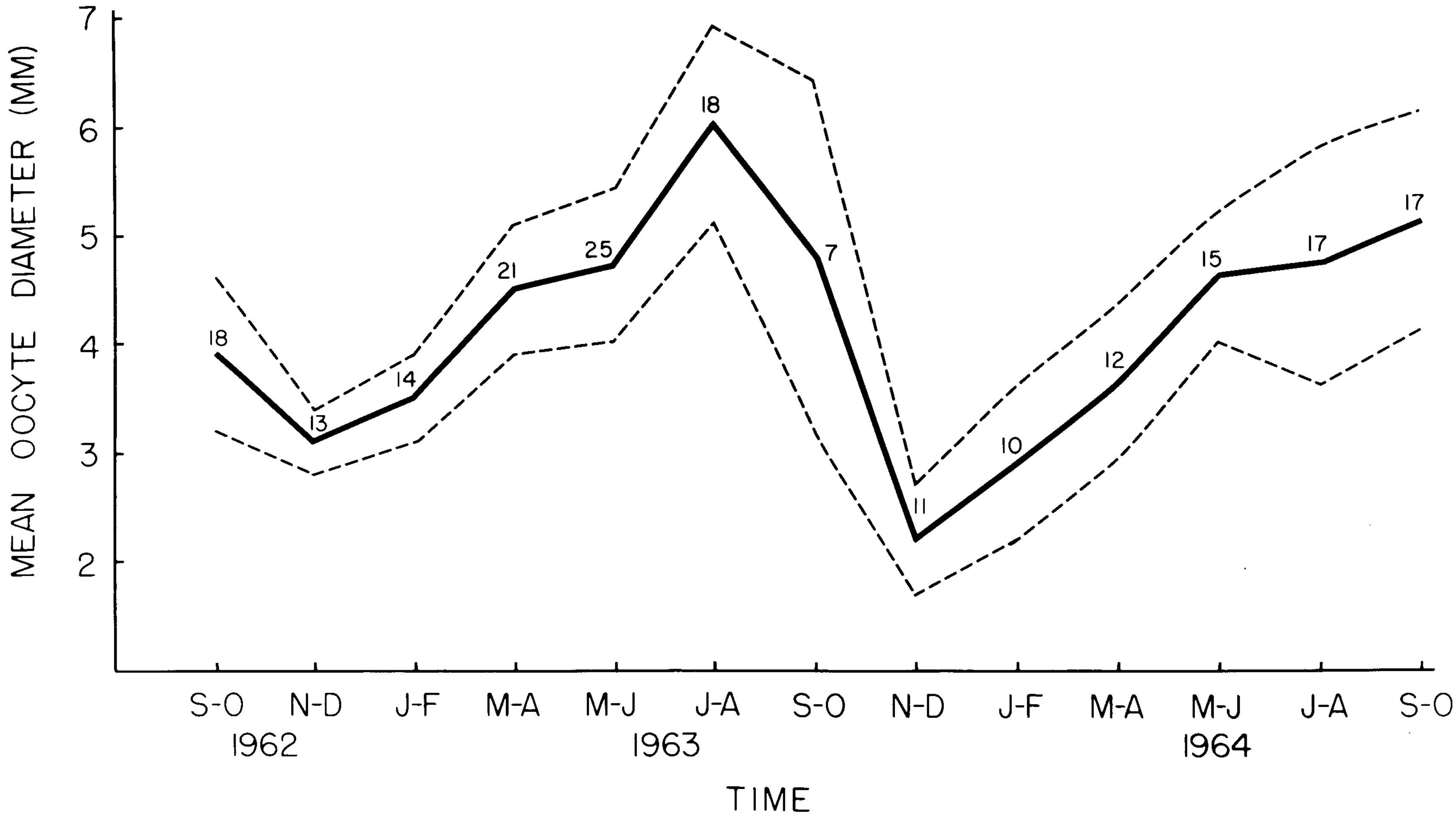

Figure 5. — Mean oocyte diameters of adult female musk ducks collected at Barrenbox Swamp from September 1962 through October 1964. Numbers indicate sample size. Broken lines represent 95% confidence limits.

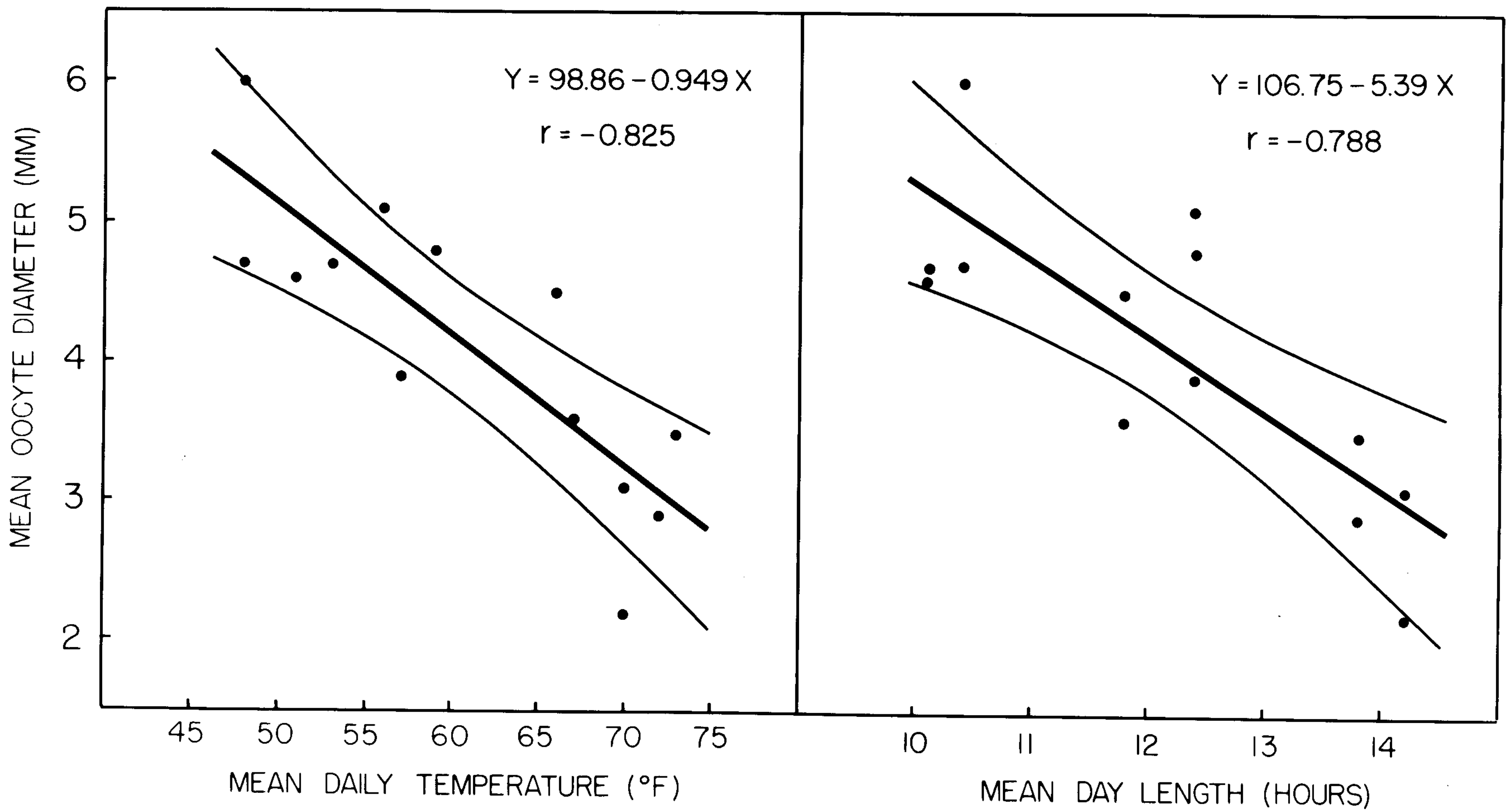

Figure 6. — Correlation of monthly oocyte diameter with monthly day length and temperature for adult female musk ducks collected at Barrenbox Swamp, 1962-64.

Early nesting began in August during the 1962-63 season. Two juveniles were collected on September 7, 1962. These were mostly feathered, with patches of down remaining on the lower back and wings. This condition of moult, plus their small size, indicated they were probably hatched in late August, although nothing is known about growth rate and plumage development in the musk duck. The bulk of the 1962-63 hatch came off in November, during which time almost every female seen was accompanied by young. Females with young were observed as late as January, but these may have been the results of renesting attempts.

From July 1963 through May 1964, collections were made by the CSIRO Wildlife Division staff; however, none were made in September, November, or January. L. W. Braithwaite (CSIRO biologist) reported that young musk ducks were numerous in October, but no brood observations were recorded for December.

One juvenile whose size and plumage development indicated late August or early September hatching was collected on September 26, 1964. The bulk of the hatch had not yet come off by the end of October, when field work ended.

(v) Age of Breeding Maturity.—Musk duck collections yielded some information about the age of breeding maturity. Of the 571 specimens taken over the study period, 157 were classed as sexual immatures. Of these, 31 had all or some down feathers, and hence were obviously young of the year. The rest, while having adult plumage, were classed as sexually immature by the following criteria: A male was immature if it had minute testes (less than 0.3 cc) and no visible lobe (lobe was not detectable unless the bird was in the hand); a female was regarded as sexually immature if the oocytes of the ovary were granular in size and the oviduct was smooth and somewhat transparent, which indicated that the bird had not yet laid eggs. In addition, weights of 78% of these birds were either below or in the lower extreme of adult weight ranges.

Since there is no plumage dimorphism in the musk duck, the fully or mostly feathered sexual immatures closely resemble adult females at shooting distances; adult males can be easily identified at a distance by the obvious lobe beneath the bill. Therefore, a bird collected for an adult female may have been either an adult female or a sexually immature male or female. Since I was mainly interested in collecting adult birds, the occurrence of these immatures in the samples can be assumed with reasonable confidence to be random. If the percentages of sexual immatures in periodic samples are plotted, they show a curve rising to a peak in summer and decreasing to a low in late winter (Fig. 7). In fact, no sexually immature musk ducks were taken in July and August in 1963, and in 1964 none occurred in the August sample. This suggests that the sexual immatures are all young of the year that mature to breeding capability the year after they are hatched.

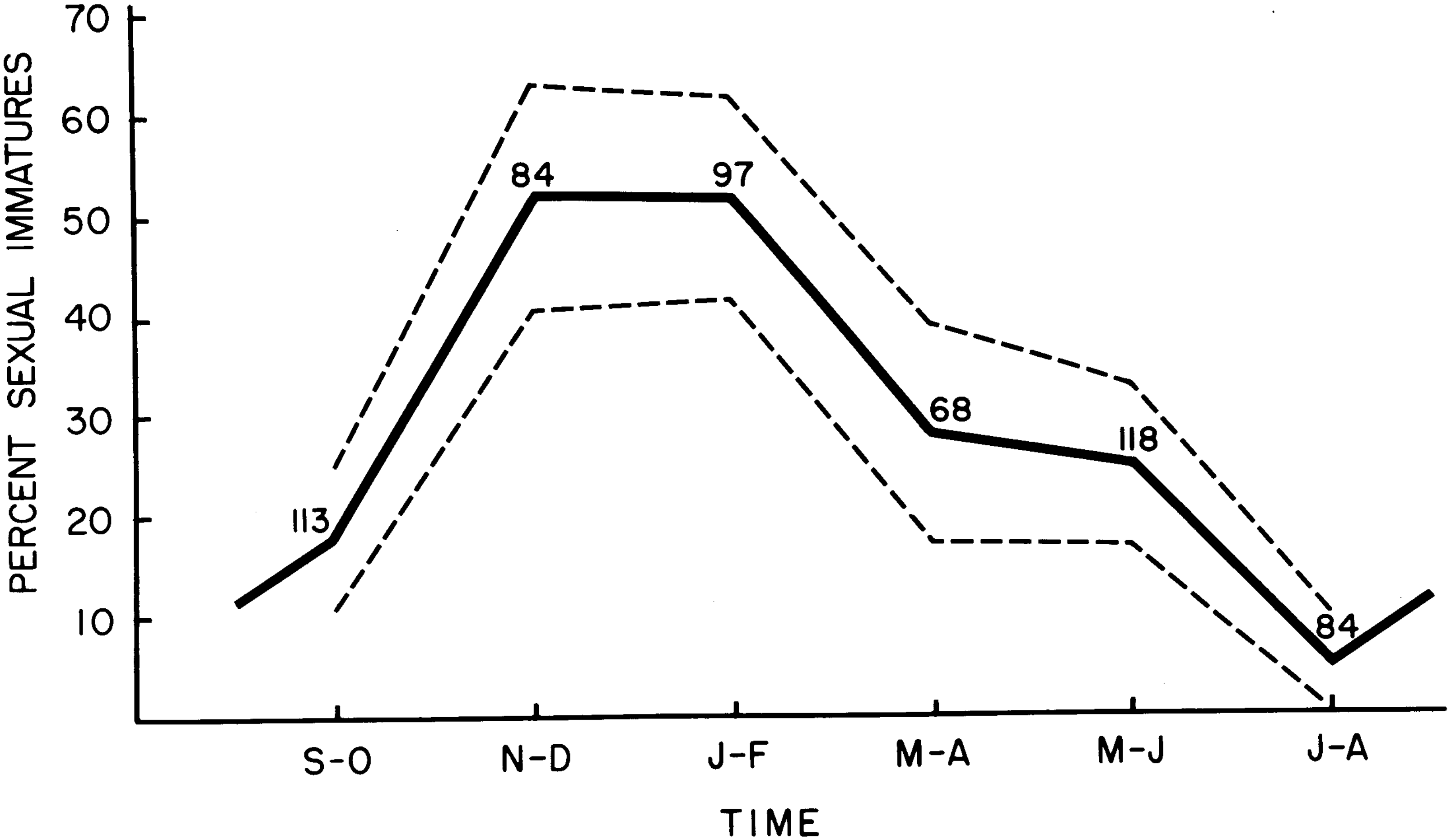

Figure 7. — Percentages of sexual immatures in samples of musk ducks collected at Barrenbox Swamp, 1962-64. Numbers indicate sample size. Broken lines represent 95% confidence limits.

(c) Summary

Peak months in the sexual cycle of the male musk duck are June to October; however, some breeding males were present in the population throughout most of the year. The testis cycle correlated inversely ($P < .01$) with temperature for both years of the study.

The submandibular lobes of breeding males were significantly larger than those of non-breeding males. Lobe size correlated highly ($P < .01$) with testis volume.

The musky odour occurred only in adult males and almost exclusively in breeding males. Incidence of the odour was highest in males at the peak of the sexual cycle. Circumstantial evidence suggests that the odour originates from the preen gland at the base of the tail. Attempts to identify the chemicals comprising the odour were unsuccessful.

Oocytes in female ovaries enlarged during the winter months. The oocyte cycle correlated inversely ($P < .01$) with both day length and temperature. Nesting began during August, and broods were observed as late as January.

Age-ratio changes in shot samples suggest that the musk duck is capable of breeding the first year after hatching.

IV. FOOD HABITS

(a) Methods

Gizzards were collected from 544 musk ducks during September 1962 through October 1964. Gizzard contents were preserved in 80 percent alcohol. Very few esophagi and proventriculi examined contained substantial amounts of food; therefore, analyses were limited to gizzard contents only. Presence or absence of food items was recorded, but no volumetric or weight measurements were taken. The mineral grit in each gizzard was separated from the food material, dried, and measured volumetrically.

(b) Results and Discussion

The musk duck obtains its food almost exclusively by diving. I have also observed individuals in shallow water dredging with their heads and necks under the surface, but not "tipping" as dabbling ducks typically do. The diet consists primarily of aquatic animals and plants. Although the musk duck is commonly seen on areas of deep, open water, it generally limits its feeding to shallower areas where submersed and/or emersed vegetation is abundant.

(i) Food Composition.—The total sample consisted of 192 adult males, 265 adult females, and 87 sexual immatures below the adult weight range. Sexual immatures within the weight range of adults were included in adult samples in this portion of the study.

Numbers in parentheses below represent frequency of occurrence in the total sample for the various food items. Items occurring in less than 1% of the sample are listed as trace.

Animal matter constituted the bulk of the musk duck's diet (Table 2). Important groups occurring in the sample were Crustacea, Mollusca, and three orders of Insecta. Crustacea (55%) consisted of two species, the freshwater yabbie (Cherax albidus) (30%) and the freshwater shrimp (Caridina mccullochi) (34%). Mollusca (37%) included two snails, Physastra sp. (25%) and Glyptanisus sp. (10%), and the freshwater mussel (Corbiculina permena) (20%).

Hemiptera (65%) were the most important animals occurring in musk duck food. Most frequent in the Hemiptera were several species of Corixidae (44%) which were not identified below the family level. Other species were Sphaerodema rusticum (24%) and Naucoris congrex (28%), both in the family Belostomatidae. Ranatra australiensis (Nepidae) (2%) and Anisops hyperion (Notonectidae) (3%) were of little importance.

Odonata (41%) included nymphal forms of dragonflies (Anisoptera) and damselflies (Zygoptera). Trichoptera (33%) were represented by both larvae and cases inhabited by larvae during development. The inclusion of emply cases as signifying that larvae were ingested may be questionable. Although the cases would almost certainly persist longer in the gizzard than the softer bodies of the larvae, it is possible that the presence of cases alone may have resulted from accidental ingestion.

TABLE 2

GIZZARD CONTENTS OF 544 MUSK DUCKS COLLECTED

AT BARRENBOX SWAMP, 1962-64

Item	Frequency of Occurrence	
	Number	Percentage
Animal Food		
Crustacea	298	55
Mollusca	202	37
Insecta		
Hemiptera	353	65
Odonata	221	41
Trichoptera	181	33
Ephemeroptera	60	11
Coleoptera	104	19
Diptera	69	13
Pisces	57	10
Miscellaneous	23	4
Total Animal Food	534	98
Plant Food		
Marsileaceae	142	26
Leguminosae	136	25
Ceratophyllaceae	108	20
Polygonaceae	100	18
Najadaceae	95	17
Boraginaceae	80	15
Cyperaceae	39	7
Gramineae	37	7
Compositae	22	4
Rosaceae	23	4
Unidentified	22	4
Miscellaneous	58	11
Total Plant Food	401	74

Among animal foods of minor importance, Ephemeroptera (11%) were limited to larval forms only. In the Coleoptera (19%), Dytiscidae were represented by _Ilybius fenestratus_ (7%), _Macroporus howiiti_ (1%), _Hydroporus_ sp. (trace), and _Noterus_ sp. (trace). _Hydrophilus latipalpus_ (10%), _Hydrophilus ruficornis_ (trace), _Hydrophilus assimilis_ (trace), and _Berosus australasiae_ (4%) comprised the Hydrophilidae.

Diptera (13%) occurred in the form of larvae of Chironomidae (12%) and Stratiomyidae (1%). Representatives of Pisces were _Gambusia affinis_ (5%), _Tandanus tandanus_ (1%), and an unidentified species (4%). Miscellaneous items included an unidentified spider (Arachnida) (2%) and an unidentified frog (Amphibia) (2%).

Plants utilized by musk ducks included both marsh and upland species. The percentages listed in Table 2 suggest a greater importance of plants in the diet than actually existed. All plants listed occurred as seeds. In virtually all samples analyzed, seeds in a single gizzard numbered no more than 10-15, and in the majority of these no more than 1-5. Since seeds may tend to persist longer in the gizzard than softer animal material, the frequency of occurrence of the former may be biased to high relative to the latter.

The most commonly occurring plants were Marsileacea (26%), represented by _Marsilea drummondii_ (16%), _Marsilea brownii_ (14%), and _Pilularia novae-hollandiae_ (2%). Other marsh plants eaten were

Ceratophyllum sp. (Ceratophyllaceae) (20%) and Potamogeton sp. (Najadaceae) (17%). Polygonaceae (18%) included Polygonum spp. (16%) and Rumex crystallina (3%), and Cyperaceae (7%) were comprised of Scirpus validus (6%) and Eleocharis sp. (1%).

Among plants normally growing in upland areas, Medicago spp. (Leguminosae) (24%) were most prevalent. Other legumes were Trifolium sp. (1%) and Lotus sp. (trace). Species of Boraginaceae (15%) and Rosaceae (4%) were unidentifiable below family.

Gramineae (7%) were represented by Panicum sp. (1%), Cynodon dactylon (trace), and Dichelachne sp. (6%), while Cirsium vulgare (3%), Cryptostemma calendula (trace), Carthamus lanatus (trace), and an unidentified species (trace) comprised the Compositae (4%).

Miscellaneous plants occurring in the sample were Azolla sp. (Salviniaceae) (2%), Atriplex semibaccata (trace) and an unidentified species (trace) of Chenopodiaceae (1%), Convolvulus erubescens (Convolvulaceae) (2%), Salix babylonica (Salicaceae) (1%), Malvastrum spicatum (Malvaceae) (trace), Nitraria schoberi (Zygophyllaceae) (2%) Ludwigia peploides (Onagraceae) (trace), and an unidentified species of moss (2%).

No measurement of relative abundance in the swamp of the various food items eaten by the musk duck was made. Subjectively, insects would almost certainly be the most abundant animal food in the swamp, if only by virtue of the number of species eaten by musk ducks. L. W. Braithwaite reported large concentrations of freshwater shrimp in the centre of the swamp in December 1963. Among plant foods, Potamogeton sp. is abundant in open pools at the northwest end of the swamp. Species of Leguminosae are very common in upland areas immediately adjacent to the swamp and Medicago spp. grow almost to the water's edge on the banks of the swamp and irrigation channels.

The presence of upland plants in gizzard samples suggests that the musk duck occasionally feeds away from the swamp. However, these plants occurred only as seeds, which could have been blown or washed into the swamp. Moreover, with the exception of Gramineae, all seeds found occurred in approximately equal numbers throughout the year. Seeds of Gramineae occurred most frequently in the months of July and August 1963, when the swamp was out of its banks and flooding adjacent pastureland.

No significant differences in incidence of food items occurred between sex and age classes, with three exceptions. Mollusca occurred in 60% of adult males, 30% of adult females and 7% of immatures. Trichoptera occurred in 36% of adults and 18% of immatures. Marsileaceae occurred in 36% of adult males, 23% of adult females and 14% of immatures.

(ii) Seasonal Variation in Food.—Major components of the musk duck's diet varied little throughout the year (Fig. 8). Insects were by far the most frequently eaten group, occurring in 89% of 544 gizzards. Plant occurrence, although not shown here, remained low and even more

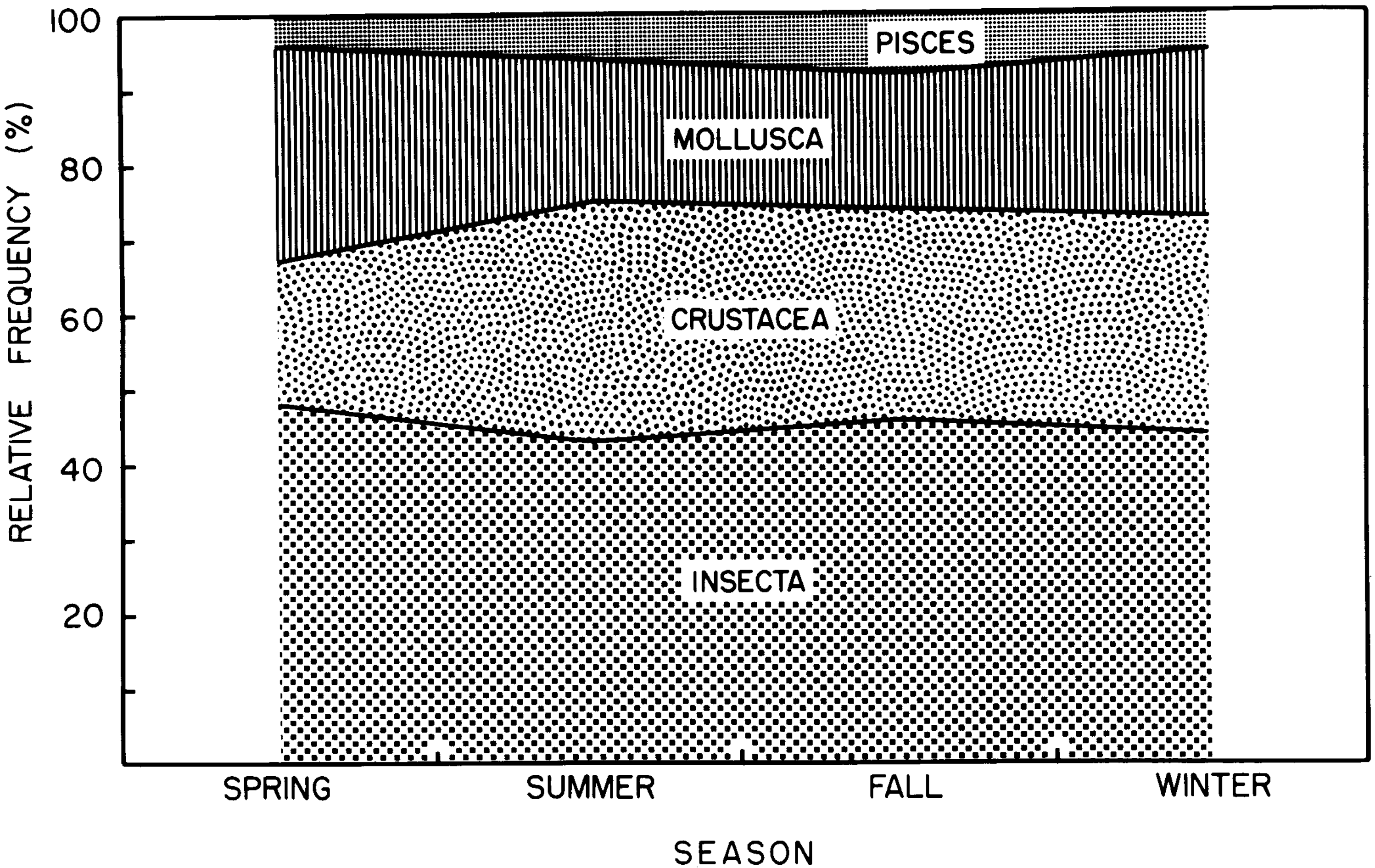

Figure 8. — Relative seasonal frequencies of animal foods occurring in gizzards of 544 musk ducks collected at Barrenbox Swamp, 1962-64.

constant over the two-year period. The lack of variation in the musk duck's diet suggests that there was no seasonal lack of availability in any of its food items. I think it unlikely that a preference for any particular food item, resulting in a greater intensity of searching for that item during periods of low availability, could so completely mask a significant reduction in availability of that food item. The only other year-round study of food habits of a non-migratory species I found was an investigation by Beckwith and Hosford (1957) on the North American Florida duck (*Anas platyrhynchos fulvigula*). They record, however, that the Florida duck is principally plant-eating and may obtain much of its food from temporary water areas. An examination of the data showed no correlation in utilization patterns for various food items between the Florida duck and the musk duck. No further comparisons were made.

(iii) Grit Consumption.—Fluctuations in the quantity of grit ingested by ducks may be influenced by changing food habits (e.g., a higher incidence of snails and mussels in the diet, where shell fragments may serve as grit) or by a reduction in the availability of grit. Musk ducks carried significantly smaller quantities of grit in their gizzards during the summer (Table 3). This may have been a result of lower water levels. Open areas of mud mixed with gravel are abundant in the shallow water around the edges of the swamp; but in summer the receding water exposed many of these, making them largely unavailable as sources of grit. I frequently observed musk ducks on these areas when they were inundated, but never when they

TABLE 3

SEASONAL VOLUMES OF GRIT IN GIZZARDS OF 446 ADULT MUSK DUCKS COLLECTED AT BARRENBOX SWAMP, 1962-64

Season	Sample Size	Mean Grit Volume (cc) (95% C.L.)
Spring	102	2.2 ± 0.4
Summer	97	1.2 ± 0.2
Fall	120	2.2 ± 0.3
Winter	127	2.6 ± 0.4

were exposed. The bottom of the swamp in the interior is covered with vegetative debris.

It is unlikely that lowered grit consumption was a result of changing food habits, since variations in grit volume did not correspond to the slight seasonal changes in food composition. Mean volumes (and 95% C.L.) of grit carried by adults were 2.98 ± 0.36 cc for males and 1.42 ± 0.14 cc for females. This difference in grit volume is a result of size. Mean weight of 182 adult male musk ducks was 2,394 ± 50 grams (99% C.L.); of 215 adult females, 1,320 ± 36 grams (99% C.L.).

(c) Summary

The major portion of the musk duck's diet consisted of animal matter. The most important groups occurring in a sample of 544 musk ducks, in descending order of frequency of occurrence, were Insecta, Crustacea, and Mollusca. Plant occurrence was limited almost exclusively to seeds. Important families, listed as above, were Marsileaceae, Leguminosae, and Ceratophyllaceae. Sex and age differences in food occurrence existed in Mollusca (60% adult male, 30% adult female, 7% immature), Trichoptera (36% adults, 18% immatures), and Marsiliaceae (36% adult males, 23% adult females, 14% immatures).

Food composition varied little throughout the study period. The volume of grit carried in the gizzard was significantly lower in summer.

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