

CHANGES IN OLDSQUAW CARCASS WEIGHT

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Data on weight changes in the Anseriformes have been reviewed by Falk et al. (1966), Weller (1957), and others. Most of this material relates to summer collections or fall-shot samples (Elder 1946, Bellrose and Hawkins 1947). Ryan (1972) determined live winter weights for several species of diving ducks captured in New York, while Ellarson (1956) examined the winter and spring weights of several thousand Oldsquaws (*Clangula hyemalis*) captured in gill nets on Lake Michigan. Changes in weights of Canada Geese (*Branta canadensis*) wintering in Illinois were noted by Hanson (1962) and Raveling (1968).

Most studies on changes in body weights have not quantified what fraction of these changes was contributed by differences in the fat depot (lipids), water (moisture), or fat-free dry weight (protein, bone tissue, etc.). Our investigation of organochlorine contamination in Oldsquaws (Peterson 1976) dictated we monitor changes in body fat levels because these pesticides are extremely lipophilic. Therefore, the purpose of this study was to: (1) document changes in the weight of Oldsquaws for different sex and age classes through the winter, spring, and summer; and (2) quantify the change in lipid, moisture, and dry weight components through the same time period. These data should lead to a better understanding of the feeding ecology, energy requirements, and survival in this species (Peterson and Ellarson 1977) and place the interpretation of body weight changes in waterfowl on a more firm basis.

METHODS

Oldsquaws wintering on Lake Michigan were obtained from commercial fishermen who found them drowned in gill nets. Birds collected on the breeding grounds were obtained by shooting. Most samples were collected between 1 December and 27 July during the period 1969-71; 2 birds were taken in late October 1970. Birds were weighed to the nearest 5 g, then sexed and aged by several techniques (Ellarson 1956, Peterson 1976).

In this report, we have adopted Hanson's (1963) classification for age categories: (1) juvenile Oldsquaws are less than fully grown and less than 1 year old; (2) subadults are more than 1 year old, and essentially fully grown although the majority of the cohort have not completed their first breeding season; (3) adults are at least 2 years old, fully grown, and the majority of the cohort has completed 1 or more breeding seasons. When adults and subadults are combined in 1 class, they are called matures in this paper.

Terminology.—For the remainder of this paper, the following terminology will be used:

Whole body weight = weight of the specimen when secured.

Carcass weight = whole body weight minus head, wings, feet, feathers, gastrointestinal tract, and reproductive organs.

Moisture = water, expressed as a % of carcass weight or total grams present in carcass as computed from the extracted sample.

Lipids = ether-extractable fat, expressed as a % of carcass weight or total grams present in carcass as computed from the extracted sample.

Dry weight = fat-free dry weight or carcass weight minus moisture and lipids.

Varying degrees of water-soaked plumage presented a major problem in studying body weights of gill-netted Oldsquaws. Birds from fresh catches were often dripping wet, while others that had been lying exposed on fish docks for a week or more were frequently quite dry. Shot specimens were usually dry, but varying amounts of moisture and mud often adhered to the feathers. Consequently, any analyses of these weights included considerable variability just from desiccation and foreign material in the plumage. Even though the weight of water absorbed in the plumage was relatively constant in different sized birds (about 10%, Ellarson 1956), we do not consider either of these wet or dry weights to be representative of the true live body weights. Because these weights would be of dubious value in more critical analyses, we decided to use carcass weights as a basis for comparing weight changes between different sex and age classes as well as time periods. Carcass weights lack 2 sources of variability present in whole bodies: (1) removal of the plumage eliminated the foreign material and absorbed water; and (2) removal of the gullet and gastrointestinal tract eliminated weight differences caused by varying amounts of ingested food.

Component determinations.—Fat, moisture, and dry weight component determinations were made by the Wisconsin Alumni Research Foundation (WARF), Madison, Wisconsin. Carcasses were prepared for analysis by severing the head, clipping the wings off at the distal end of the humerus, removing the feet at the tarso-metatarsal joint, shearing all feathers to within a few mm of the skin, and removing the gastrointestinal and reproductive tracts. All abdominal fat was left in the cavity. The carcass was then weighed to the nearest g, homogenized in a Hobart food chopper, and a 25 g sample removed.

Moisture content was determined by weighing samples before and after drying in a 40°C oven for 72–96 h. Although the 40°C was low, this temperature was necessary to prevent driving off the polychlorinated biphenyls (PCB's) at higher heat ranges. The samples were then ground with 100 g Na₂SO₄ and extracted 8 h on a Soxhlet extractor using 70 ml ethyl ether and 170 ml petroleum ether. An aliquot of the extract was then reduced to dryness, desiccated, weighed, and the amount of ether-soluble lipid determined. At a minimum, the nonpolar ether would extract only the stored fat, but since the samples were desiccated prior to extraction, the structural lipids were presumably removed as well (Sperry 1955, Giese 1967).

Statistical analysis.—The data were grouped by sex and age classes for a particular month then subjected to the Student's *t*-test. Changes that occurred between periods, as well as sex and age classes, were then assessed for significance.

RESULTS

Differences in carcass weights.—Average monthly carcass weights, October through May, were plotted for 5 age and sex classes (Fig. 1). During the

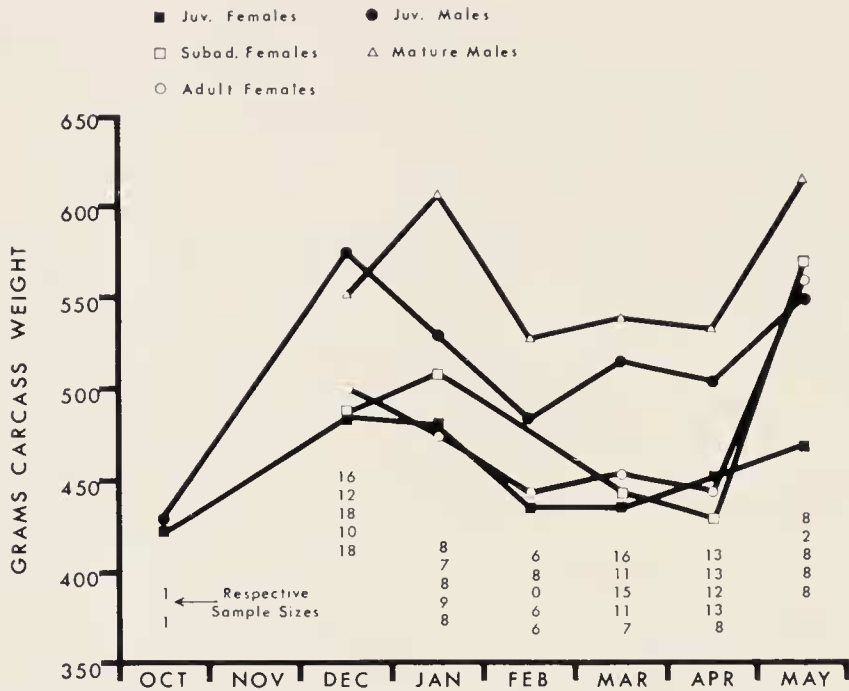


FIG. 1. Average monthly weight of Oldsquaw carcasses collected on Lake Michigan, 1969-71.

winter, carcass weights of Oldsquaws on Lake Michigan were highest during December and January, then declines were recorded through February in mature males, juvenile males and adult females ($P < 0.05$). Subadult females were not sampled in February, but differences were noted in carcass weights between January and March ($P < 0.01$).

Beginning in April, abrupt increases in carcass weights were recorded, especially in Oldsquaws over 1 year old. Between April and May, mature male and female carcasses increased 13 and 24% ($P < 0.01$), respectively. Juveniles also gained weight between April and May, but less than the matures. Juvenile males increased 8% ($P < 0.01$) while juvenile females increased 4% ($P > 0.05$).

In general, carcass weights varied by sex and age. Mature males averaged 15% larger than adult females and differences during the winter and spring were significant ($P < 0.02$) in all months except May. Juvenile males averaged 13% heavier than juvenile females, but differences were significant ($P < 0.01$) only in December, March, April and May. Within the same sex, mature Oldsquaws were generally larger than juveniles, but these differences were smaller than those attributable to a specific sex. Mature males were 6% heavier than juvenile males, and adult females 4% heavier than juvenile females. Mature male carcasses were significantly heavier ($P < 0.05$) than juvenile males only in January and May, and adult female weights did not differ significantly from juvenile female weights except in May ($P < 0.001$).

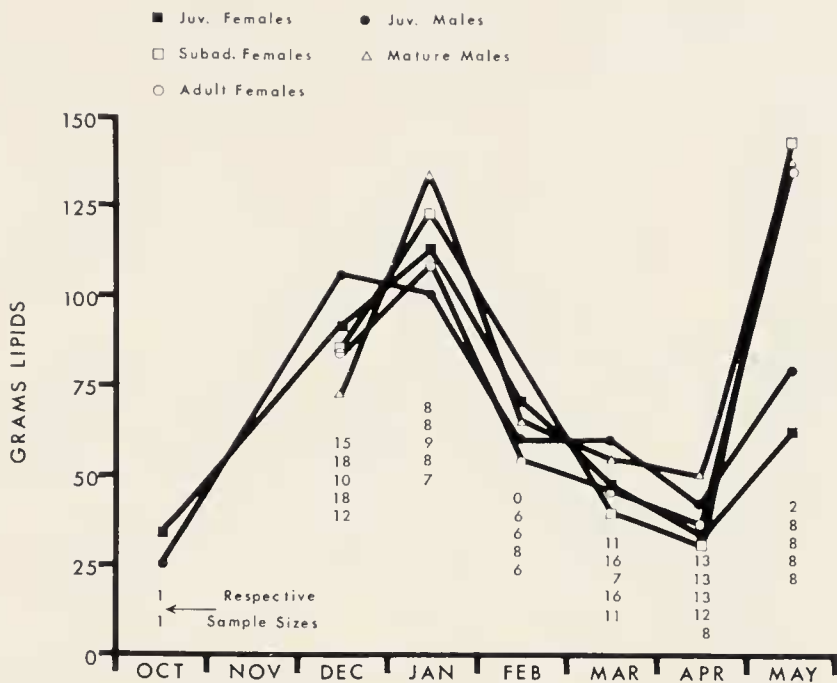


FIG. 2. Average monthly weight of the ether soluble lipid component in Oldsquaw carcasses collected on Lake Michigan, 1969-71.

Differences in lipid weights.—Trends in the ether-soluble lipid fraction (Fig. 2) followed a pattern similar to that observed in carcass weights. Lipid deposition was highest in December or January when an average of 72-106 g of fat was present (19-24% of carcass weight) in the different age and sex classes. Losses of lipids occurred in all sex and age classes from January through April ($P < 0.01$). An average of 58-74% of the lipid fraction was lost during this period so that by April carcasses contained an average of 31-50 g of fat (7-9% of carcass weight), depending on the age and sex class. Between April and May, the lipid fraction of the carcass increased substantially in all age and sex classes ($P < 0.01$). In mature males as well as subadult and adult females, the lipids increased 1.8 to 3.5 times, so that the average weight of lipids in these carcasses was 135-142 g in May (23-25% of carcass weight). Although differences occurred in the weight of the lipid fraction in juveniles between April and May, lipid deposition during this period was not as heavy as in adults because an average of 62-79 g of fat (13-14% of average carcass weight) was present during May versus 135-142 g in matures. The weight of the lipid fraction in all sex and age classes fluctuated together between December and May, but differences among these classes within a month were not apparent except in May when matures were different from juveniles ($P < 0.01$).

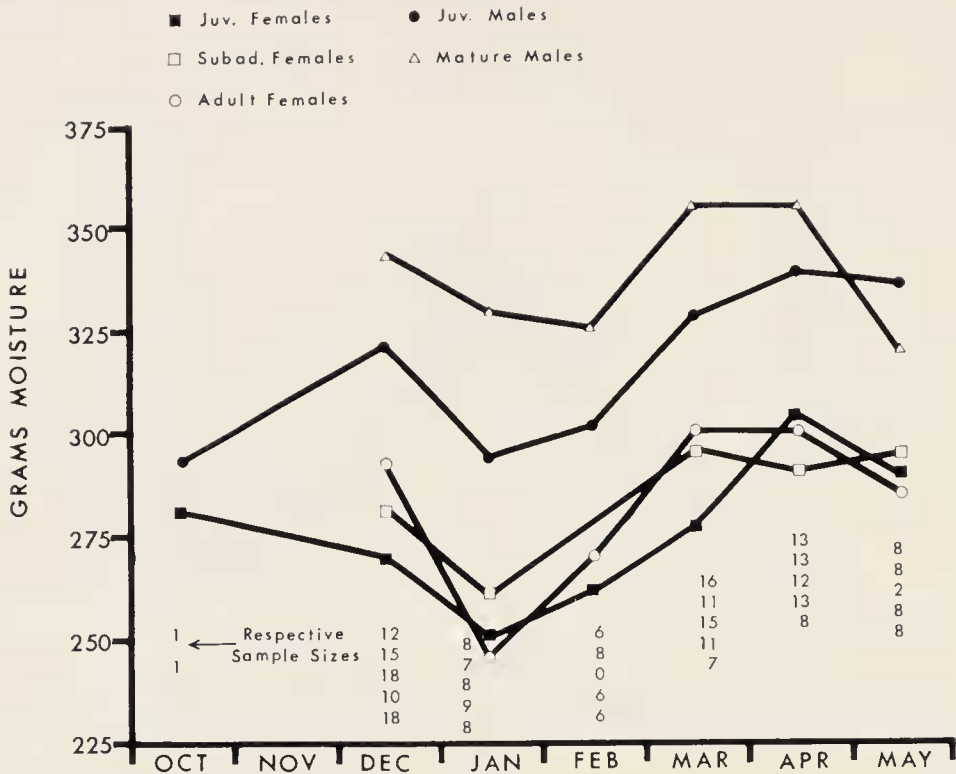


FIG. 3. Average monthly weight of moisture in Oldsquaw carcasses collected on Lake Michigan, 1969-71.

Differences in moisture.—The moisture present in Oldsquaw carcasses during the winter and spring (Fig. 3) generally trended opposite to those shown for lipids and carcass weights. When lipid deposits were high, as in January, moisture content in the carcass was relatively low, averaging 52–56% depending on the age and sex class. In April, when the lipid content and carcass weights were relatively low, the moisture fraction was high, averaging 66–68%. Between December and January, declines in moisture content were noted in all age and sex classes, but the only significant difference occurred in adult females ($P < 0.01$), where moisture dropped 16%. There was a generally increasing trend in moisture content between January and April ($P < 0.001$) for juvenile males, juvenile females, and adult females, followed by a decrease in moisture between April and May (significant only in mature males, $P < 0.05$).

Relative differences in moisture content between age and sex classes for a given month were similar to those exhibited in carcass weights. Mature male carcasses were heavier and contained more moisture than adult females for all months during the winter and spring except May ($P < 0.01$). However, the % moisture in the carcasses during the same month was essentially the same for mature males and adult females as well as for juvenile males and females.

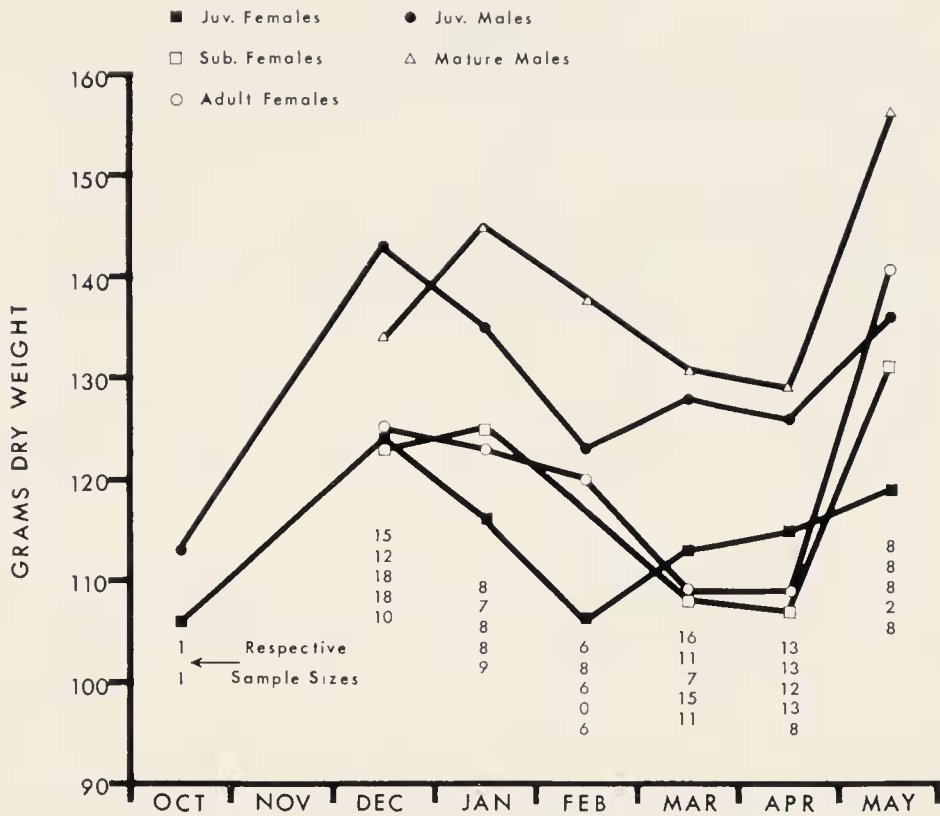


FIG. 4. Average monthly fat-free dry weight of Oldsquaw carcasses collected on Lake Michigan, 1969-71.

Differences in fat-free dry weight.—A peak in dry weight was reached between December and January, followed by a general decline through the remainder of the winter with increases occurring again between April and May (Fig. 4). Differences in dry weight of the carcasses between January and April occurred in mature males, adult females, and subadult females ($P < 0.02$), while differences between April and May were only recorded between males and adult females ($P < 0.01$).

Differences in dry weight between age and sex classes for a specific month were also examined. The dry weights of mature male carcasses were different from those of adult females for all months January through April ($P < 0.02$), but not in December and May. Juvenile male and female dry weights were different during December, February, March and May ($P < 0.05$). Dry weights of mature males were different from those of juvenile males in February and May, while dry weights of adult females were different from those of juvenile females only in May ($P < 0.05$).

Changes in adult female carcass components on the breeding grounds.—Table 1 summarizes changes in carcass components of adult females from just prior to spring migration on Lake Michigan until broods appeared on

a breeding ground in northwest Hudson Bay. Carcass weights declined steadily through this period. Approximately 13% of the carcass weight was lost between each of the 4 major periods sampled. Overall, adult females lost an average of 35% of their carcass weight between the middle of May and the end of July.

While carcass weights were declining, no changes were noted in moisture content. There was a difference of only 8% between the average weight of moisture in birds on Lake Michigan prior to migration and birds analyzed just after the broods hatched.

There was a considerable loss in average dry weight of the carcasses over the period. Dry weights declined from an average of 141 g on Lake Michigan to 98 g in females accompanying broods in the Arctic (-31%, $P < 0.02$).

The greatest loss in weight occurred in the lipid fraction. On Lake Michigan prior to migration, adult females had deposited an average of 135 g of lipids, or 24% of their carcass weight was fat. Paired females collected on the breeding grounds 25 days later averaged 81 g of fat (17% of carcass weight). Forty percent of the lipid fraction may thus have been lost on spring migration, if we assume that the pre-migratory lipid reserve of birds collected in the Arctic were similar to those of the Lake Michigan birds.

These data give some insight on the amount of stored energy available to migrating Oldsquaws. A weight loss of 54 g of fat (135-81) represents about 513 kcal metabolized. If the bird is migrating (estimated migration rate at $3.22 \text{ kcal/h} \times 8$ for flight) it would metabolize 25.76 kcal/h. The existence energy for a 900 g bird is about 158 kcal/day (6.58/h). If an Oldsquaw migrates 7 h and "exists" 17 h a day, it would require about 292 kcal/day during migration. This suggests Oldsquaws could do this for 1-2 days on that quantity of fat lost, but the birds most likely feed during the day, thereby increase flight time and range.

During the egg-laying period, a 69% loss in the fat reserve reduced the lipid fraction, on the average, from 81 g to 25 g. Therefore, when the females started incubating, 6% of their carcass weight was fat. By the time the eggs hatched, 72% of this remaining lipid fraction had been lost, so that by 1 August, carcasses of adult females contained less than 2% fat. Over the whole period, then, from just prior to migration until just after the eggs hatched, adult females lost 95% of their fat reserve.

These data indicate that most of the change in adult female carcass weights during the breeding season is due to changes in the lipid reserves. Table 1 indicates that 66% of the weight loss in adult female carcasses was accounted for by the 95% loss in body fat reserves. Changes in the dry weight accounted for another 31%, and moisture accounted for only 8%.

TABLE 1
CHANGES IN ADULT FEMALE OLDSQUAW BODY COMPONENTS PRIOR TO SPRING MIGRATION
AND ON THE BREEDING GROUNDS¹

	Approximate date	Sample size	Ave. \pm SE carcass weight (g)	Ave. \pm SE weight of moisture (g)	Ave. \pm SE fat-free dry weight (g)	Ave. \pm SE weight of lipids (g)
Lake Michigan, prior to migration ²	15 May	8	561 \pm 14 *	285 \pm 11	141 \pm 8	135 \pm 19 *
Paired females on breeding grounds ²	10 June	10	486 \pm 11 *	277 \pm 5	128 \pm 2	81 \pm 7 *
Incubating females ²	10 July ³	11	427 \pm 9 *	281 \pm 6	121 \pm 5	25 \pm 3 *
Females with broods ²	27 July	3	367 \pm 20	262 \pm 14	98 \pm 2	7 \pm 2
Total weight loss			194	23	43	128
Percent overall weight loss			35	8	30	95

¹ Samples from Lake Michigan and the Arctic may not be from the same population.

² Stage of breeding cycle.

³ Examination of egg contents indicated clutches had been incubated ca. 3 days.

* Indicates 2 periods different at the 0.02 level of significance.

This is essentially the same relationship observed in different age and sex classes of Oldsquaws on the wintering grounds. The moisture tends to compensate for some losses in the dry or lipid weights, but not enough to keep carcass weights constant. Any substantial change in carcass weight is caused by changes in both the dry weights and the lipid reserves, but primarily the latter.

Composite samples of Oldsquaw eggs averaged 13.7% lipids. The average whole fresh weight of an Oldsquaw egg is 42.7 g ($N = 77$), of which 5.9 g is fat. If the average Oldsquaw clutch is 6.8 eggs (Alison 1975:17), then an adult female transfers an average of 40.1 g of lipids per clutch. Adult females lose an average of 56 g of lipids between the time they arrive on the breeding grounds and the time they commence incubation (Table 1).

Gross internal examination of adult female Oldsquaws collected on the breeding grounds suggested reduced food intake. Food was seldom found in the gullet or gizzard, and the liver, as well as the entire digestive tract, was much reduced when compared with birds collected on Lake Michigan in

May. The data in Table 1 indicate these birds would have had to feed regularly during this period. If one calculates kcal available from the 128 g of fat and 43 g of fat-free dry weight lost between the time the birds left Lake Michigan and the end of incubation, you get approximately 1400 kcal at maximum conversion efficiency, or a total of 8–9 days survival. Of those 1400 kcal, 381 ($40.1 \text{ lipid} \times 9.5 \text{ kcal/g lipid}$) go into eggs. Therefore, 1019 kcal/158 kcal/day existence leaves only 6 days of survival without food. If one includes the calories necessary to convert adipose fat to egg lipid, the fat necessary for egg production then, must account for a substantial portion of the lipids lost during the egg-laying period.

DISCUSSION

Relationship of body weight to sex and age.—Age-related weight variations in Oldsquaws are not as apparent as differences associated with sex, but adults averaged heavier than juveniles. Hanson (1962) also showed this to be true in Canada Geese, and Bellrose and Hawkins (1947) found a similar relationship in several species of ducks. Differences in the weight of Oldsquaws related to age were about $\frac{1}{3}$ as much as those associated with sex. Bellrose and Hawkins (1947) found this difference in several other species of ducks to be about $\frac{1}{2}$ the difference associated with sex. On a monthly basis, our Oldsquaw data indicate these differences can vary from -4% to $+15\%$. Therefore, age-weight measurements collected over a short time period could be misinterpreted as to whether real differences exist throughout the year between juveniles and adults.

Connell et al. (1960) showed that the fat-free weight of males averaged significantly greater than females, and adults averaged larger than juveniles, but not when individuals of the same wing length were compared. In other words, individuals of the same wing length do not differ in weight because of sex or age (Rogers and Odum 1964). Data we collected on the Oldsquaw indicated a strong relationship between wing length and carcass weight ($r = 0.5$, $P < 0.001$), but wing length was actually a poor physical measurement to separate sex and age differences in carcass weight. Up to $\frac{1}{3}$ of an Oldsquaw carcass can be fat, depending on the condition of the bird, and since wing length is relatively constant in an adult bird, considerable variation is encountered as fat is deposited or metabolized. Consequently, only 25% of the variability in carcass weight was accounted for by wing length.

Relationship of body weight to time.—Several hypotheses have been suggested to explain decreases in weight through the winter, the most common being a negative energy balance related to temperature or lack of food. However, Kirkpatrick (1944) found the weights of pen-reared Ring-necked

Pheasants (*Phasianus colchicus*) fluctuated similarly to weights of wild-caught birds, and in Canada Geese weight losses have occurred under *ad libitum* food and water conditions (Raveling 1968).

Oldsquaws are known for their ability to dive to extreme depths (in excess of 45 m; Schorger 1951, Ellarson 1956) to secure their bottom-dwelling foods (primarily deep water amphipods [*Pontoporeia affinis*]; Ellarson 1956, Peterson and Ellarson 1977). When Lake Michigan is free of ice, Oldsquaws are commonly seen diving in 23–38 m of water. During January and February, skim ice can extend for several km offshore, and this forces the birds to feed in deeper water. The decrease in lipid reserves from January to April is probably caused by the birds being forced to make deep dives in which the energy expended to obtain food exceeds that derived from the material ingested. If Oldsquaws are concentrated by ice in water so deep that food cannot be secured, they would die in a matter of weeks. Only on rare occasions does the lake become so completely ice covered that Oldsquaws die of starvation (Gromme 1936, Kumlien and Hollister 1951).

Relationship between carcass components.—Our data on the Oldsquaw indicate lipid weight and dry weight vary together. These data are consistent with other studies that show the degradation of protein and lipids are interlinked. Benedict and Lee (1937:4) concluded a fasting goose first draws upon its glycogen reserves but then “drafts are made almost exclusively upon body fat, although there is a fairly constant draft upon protein representing usually about 10% of the total catabolism.” Similar relationships between fat and nonfat weights have been demonstrated in the Bullfinch (*Pyrrhula pyrrhula nesa*; Newton 1969) and Slate-colored Junco (*Junco hyemalis*; Helms et al. 1967). Fry et al. (1970) also noted an increase in the fat-free dry weights during the first few days of fattening prior to migration.

The relationship of moisture to dry and lipid weights is not as clear in the literature as the interrelationship between the latter 2 components. Odum et al. (1964) maintain that during migration “fat is added to and used from pre-existing tissue spaces without appreciable change in the water content or the nonfat dry weight of the body as a whole.” On the other hand, Fry et al. (1970) found that the moisture content increased along with the fat-free dry weight when the birds were fattening, while McGreal and Farner (1956) found the water content decreased as the pre-migratory deposition of fat developed. Our data essentially agree with Helms et al. (1967) who found moisture varied inversely with lipids, and also support their conclusion that early fat deposition replaces water concurrent with an addition of dry weight.

Importance of increased dry weight and fat deposition.—Child (1969),

Evans (1969), and other authors generally attribute the spring increase in dry weight as an adaptation to increased flight power for migration, but this does not explain the December–January increase observed on the wintering grounds. The Oldsquaw, as in all alcids and penguins, extends its wings while diving (Johnsgard 1965). On the breeding grounds, most of the diving is limited to shallow tundra ponds, but on Lake Michigan, diving is performed in much deeper water. The winter increase in dry weight could be an adaptation to deep diving. That is, breast muscles, besides being used to help propel the bird through the water with its wings, may be used as a large myoglobin storage area for oxygen.

Fat deposition serves 2 important functions in the Oldsquaw: as fuel during migration, and as energy reserve for a few days during periods of stress on the wintering grounds. The invertebrate bottom fauna on Lake Michigan is the principal food source of Oldsquaws wintering on the lake and consequently is a critical factor in the survival of this population. Any influences adversely affecting the bottom fauna will also adversely affect Oldsquaws.

SUMMARY

Oldsquaws were collected from commercial fishing gear between December and May on Lake Michigan, and in the Arctic during the breeding season. Carcasses were analyzed for lipids, moisture, and dry weight content.

Males were heavier than females in the same age class, and matures were heavier than juveniles in the same sex class, but differences were not always significant within a particular month.

Carcass weights varied seasonally with the heaviest weights being recorded in January and May and the lightest birds being found in April and late summer.

During the summer, adult females steadily lost weight from the time they arrived on the breeding grounds in early June until the eggs hatched in early August. During the winter and spring, changes in the carcass weight as well as the component fractions varied together in the different age and sex classes.

Trends in the lipid and dry weight fractions were similar to those exhibited in carcass weights, but the moisture fraction generally varied opposite to lipids and dry weight.

Most of the seasonal variability in carcass weight could be accounted for by changes in the lipid fraction.

ACKNOWLEDGMENTS

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- DEPT. OF WILDLIFE ECOLOGY, UNIV. OF WISCONSIN, MADISON 53706. (PRESENT ADDRESS: SRP: DEPT. OF WILDLIFE RESOURCES, UNIV. OF IDAHO, MOSCOW, IDAHO 83843.) ACCEPTED 25 NOV. 1977.

REQUEST FOR ASSISTANCE

Least Tern sightings.—I have initiated research on the population dynamics and site requirements of Least Terns on the Texas coast to identify possible causes of a recent decline in breeding pairs. Both adult and young terns will be marked with colored patagial tags (streamers) during the 1979, 1980, and 1981 breeding seasons. Tags will be placed on both wings and will bear a single letter and digit for individual recognition of birds. Anyone observing Least Terns marked in this manner is requested to record the following: *date, time, specific location, tag color, alphanumeric symbol, general activity, plumage, association with other birds, observation distance and direction, and name, address, and telephone number of observer.* Also, further information is needed concerning concentration areas (feeding, loafing, courting, nesting) used by Least Terns in Texas. Information recorded on such sites should include that requested above, excluding tag description. Please send all information to: Bruce C. Thompson, Dept. of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843. Also, report sightings of marked terns to: Bird Banding Laboratory, Office of Migratory Bird Management, USFWS, Laurel, Maryland 20811.

ZOOLOGICAL NOMENCLATURE ANNOUNCEMENT

The required six months' notice is given of the possible use of plenary powers by the International Commission on Zoological Nomenclature in connection with the following name listed by case number (see *Bull. Zool. Nom.* 35, part 3, 19 February 1979):
2233 *Sterna cerulea* Bennett, 1840 (Aves): proposed conservation under the plenary powers.

Comments received early enough will be published in the *Bulletin of Zoological Nomenclature*. Responses should be sent in duplicate (if possible within 6 months of the date of publication of this notice in *Bull. Zool. Nom.* 35, part 3) to R. V. Melville, The Secretary, International Commission on Zoological Nomenclature, c/o British Museum (Natural History), Cromwell Road, London, SW7 5BD, England.