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SHORT COMMUNICATIONS

Diurnal time budgets of Common Goldeneye brood hens.—Egg production and incubation by female waterfowl have high energetic and nutrient costs (Alisauskas and Ankney 1992, Afton and Paulus 1992). As a consequence, female body mass and condition at the end of incubation are often at or near their lowest points of the year. Thus, the brood-rearing period is important, as females must care for their young while regaining their body condition and preparing to molt. Although waterfowl studies (Lazarus and Inglis 1978, Afton 1983, Rushforth Guinn and Batt 1985) have used descriptive data collected from brood hens to test various aspects of parental investment theory (Trivers 1972), data for many species have not been collected, and factors affecting parental investment are not well known.

We studied time-activity budgets of Common Goldeneye (*Bucephala clangula*) females with broods because this aspect of their biology has received little attention. Our objective was to describe time-activity budgets of Common Goldeneye brood hens. Lakes that are used most for nesting and brood rearing in north-central Minnesota also support highly productive populations of fish. This contrasts with other locations where fishless lakes or those having few fish have been reported as being most important for brood rearing and where goldeneyes are believed to compete with fish for invertebrate foods (Eriksson 1979, Eadie and Keast 1982, Blancher et al. 1992, and others). Our data should add to the understanding of waterfowl parental investment and fish competition in Common Goldeneyes.

Study area and methods.—Brood hen time-activity budgets were studied on two north-central Minnesota lakes in 1984 and 1985. Island Lake (1250 ha) had moderate to heavy year-round and summer residential shoreline development. Shoreline and mid-lake stands of hardstem bulrush (*Scirpus acutus*) and reed grass (*Phragmites communis*) were extensive, and 39% of the basin was <3 m in depth. Each year, 30–35 goldeneye broods occupied the lake. Lake Bemidji (2600 ha) had heavy residential shoreline development. Shoreline stands of emergent vegetation were limited, and 29% of the basin was <3 m in depth. Approximately 20 goldeneye broods occupied the lake. Fish communities in both lakes were dominated by populations of Percidae and Esocidae, and fishing and boating were intensive beginning in May. Recreational boating was more prevalent on Lake Bemidji. Morphoedaphic indices (MEI) (Ryder 1965) were 18.01 and 8.72 for Island Lake and Lake Bemidji, respectively (Minn. Dep. Nat. Resour., Section of Fisheries, unpubl. data). These MEI values are near optimum for highly productive fish communities (Ryder et al. 1974).

Activities of unmarked females with broods were sampled using the focal animal method (Altmann 1974) and 1-h observation sessions. The period from 0.5 h before sunrise to 0.5 h after sunset was divided into four equal-length blocks that were adjusted daily to account for changing day length. For each block, a random start time was selected such that the latest possible start would be 1 h before the end of the time block. We tried to minimize any systematic bias in our sample by alternately using access points at opposite ends of the lakes and also alternating the directions travelled from the access points to locate broods. We sampled the first brood hen encountered after determining the random start time and sequentially sampled as many as we could thereafter in the time block. Usually little time elapsed between independent samples as two or more broods sometimes could be observed without moving our boat. Broods were aged according to plumage development (Gollop and Marshall 1954).

Activities were recorded every 30 sec using a metronome (Weins et al. 1970) and categorized as (1) foraging (dive, dive-pause, food sorting at the surface), (2) alert, (3) locomotion, (4) agonistic (surface-threats, shallow dive-threats, fights) (see Savard 1984, 1988),

TABLE 1

PERCENT OF DIURNAL TIME SPENT IN VARIOUS ACTIVITIES BY COMMON GOLDENEYE BROOD HENS IN NORTHCENTRAL MINNESOTA, 1984–1985[a]

		Brood size			
		Small		Large	
Activity	Lake	1984	1985	1984	1985
Alert	Island	36.9 (4.0)[b]	33.9 (3.6)	32.0 (5.8)	36.7 (4.7)
	Bemidji	20.4 (3.6)	28.5 (2.7)	26.1 (9.0)	28.7 (2.7)
Foraging	Island	18.9 (3.8)	15.9 (2.4)	11.8 (2.6)	26.2 (3.5)
	Bemidji	20.4 (4.1)	23.0 (4.1)	28.3 (8.0)	28.4 (3.7)
Locomotion	Island	11.8 (1.8)	12.0 (1.6)	20.7 (3.5)	12.9 (1.8)
	Bemidji	11.9 (2.1)	10.5 (2.3)	37.3 (2.0)	17.2 (2.5)
Resting	Island	7.3 (2.2)	17.5 (3.7)	19.5 (4.3)	10.8 (4.5)
	Bemidji	19.2 (6.2)	22.3 (5.9)	4.8 (4.8)	14.5 (3.9)
Comfort	Island	21.1 (3.2)	12.6 (1.5)	15.2 (2.6)	9.9 (1.8)
	Bemidji	17.7 (2.5)	11.0 (2.1)	2.3 (0.4)	8.4 (1.6)
Left brood	Island	3.5 (2.7)	3.2 (1.7)	0.0 (0.0)	1.9 (1.9)
	Bemidji	3.6 (3.6)	3.1 (2.2)	0.0 (0.0)	1.6 (0.8)
Agonistic	Island	0.6 (0.3)	4.9 (2.2)	0.8 (0.4)	1.6 (1.0)
	Bemidji	6.7 (2.6)	1.7 (0.9)	1.1 (0.6)	1.1 (0.3)

[a] Island Lake sample size (1984 = 27 h, 1985 = 51 h), Lake Bemidji sample size (1984 = 16 h, 1985 = 38 h).
[b] Mean (SE).

(5) comfort movements, (6) resting, (7) away from brood, or (8) out of sight. Observation sessions were analyzed if females were visible for $\geq$ 30 min. Activities were summarized as the percent of the session that they comprised while the bird was in sight. We collapsed activities into categories of parental care (alert, locomotion, and agonistic) and self-maintenance (foraging, comfort, and resting) in a fashion similar to Rushforth Guinn and Batt (1985) except that we also considered foraging dive-pauses to be parental care and away from brood to be self-maintenance. We recognize, as have others, that any one activity may not exclusively serve one category or the other.

Effects of location, year, brood age (class I or II), brood size ($<$7 or $\geq$7 ducklings), and their interaction on percent time spent in each activity were examined using a two-way factorial ANOVA on the arcsine-transformed data. We set our significance level at α = 0.05. We maintained the overall α level in analyses having $\geq$ three response variables by preceding the ANOVAs with a single two-way factorial MANOVA on the transformed data using SAS PROC GLM (SAS Institute Inc. 1991). When interactions were not significant, we repeated the MANOVA using the reduced model. Significant multivariate main effects were followed by their corresponding univariate ANOVAs.

Results.—Hens with broods were observed for a total of 132 hours. Observations were reasonably well-balanced among time blocks within lakes and years. Wilk's Lambda test criterion indicated that no interaction among year, location, brood age, or brood size was significant (all P values $>$ 0.16). For the main effects model, location, year, and brood size influenced activity budgets (MANOVA F = 2.76; df = 7, 121; P = 0.011; F = 2.27; df = 7, 121; P = 0.033; and F = 2.95; df = 7, 121; P = 0.007, respectively), but brood age did not (P = 0.812). Brood hens spent most of the diurnal period alert and foraging (Table 1). Females on Island Lake were alert more often than those on Lake Bemidji (F = 8.00; df

TABLE 2

PERCENT OF DIURNAL FORAGING TIME SPENT IN VARIOUS ACTIVITIES BY COMMON GOLDENEYE BROOD HENS IN MINNESOTA, 1984–1985[a]

Activity	Brood age: Class I (N = 63 h)	Brood age: Class II (N = 69 h)
Diving	82.9 (2.8)[a]	92.0 (2.4)
Pausing	8.8 (1.5)	2.8 (0.9)
Sorting	8.3 (2.4)	5.2 (2.2)

[a] Mean (SE).

= 1, 127; P = 0.005), and they foraged less (F = 5.83; df = 1, 127; P = 0.017). We detected no other behaviors that were influenced by location (all P values > 0.17). Time spent in locomotion and in comfort behaviors were the only times affected by year, and both were generally greater in 1984 than 1985 (F = 4.21; df = 1, 127; P < 0.042; F = 11.96; df = 1, 127; P < 0.001; all other P values > 0.17). Hens accompanying small broods spent more time in comfort activities and less time moving than those with large broods (F = 6.34; df = 1, 127; P = 0.013 and F = 11.72; df = 1, 127; P < 0.001). Brood size had no effect on any other behavior (all P values > 0.05). Brood females spent comparable amounts of time resting, in locomotion, and in comfort activities. Time away from the brood and in agonistic activities were the least observed.

Most foraging time was spent in underwater dives and the least in sorting items at the surface and pausing between dives (Table 2). For the main effects model, brood age was significant (MANOVA F = 7.47; df = 3, 113; P < 0.001), but other factors were not (all P values > 0.19). Hens accompanying younger broods spent less time in dives and more time pausing between dives (F = 12.19; df = 1, 115; P < 0.001 and F = 13.70; df = 1, 115; P < 0.001), but we detected no difference in the proportion of time they spent sorting food at the surface (P = 0.72).

We detected no influence from year, location, brood age, or brood size on the proportion of agonistic activity directed at other goldeneyes versus non-goldeneye hens (all P values > 0.12). Most agonistic activity was directed at other goldeneye brood hens (81%), but some (19%) involved Mallard (*Anas platyrhynchos*) and Wood Duck (*Aix sponsa*) brood

TABLE 3

PERCENT OF DIURNAL AGONISTIC TIME SPENT IN VARIOUS ACTIVITIES BY COMMON GOLDENEYE BROOD HENS IN MINNESOTA, 1984–1985

Activity	Interacting species: Goldeneye (N = 50)	Interacting species: Other[a] (N = 17)
Surface threat	66.7 (4.9)[b]	82.2 (8.7)
Shallow dive threat	23.7 (4.3)	12.4 (6.6)
Fighting	9.6 (3.4)	5.4 (3.4)

[a] Mallard and Wood Duck.
[b] Mean (SE).

TABLE 4

PERCENT OF DIURNAL TIME SPENT IN PARENTAL CARE OR SELF-MAINTENANCE ACTIVITIES BY COMMON GOLDENEYE BROOD HENS IN MINNESOTA, 1984–1985

Activity	Island Lake (N = 78 h)	Lake Bemidji (N = 54 h)
Parental care	52.4 (2.1)[a]	45.8 (2.2)
Self-maintenance	47.6 (2.1)	54.2 (2.2)

[a] Mean (SE)

hens. However, type of agonistic activity was influenced by whether or not another goldeneye brood hen was involved (Table 3). Above water threats were more common when Mallard and Wood Duck hens were involved (F = 5.36; df = 1, 65; P = 0.024), whereas more intense dive threats and actual fighting were more prevalent when the interactions involved another goldeneye hen.

The proportion of time devoted to parental-care and self-maintenance behaviors was affected by location (F = 5.15; df = 1, 127; P = 0.025 and F = 4.75; df = 1, 127; P = 0.031) but not by year, brood age, or brood size (all P values > 0.11). Brood hens on Island Lake spent more time in parental-care activities and less time in self-maintenance than those on Lake Bemidji (Table 4).

Discussion.—Common Goldeneye hens divided their time nearly equally between parental care and self-maintenance. In contrast, Northern Pintail (*Anas acuta*) and Lesser Scaup (*Aythya affinis*) hens spent twice as much time in self-maintenance as they did in parental care (Rushforth Guinn and Batt 1985, Afton 1983). Likewise, activities that we considered self-maintenance also comprised about two-thirds of the time budgets recorded for Black Duck (*Anas rubripes*) and White-winged Scoter (*Melanitta fusca*) brood hens (Hickey and Titman 1983, Brown and Fredrickson 1987). Foraging generally is the largest fraction of self-maintenance and, except for scaup, time spent foraging by other species (35–50%) appears to be twice that of Common Goldeneyes. Foraging time was comparable to that of Lesser Scaup (Afton 1983) and Barrow's Goldeneyes (*Bucephala islandica*) (Savard 1988), and averaged 185 min/day on Island Lake and 255 min/day on Lake Bemidji. In comparison, goldeneye females on a nearby lake spent substantially less diurnal time foraging during egg laying but comparable time foraging during incubation (Zicus and Hennes 1993). Alert behavior was the major component of parental care, and goldeneye hens spent more time alert than species using less open habitat (see review in Afton and Paulus 1992).

We detected no brood-age or brood-size effects on parental investment by Common Goldeneye hens. Although these effects have been noted in other species (Morehouse and Brewer 1968, Johnson and Best 1982, and others), most studies have concerned species with altricial young. Factors influencing parental investment have been examined for some waterfowl (e.g., Afton 1983, Rushforth Guinn and Batt 1985, Lazarus and Inglis 1978), and hens of some species accompanying young broods have been reported to spend more time alert than when with older broods. However, the results have been equivocal (see review in Afton and Paulus 1992); perhaps, in part, due to difficulties in measuring alert behavior or that portion of it that is attributable to parental investment. Whereas we detected no brood-age effects on alert time, goldeneye hens spent more time pausing between foraging dives (and presumably alert) when with younger ducklings. In many studies, pauses between foraging dives have been considered foraging activity (e.g., Tome 1991, but see Brown and Fredrickson 1987). Because few relationships between brood size and parental investment have been detected, Afton and Paulus (1992) concluded that parental investment in waterfowl is largely unshared (sensu Lazarus and Inglis 1986). Although total time in parental care was unrelated to brood size, goldeneye females with larger broods moved more as the brood foraged and spent less time in comfort activities than those with smaller broods. Females appeared to move more to remain vigilant over individual ducklings that were foraging somewhat independently of their broodmates.

Of the effects we examined, only lake had a significant influence on the division of diurnal time between parental care and self-maintenance. Most previous studies have not considered the effects that different locations or years might have on brood hen time-budgets. Influences of location or year on time allocation may be large relative to effects from such factors as brood age or size, thus making them easier to detect. Island Lake brood hens foraged, on average, 70 min/day less and spent 92 min/day more time alert than those on Lake Bemidji. Furthermore, although we detected no statistical difference, hens with broods tended to move more ($\bar{x}$ = 50 min/day) on Lake Bemidji than on Island Lake. Hunter et al. (1984) observed that Black Duck and Mallard ducklings spent more time moving and searching for food after invertebrate numbers were experimentally reduced. They also speculated that greater movement and other activities associated with increased foraging combined with decreased hen attentiveness might lower duckling survival.

Brood-rearing conditions on Island Lake are likely better than those on Lake Bemidji. A shallower basin with more highly developed stands of vegetation as well as a greater MEI should provide a more productive and diverse environment for invertebrates important as food. Additionally, less recreational boating might allow hens and broods to forage with greater efficiency and spend more time alert. Despite these lake differences, our observations are consistent with conclusions by Eadie and Keast (1982) that sites supporting both goldeneyes and fish should tend towards high levels of food production and resource diversity. Lake Bemidji was a productive lake and had many goldeneye pairs and broods. We also know of overland movements to the lake by goldeneye broods (Zicus, unpubl. data). Still, a better understanding of the relationships among invertebrate productivity and diversity in wetlands, waterfowl parental investment, and ultimately hen and duckling survival is needed before questions regarding possible fish-waterfowl competition for invertebrates can be fully resolved.

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MICHAEL C. ZICUS AND STEVEN K. HENNES, *Wetland Wildlife Populations and Research Group, Minnesota Department of Natural Resources, 102 23rd St., Bemidji, Minnesota 56601.* (Present address of SKH: *2065 W. County Rd. E, New Brighton, Minnesota 55112.*)
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