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SHORT COMMUNICATION

Short communication articles are short scientific entities often dealing with methodological problems or with byproducts of larger research projects. The style should be the same as in original articles.

Identifying inter-dive intervals in time-activity budget studies of diving ducks

Ingvar Byrkjedal

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In order to identify inter-dive intervals in diving ducks, i.e. the time spent regaining breath between consecutive feeding dives, the position of the tail, carpal joints and head was recorded in different behavioural categories for eight species on the southwestern coast of Norway in March. Inter-dive intervals are part of the feeding behaviour and are easily confused with the behavioural categories of swimming and loafing. During inter-dive intervals the ducks adopt a more or less hunch-backed position, preparing for the next dive. In this position the tail touches the water surface and the head is held in a more forward position than during loafing and swimming. Some species expose carpal joints in inter-dive intervals, while most of the wings are covered by the flank feathers during non-feeding behaviour. Logistic regressions showed that a near perfect classification was obtained from the position of the wings alone in common eider *Somateria mollissima*, velvet scoter *Melanitta fusca*, and long-tailed duck *Clangula hyemalis*. An almost equally good classification was obtained for the two last mentioned on the position of the tail, for scaup *Aythya marila* on the position of the head, and for red-breasted merganser *Mergus merganser* on the position of the head and the stretching of the neck. Less reliable classifications were obtained for goldeneye *Bucephala clangula* and tufted duck *Aythya fuligula*, whereas in common scoter *Melanitta nigra* none of the variables fulfilled the criteria for entering a logistic regression function.

Key words: behaviour, methodology, time-activity budgets, waterfowl

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Recording time-activity budgets of animals is a frequently used technique in studies of social behaviour, energetics, and behavioural responses to environmental conditions. Two methods of temporal sampling of behaviour are in common usage: scan-sampling and focal-animal sampling (Altmann 1974). In scan-sampling, the behaviour of a number of individuals is recorded as the individuals are scanned at instances spaced at fixed time intervals. In focal-animal sampling an individual animal is observed over a certain

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time span, behaviour either recorded continually or at fixed instances. While focal-animal sampling gives a more detailed time budget of individuals, the number of individuals sampled per time unit is bound to be restricted. Scan-sampling may give information from a large number of individuals, but may lose out on less frequent, but important behaviour.

In scan-sampling, categorisation of observed behaviour must be done more or less immediately as the view is shifted across individuals (e.g. Campbell 1978, Austin 1987). Confident identification of behavioural categories may be difficult, and more so the shorter time spent watching each bird to identify its behaviour. Also focal animal sampling based on continual timing of behaviour requires immediate recognition of behavioural categories for the observer to time activities accurately.

In birds that dive from lying on the water surface, the distinction between swimming and loafing on the one hand and inter-dive intervals on the other may be difficult to make. In time-activity budgets, inter-dive intervals are usually considered part of the feeding behaviour. However, the behaviour of a bird paddling a few strokes or lying motionless on the surface could be classified as swimming (locomotion) or loafing (resting) when feeding actually might have been the correct behavioural category. A standard way to record behaviour as either would be desirable, and confident identification of these behavioural categories would lead to a higher consistency in time-activity recordings of these species.

In some studies of diving ducks a time criterion has been used to separate inter-dive intervals from loafing (e.g. <15 secs vs >15 secs, Austin 1987; <30 secs vs >30 secs, Brown & Fredrickson 1987), while a few studies separated these behavioural categories on the basis of postures, notably those of the head and neck (Brown & Fredrickson 1987, Bergan, Smith & Mayer 1989, Hohman & Rave 1990), but none of the studies showed how reliably different postures could be used to distinguish between the behavioural categories.

In studies of time-budgets of velvet scoters *Melanitta fusca* (Byrkjedal, Eldøy, Grundetjern & Løyning 1997) I noticed that the position of wings, tail, and perhaps head varied between activities. Position of wings, tail or head can be relatively easily observed, and a consistent link to particular behavioural categories would make them convenient for behavioural categorisation. I recorded these variables in seven species of diving ducks and one merganser in the non-breeding season to find out whether they could be used to identify inter-dive intervals from loafing and swimming, other kind of non-feeding behaviour being readily identified from specific actions (bill tucked in scapulars while sleeping, manipulating plumage while preening, powerful locomotion with stretched neck while performing alert swimming, display postures and movements in social behaviour (e.g. McKinney 1965, Johnsgard 1965)).

Material and methods

To clarify terms, an inter-dive interval ('pausing between dives', Goudie & Ankney 1986, Beauchamp 1992; 'dive pause', Austin 1987, Brown & Fredrickson 1987, Zicus & Hennes 1993; 'preparation for diving', Hohman & Rave 1990; 'inter-dive loaf', Bergan et al. 1989, Frimer 1994) is the time spent between two dives in order for the bird to regain breath and recover physiologically to continue diving for food (Beauchamp 1992). The term loafing, here used in a narrow sense, denotes a resting category distinguished from sleeping by bill not being tucked into the shoulder feathers (e.g. Brown & Fredrickson 1987); the birds appear to do nothing in particular. In a broader sense, however, some authors include resting, preening and comfort movements, and roosting, in this term (Cramp & Simmons 1977, Goudie & Ankney 1986).

The present study was performed in March 1996 along the coast of Jæren, southwestern Norway (see Byrkjedal et al. (1997) for a brief description of this coast and its waterfowl). I recorded behaviour of the following species: tufted duck *Aythya fuligula* (122 birds), scaup *A. marila* (32), common eider *Somateria mollissima* (51), long-tailed duck *Clangula hyemalis* (56), common scoter *Melanitta nigra* (117), velvet scoter (23), goldeneye *Bucephala clangula* (70), and red-breasted merganser *Mergus serrator* (25 birds). I observed the birds from vantage points along the coast, at distances of 50-300 m, using 8X binoculars and a 15-45X telescope, and recorded the position of the tail (two positions: on water - out of water), head (four positions: between shoulders, bill tip aligning with, or behind breast - central part of bill aligning with breast - base of bill aligning with breast - base of bill forward beyond breast), and wings (two positions: carpal joint lowered and exposed - hidden in flank feathers), in inter-dive intervals and in swim-

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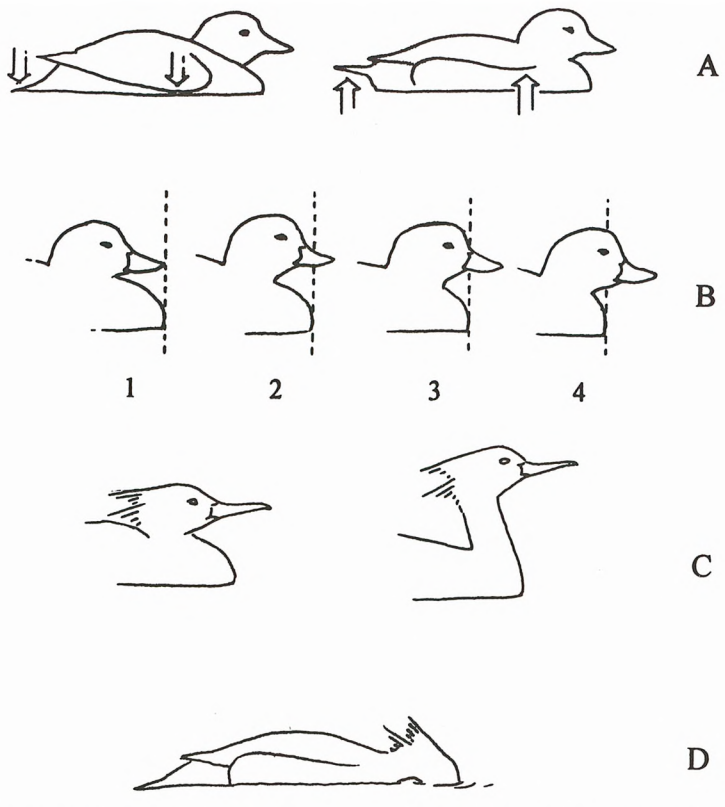


Figure 1. Postures of tail, wing, and head recorded in various behavioural categories. Tail and wing positions were recorded in two position categories (A) while four categories were used to record the head position (B), the latter being defined as the bill's position relative to the breast (1-4 are the head positions referred to in Figure 2). Retracted and erect neck, recorded for red-breasted merganser, is indicated in (C), while merganser peering under water is shown in (D).

ming and loafing. Furthermore, in red-breasted merganser it soon became apparent that the neck was held either in a stretched or a retracted position, and the position of the neck was recorded in this species. Also, peering under water, a behaviour found in birds hunting by pursuit-diving (Cramp & Simmons 1977, MacIntyre 1989) and frequently seen in mergansers, was recorded. The positions are evident from Figure 1.

Actively diving birds that could be tracked individually were observed continually for a varying period of time, dependent on observation conditions. Each inter-dive interval was timed with a stop watch and the position of the tail, wings, and head recorded. During feeding ducks dive in bouts (Guillemette, Ydenberg & Himmelmann 1992), comprising a number of dives performed with a certain regularity. The duration of inter-dive intervals, i.e. when birds did not change behaviour between dives into sleeping, preening, or social activity, was on average considerably shorter than half a minute for the species studied (average 10-26 secs depending on species), and only rarely exceeded one minute, maximum values varying between 29 secs and 67 secs (Dow 1964 and pers. data). After feeding bouts, bouts of preening, sleeping, loafing, or swimming follow and these bouts may last 10-20 minutes per bird. In order to augment the material on loafing and swimming, I adopted a sampling procedure whereby I watched each target bird for three minutes to be sure that it did not dive, a period of time far in excess of the inter-dive intervals found while watching feeding birds continually.

Statistical computations were done using SAS, version 6.11 (1996). I classified inter-dive intervals vs swimming-loafing from logistic regressions, using the all possible subsets algorithm. Logistic regression functions were found for each predictor variable and for all combinations of two or more predictor variables that showed a significant chi-square score value. Estimates of correct classification rates from the various functions were obtained by the jackknife method. Frequencies were compared using log-likelihood ratio G-tests.

Results

In none of the species did positions of tail, head or wings differ significantly between swimming and loafing ($P > 0.05$, G-tests, swimming making up the following proportions of the two activities: 43% in tufted duck, 79% in scaup, 74% in common eider, 78% in long-tailed duck, 71% in common scoter, 73% in velvet scoter, 69% in goldeneye and red-breasted merganser; numbers, see Fig. 2). Following this result, swimming and loafing were pooled for each species, to be tested against inter-dive intervals, the two non-feeding activities most likely to be confused with inter-dive intervals.

A tendency to adopt a more forward-positioned head during inter-dive intervals than during swimming and loafing was seen in all eight species, and a

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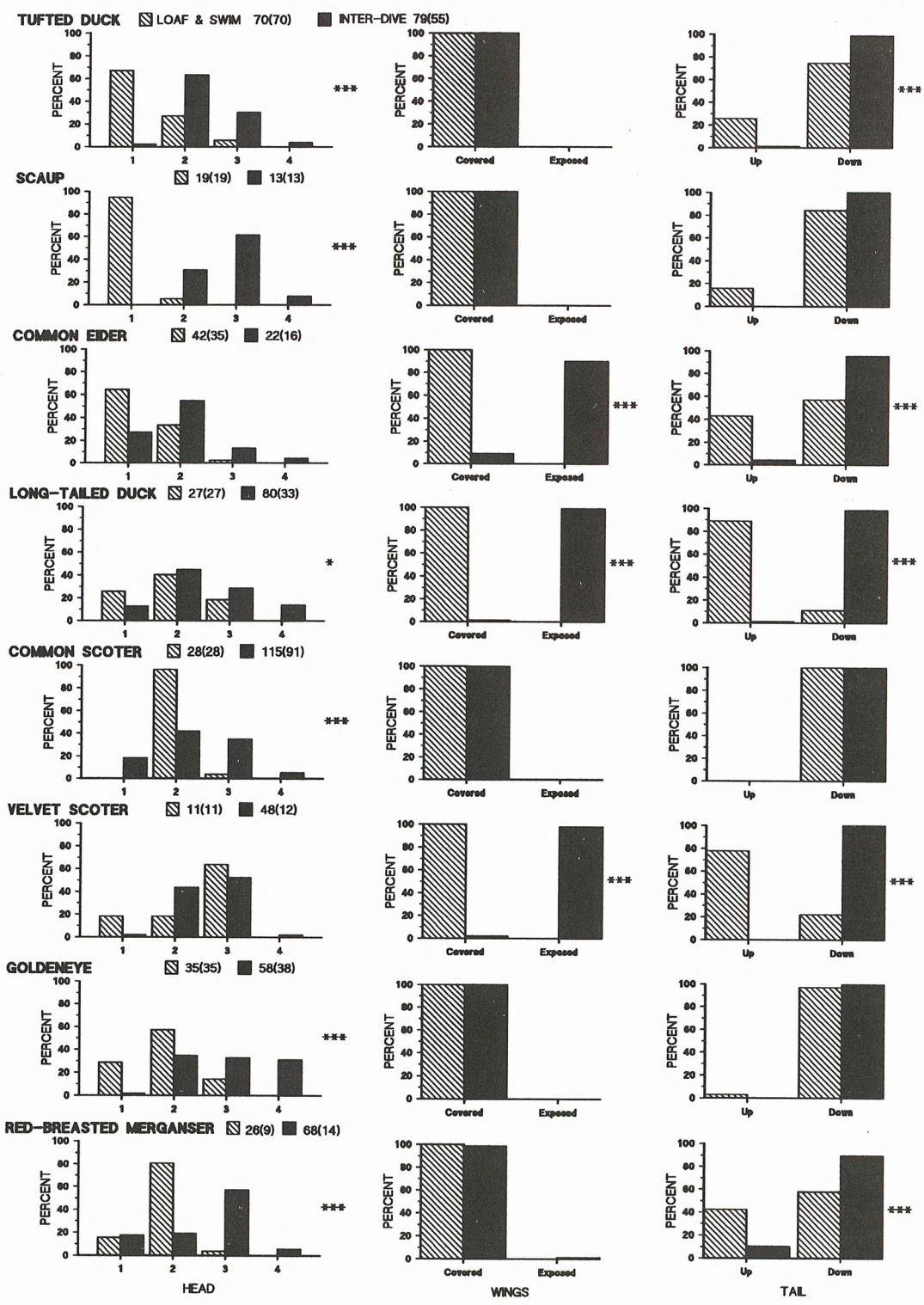


Figure 2. Positions (as percentage of cases) of head, wings and tail in seven species of diving ducks and one merganser during loafing and swimming (shaded) and during inter-dive intervals (black). Number of cases observed are given for each species, with number of individuals in parentheses. Asterisks indicate significance levels of G-tests for differences between the two behavioural categories (*** $P < 0.001$, * $P < 0.05$).

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significant difference was found for all but common eider and velvet scoter (Fig. 2). A variation in the position of the wing with behaviour was found for common eider, long-tailed duck and velvet scoter, and these three species exposed their carpal joints in a lowered position significantly more often during inter-dive intervals than during loafing and swimming. During the latter, the carpal joints and most of the wings were hidden by the flank feathers. In all eight species the tail was on the water surface during almost all the inter-dive intervals (see Fig. 2). Tail held above the water was to a varying degree associated with the non-feeding activities except in scaup, common scoter and goldeneye; in the other species the differences were statistically highly significant.

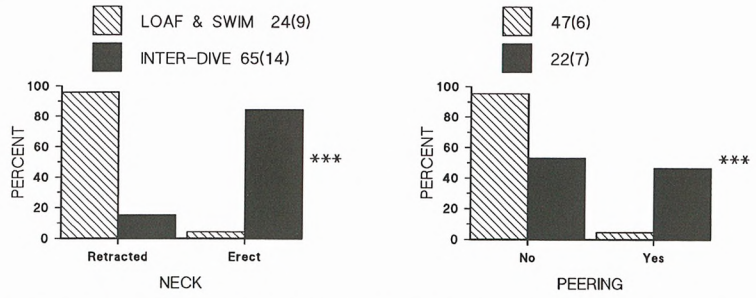


Figure 3. Positions of neck and occurrence of underwater peering (percentage of incidents) in red-breasted merganser during loafing and swimming and during inter-dive intervals. Legends as in Figure 2.

In red-breasted merganser the neck was significantly more often erect during inter-dive intervals, and the birds peered under the water significantly more often, than during swimming and loafing (Fig. 3). However, whereas during swimming and loafing the neck was virtually always retracted and peering almost absent, either states of neck and peering was frequently recorded during inter-dive intervals.

Table 1. Logistic regression functions on the independent variables from maximum likelihood estimates, their score values, and jackknife classification results. Only functions with significant score values are given. In combined variable functions only variables with significant score values in single-variable functions were entered. Asterisks indicate significance levels (** P<0.01, *** p<0.001, **** P< 0.0001).

				% correctly classified		
Species	Functions (logit (P)=)	χ^2 score values	(DF)	Overall	As inter-dive interval	As swimming and loafing
Tufted duck	-4.964 + 2.781*Head	60.53****	(1)	83.9	97.5	68.6
	3.794 - 3.369*Tail	21.39****	(1)	65.1	98.7	27.1
	-0.774 - 4.154*Tail + 2.909*Head	68.11****	(2)	85.2	96.2	72.9
Scaup	-24.720 + 13.053*Head	25.99****	(1)	96.9	100	94.7
Common eider	29.885 - 16.465*Wings	55.54****	(1)	96.9	90.0	100
	3.119 - 3.140*Tail	14.35***	(1)	34.4	0	52.0
	-2.882 + 1.367*Head	10.27**	(1)	70.3	18.2	97.6
	53.288 - 10.317*Tail - 22.637*Wings	55.91****	(2)	95.3	86.4	100
	76.310 - 8.021*Head - 35.446*Wings	55.64****	(2)	95.3	86.4	100
	1.059 - 2.833*Tail + 1.069*Head	19.03****	(2)	78.1	72.2	81.0
	86.002 - 10.158*Tail - 8.062*Head - 34.787*Wings	56.07****	(3)	95.3	86.4	100
Long-tailed duck	32.414 - 17.855*Wings	101.89****	(1)	99.1	98.8	100
	9.720 - 6.449*Tail	86.59****	(1)	96.3	98.8	88.9
	-0.624 + 0.788*Head	7.172**	(1)	74.8	100	0
	56.140 - 11.808*Tail - 22.716*Wings	102.77****	(2)	98.1	97.5	100
	35.712 + 10.161*Head - 33.902*Wings	101.97****	(2)	99.1	98.8	100
	7.705+ 0.994*Head - 6.513*Tail	86.96****	(2)	96.6	98.8	88.9
	29.874 - 10.536*Tail + 8.716*Head - 20.724*Wings	102.83****	(3)	99.1	98.8	100
Velvet scoter	3.009 - 17.204*Wings	52.86****	(1)	98.3	97.9	100
	19.279 - 16.100*Tail	46.34****	(1)	96.6	100	81.8
	36.534 - 12.229*Tail - 12.499*Wings	54.61****	(2)	94.9	97.9	81.8
Goldeneye	-3.765 + 1.819*Head	28.36****	(1)	71.7	63.2	85.7
Red-breasted merganser	-5.673 + 4.840*Neck	48.62****	(1)	87.6	84.6	95.8
	-1.164 + 0.989*Head	9.98**	(1)	64.0	81.5	16.7
	2.956 - 1.604*Tail	8.49**	(1)	75.3	89.2	37.5
	-4.494 + 4.705*Neck - 0.805*Tail	49.29****	(2)	87.6	84.6	95.8
	-5.711 + 0.034*Head + 4.815*Neck	48.63****	(2)	87.6	84.6	95.8
	0.815 - 1.648*Tail + 1.008*Head	17.13***	(2)	80.9	96.9	37.5
	-4.527 - 0.805*Tail + 0.030*Head + 4.681*Neck	49.29****	(3)	87.6	84.6	95.8

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Jackknife estimates of classification results from the logistic regressions gave an overall 96-99% correct classification of inter-dive intervals, and swimming and loafing, in common eider, long-tailed duck, and velvet scoter on the basis of the position of the wings, in long-tailed duck and velvet scoter also on the position of the tail, and in scaup on the head position (Table 1). The best classification was obtained from head position also in tufted duck and goldeneye, but the correct classification rates were lower (84% and 72%). In red-breasted merganser neck position offered the best classification results (88%), the variable 'peering' often used in inter-dive intervals having been recorded in only a limited number of cases and hence not included in the logistic regression. None of the single best variable classifications were improved by adding variables to the functions, except for a slight improvement in tufted duck by entering head and tail. Classifications from head and tail improved slightly if these variables were combined also in common eider, long-tailed duck, and red-breasted merganser. No classification results were computed for common scoter, as none of the variables contributed significantly to a logistic regression function for this species.

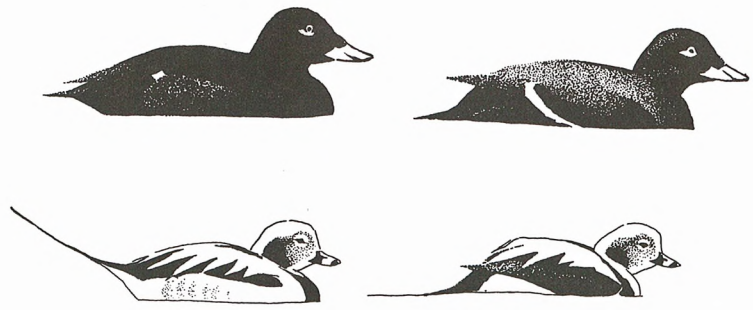


Figure 4. Typical positions in loafing (left) and inter-dive intervals (right) of velvet scoter (top) and long-tailed duck, showing changes in exposed plumage patterns dependent on the position of the wings.

Discussion

The study shows that the position of tail, wings, and head can be successfully used to differentiate between inter-dive intervals (part of the feeding behaviour) and swimming-loafing behaviour in ducks. In all eight species the tail was held down on the water and the head was in the more forward position during inter-dive intervals. This, somewhat hunch-backed posture, is probably efficient for initiating a dive, starting with both feet being brought forward to the mid-sternum region to facilitate a power stroke for the forward rotation (Brooks 1945, Humphrey 1957, Tome & Wrubleski 1988). During swimming, loafing and other non-feeding activities feet are held more posteriorly and a less hunched posture with a lifted tail results.

The best separation of behavioural categories is obtained in species which vary in the position of their carpal joints. These are the species which open their wings slightly while diving (eiders, long-tailed duck, velvet scoter). The wings are used under water for propulsion and/or steering in these species (Brooks 1945, Humphrey 1957, 1958, Cramp & Simmons 1977, Snell 1985), probably necessitated by a high buoyancy and perhaps partly by relatively small paddles (Raikow 1973, Lovvorn & Jones 1991). Species not using their wings under water (members of *Aythya, Bucephala*, and *Merganser*, and common scoter) do not show exposed carpal joints during inter-dive intervals or in non-feeding behaviour. Judging from Brooks (1945), Tome & Wrubleski (1988), and personal casual observations of single birds, prediction from phylogenetic relationships can probably be made based on this characteristic, extending its usefulness to species not covered by the present study, e.g. surf scoter *Melanitta perspicillata*, king eider *Somateria spectabilis*, and Steller's eider *Polysticta stelleri*. However, the fact that common scoter differed from velvet scoter shows that caution is necessary when inferring from phylogenetic relationship. Yet, the lack of exposed carpal joints in common scoter conforms with the lack of underwater use of wings (Brooks 1945, Cramp & Simmons 1977).

While the position of the tail and carpal joint may be convenient characters to observe, the position of the head may be less easily judged, although it may yield reliable classification of behaviour. In common scaup and goldeneye, this seems the only practical characteristic to use. In red-breasted merganser the position of the head along with that of the tail gave a useful basis for classification.

In some of the species, wing position may be especially easy to see, as characteristic plumage patterns are associated with the position. In long-tailed duck and velvet scoter this is readily apparent (Fig. 4). In

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velvet scoter a lowered wing exposes the white wing speculum, whereas most or all of the speculum is hidden when the wings are covered in the flanks, a situation apparently also found in female common and Steller's eiders, showing white speculum margins (Högström 1977, pers. obs.).

Classification of behaviour using the criteria outlined above can be of help in standardising categorisation of duck behaviour, and may speed up the recording of activities in time-activity budget studies. Although inferences might be made to closely related species not included in this study, I nevertheless recommend that some time is spent familiarising oneself with the behavioural patterns and postures of target species before recording of behaviour is initiated.

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