Winter Age Ratios and the Assessment of Recruitment of Harlequin Ducks

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Abstract.—Recruitment is the process by which young birds are added to the breeding population. The two most commonly used methods to estimate recruitment in ducks are pair/brood counts, and fall age ratios based on wings returned by hunters. Direct counts on the wintering area to determine the proportion of young males to adult males (age ratios), can be used for species with delayed plumage maturation. This is useful for species that are difficult to study on the breeding grounds and are seldom hunted, such as Harlequin Ducks (*Histrionicus histrionicus*). Such an approach is only valid if age classes are equally sampled. Between 1994 and 1999, the proportion of male Harlequin Ducks that were immatures in the Strait of Georgia, British Columbia, was estimated at 0.068. The proportions differed across years. Little difference occurred through the winter months until spring, when there was a significant increase in proportions in March. If these age ratios are accurate, then recruitment would not be compensating for annual adult mortality and the population could have been declining during the period of our study. However, if immature males are not distributed evenly among the population, then our assessment may underestimate or overestimate proportions. Delayed breeding means that immature birds experience several additional seasons of mortality prior to breeding, and thus the actual recruitment rate into the breeding population would be lower than that presented here. *Received 11 April 2000, accepted 18 July 2000.*

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Population size is a function of both how many individuals are added to it, through birth or immigration, and how many leave it, through death or emigration. The process by which young birds are added to the breeding population is known as recruitment and reflects natality and pre-breeding mortality (Cowardin and Blohm 1992). For a population to remain stable, each breeding adult must recruit at least one individual into the breeding stock (Owen and Black 1990). For large populations that are difficult to count, recruitment cannot be measured directly, but must be estimated.

The two most commonly used methods to estimate recruitment of ducks are pair/brood counts and autumn age ratios. A pair count, followed by a brood count on the same area, is used as an index to recruitment. This method is often suspect because it does not account for loss of entire broods, and the number of broods is often underestimated due to the ducklings' tendency to hide in emergent vegetation (Cowardin and Blohm 1992). Such counts also exclude nonbreeding females. Autumn age ratios are the proportion of all ducks that are immature. Immature males can be distinguished from adult males by plumage (Weller 1980), but usually only in the hand. For most duck species, age ratios are obtained from wings turned in by hunters (Bellrose *et al.* 1961; Cowardin and Blohm 1992). This method, used as a relative measure across years, needs

to be corrected for differential vulnerability of the age and sex classes to hunting, relative recovery rate and hunter effort.

Age ratios, based on direct counts of birds on both autumn staging and wintering areas after hunting seasons close, do not require the extensive corrections of wing-based ratios. Direct field counts are themselves subject to potential sources of error, most of which involve ability to sample age classes equally: timing of migration, geographic location, accurate identification of age classes, differential use of habitats and behavioral differences between age groups, and variable group composition (Owen 1980; Lambeck 1990). This method has been used successfully for Arctic-breeding geese (Ebbinge 1985; Lambeck 1990; Ely *et al.* 1993), but to our knowledge has only been used in one duck, the Common Goldeneye (*Bucephala clangula*) (Duncan and Marquiss 1993).

Obtaining age ratios on the wintering area can be particularly useful for species that are difficult to study during the breeding season, such as the Harlequin Duck (*Histrionicus histrionicus*). Also, this species is seldom hunted, so wings are rarely found in hunter-based samples. This small sea duck breeds at low densities along fast-flowing streams and rivers in mountainous terrain throughout its range (Palmer 1976). Broods can be difficult to observe in this habitat. On the wintering areas, however, these birds feed and rest within shallow near shore waters of the rocky coastal zone. Age ratio counts only work in the field if plumages are distinct and non-overlapping. Due to a partial body molt into first alternate plumage in autumn (Witherby *et al.* 1943; Palmer 1976; Cramp and Simmons 1977), hatch-year males can be distinguished from females as early as late September (Smith *et al.* 1998), and attain definitive alternate plumage after the following year's autumn molt (Robertson *et al.* 1997).

Between 1994 and 1999, we studied a population of Harlequin Ducks wintering in the Strait of Georgia, British Columbia. Our objective was to estimate the proportion of immature males in the population and thus provide an index of recruitment. To check for biases in the protocol we also investigated annual, seasonal and site-specific differences.

Methods

The main study area was in the Strait of Georgia, British Columbia and encompassed the shore of Vancouver Island, from Sooke (123°43'W, 48°21'N) to Campbell River (125°13'W, 49°59'N), including Denman, Hornby and Quadra islands. Occasional observations were included from the east side of the Strait, between Powell River and White Rock.

We counted Harlequin Ducks in the autumn and winter months (November to March) between fall 1994 and spring 1999. We started our surveys in November because by then all juveniles have arrived from the breeding areas and should have had time to molt into first alternate plumage. We ended our surveys in March because in April many adult males leave for the breeding streams. Observations were made from land using 8 × 30 binoculars and 20-60× telescopes. All individuals were identified as to sex, based on plumage characteristics, and males were aged as immature or adult. Observations from December 1994 to March 1996 are from Goudie (1996). Goudie originally thought that there were two age classes with subadult plumages, but Smith *et al.* (1998) showed that only one class exists, so all males showing incomplete adult plumage were classed as immatures.

Twelve road-accessible survey sites were identified between Hornby Island and Quadra Island. These sites varied in length from a few hundred meters to several kilometers of shoreline. Five surveys from these locations between October 1997 and March 1999 were used to investigate seasonal trends and site usage.

Areas not accessible by road were surveyed by inflatable boat during 10-16 December 1998. By traveling at slow speed, the observers were generally able to approach to within 50 m of groups of Harlequin Ducks. Distance from boat to shore during surveys varied due to exposed rocks, but averaged 100 m. Two observers used 8 × 30 binoculars to scan groups of birds to classify them by sex, and the males by age as above. Birds that were too far away from the boat to be classified were not counted. This survey was used to compare proportions among sites, but was not included in overall numbers because it occurred outside of the roadside survey areas.

Variation in the proportion of immature males by year, season, or by site were analyzed using the G-test (Fowler and Cohen 1996). The data for birds observed by year and by season are not independent, as some sites were visited more than once, and cumulative totals are given.

We define year as the winter months, November to February, spanning two calendar years (e.g., 1997-1998). Observations from March are considered separately, in comparison to the rest of the winter. Unless otherwise noted, proportion (prop.) refers to the ratio of immature males to total males, P is significant at <0.05, and 95% confidence interval (CI) is presented.

Results

During random observations and site surveys the combined proportion of immature

males from November to February was 0.068 (range 0.042-0.082; Table 1) between 1994 and 1999. The ratio differed significantly among years ($G_4 = 17.59$, $P < 0.01$), but linear regression analysis showed that there was no trend ($R^2 = 0.079$, n.s.).

Age ratio differed among months, from November to February, in one of four years (Table 2). In three of the four years, there was an increase in the mean proportion from February to March (Fig. 1; 1995, $G = 22.7$, $P < 0.001$; 1997, $G = 8.8$, $P < 0.01$; 1998, $G = 0.26$, n.s.; 1999, $G = 54.1$, $P < 0.001$).

Analyses of roadside surveys showed significant differences in proportions of immature males at different locations on two of the five roadside surveys (Table 3). During the boat survey during 10-16 December, 1998, the mean proportion of immature males was 0.089 (N = 1,015), but ranged from 0.034 to 0.161 among the five areas (Table 4). These differences between sites were highly significant ($G_4 = 28.6$, $P < 0.001$).

DISCUSSION

To maintain a stable population, the rate of recruitment must be equal to annual adult mortality. During the five years of our study, the mean proportion of immatures in the male Harlequin Duck population (our index of recruitment) in the Strait of Georgia, British Columbia, did not exceed 10%; this rate is below what is required to offset annual adult male mortality. The local mortality rate of adult males was estimated at ca. 18% at White Rock, British Columbia, from 1994 to 1999 (Cooke *et al.* 2000). There are four possible explanations for the apparently low proportions: 1) immature males misidentified as females, 2) high proportions of immatures in other locations where we did not survey, 3) local adult survival rates in the literature are underestimated, or 4) the proportions are real and the population is declining.

All seven marked hatch-year males observed in the autumn were distinguishable from females by mid-October (Smith *et al.* 1998). One marked immature male observed on 9 October 1998, and again on 26 February 1999, was given the same plumage score both times (C. Smith, unpubl. data; H. Regehr and M. Rodway, pers. comm.). This suggests that there is no change in plumage characteristics that would make immature males either easier to distinguish from females or more difficult to distinguish from adult males, as winter progresses, thereby affecting age ratios.

If immature males were not distributed evenly among the population then we might expect significant variation among sites or seasons. Site differences were significant on two of the five roadside surveys, and during the single boat survey. We tested seasonal differences by comparing proportions through the winter, partitioned by month. Seasonal differences could also have been influenced by survival if immatures have lower survival than adult males. There was a significant difference in proportions from November through February in only one of the four years. This suggests that immature survival was relatively constant through the winter.

Table 1. Number of Harlequin Ducks observed in the Strait of Georgia, British Columbia, 1994-1999, by age and sex (F = females, M = males) class.

Year[a]	Total	F[b]	M[c]	Adult M	Imm. M	Proportion[d]	95% CI
1994-1995	1423	580	843	779	64	0.076	+0.030 to +0.122
1995-1996	1071	433	638	586	52	0.082	+0.026 to +0.137
1996-1997	526	219	307	294	13	0.042	-0.071 to +0.156
1997-1998	2413	1036	1377	1310	67	0.049	+0.013 to +0.084
1998-1999	4006	1682	2334	2156	178	0.076	+0.055 to +0.098
Total	9439	3950	5499	5125	374	0.068	+0.056 to +0.080

[a]November to February.
[b]Adult and immature females.
[c]Adult and immature males.
[d]Proportion of all males that are immature.

Table 2. Tests for homogeneity in the proportion of immature male Harlequin Ducks to adult males in the Strait of Georgia, British Columbia, November to February, 1994-1999. The proportion, number of adult males and number of immature males given for each month. G-test statistic, degrees of freedom and probability reported for monthly comparisons in each year.

Year[a]		Months				G	d.f.	P
		Nov.	Dec.	Jan.	Feb.			
1994-1995	Proportion	n.d.[b]	0.058	0.098	0.081	3.05	2	n.s.
	Adult male	n.d.	310	185	284			
	Imm. male	n.d.	19	20	25			
1996-1997	Proportion	n.d.	n.d.	0.038	0.047	0.02	1	n.s.
	Adult male	n.d.	n.d.	127	163			
	Imm. male	n.d.	n.d.	5	8			
1997-1998	Proportion	0.033	0.038	0.108	0.076	11.15	3	<0.025
	Adult male	297	585	74	182			
	Imm. male	10	23	9	15			
1998-1999	Proportion	0.075	n.d.	n.d.	0.055	1.50	1	n.s.
	Adult male	826	n.d.	n.d.	308			
	Imm. male	67	n.d.	n.d.	18			

[a]Only one month available for 1995-1996; no comparison possible.
[b]No data available for this month.

There was a highly significant increase in proportions, however, from February to March, driven by very high proportions of immature males at Hornby Island. This might have occurred for two reasons: 1) Immature birds may winter in small numbers scattered throughout the Strait, or in large aggregations outside our study area, and then migrate to Hornby Island in spring. They may follow adults to participate in social behavior, or to exploit the spawn of Pacific Herring (*Clupea pallasi*) (Haegele 1993). Unpaired Barrow's Goldeneye (*Bucephala islandica*) males and yearlings sometimes form large flocks separate from females (Savard 1987); 2) The high proportions observed in March could be caused by early movements of adult males, particularly unpaired birds, to the breeding grounds. Unpaired males were observed on breeding streams in the Cascade Mountains in Oregon by 22 March, when Bruner (1997) started fieldwork. Rosenberg and Petrula (1998) suggested that age ratios were higher in spring surveys (prop. = 0.31, N = 9,312) than in their one winter survey because of movements by adult males to breeding areas. Their departure might vary year-to-year depending on environmental variables.

The occasional differences in proportions between sites on roadside surveys and on the one boat survey, and the sudden increase in some years in March, show weak support for clumped distribution of immature birds. However, surveys need to be conducted over a broader study area to investigate this possibility. The low proportions of immature male Harlequin Ducks observed in the Strait of Georgia are similar to proportions observed in other areas. In Prince William Sound, Alaska, from 13-19 March, 1997, the ratio was 0.09 (N = 1,679 males total; Rosenberg and Petrula 1998). Winter age ratio surveys in Iceland showed a ratio of 0.09 from January to March.

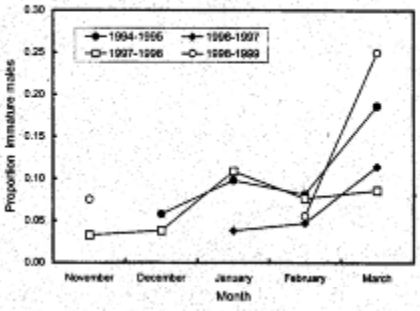

Figure 1. Seasonal trends (November to March) in proportion of male Harlequin Ducks that were immature in the Strait of Georgia, British Columbia, for 1994-1995 and 1996-1999.

Table 3. Tests for homogeneity in the proportion of immature male Harlequin Ducks to adult males in the Strait of Georgia, British Columbia, between sites on specific surveys, 1997-1999. The means and ranges (in parentheses) of proportions, number of adult males and number of immature males are given for each survey. G-test statistic applies to site comparisons within survey; degrees of freedom and probability reported.

Survey date	No. of sites[a]	Proportion	Adult male	Imm. male	G	d.f.	P
29-31 Oct., 1997	7	0.045 (0-0.125)	39.7 (7-111)	1.9 (0-6)	6.36	6	n.s.
4-9 Dec., 1997	8	0.039 (0-0.127)	71.0 (33-112)	2.9 (0-10)	20.2	7	<0.01
19-20 Feb., 1998	6	0.076 (0-0.129)	30.3 (7-66)	2.5 (0-8)	8.01	5	n.s.
8-11 Nov., 1998	12	0.076 (0-0.289)	50.6 (8-151)	4.8 (0-13)	39.0	11	<0.001
25 Feb. - 1 Mar., 1999	11	0.052 (0-0.200)	31.5 (6-80)	1.7 (0-4)	16.8	10	n.s.

[a]Number of sites sampled during survey.

1999 (N = 1,314; A. Gardarsson, unpubl. data). Winter (January to March) ratios at Isle au Haut, Maine, between 1989 and 1998 averaged 0.11 (N = 1,700 ± 0.008), but ranged from a low of 0.03 in 1991 to 0.22 in 1996 (Mittelhauser 1999). There has been an increasing trend in proportion of immature males over the 10-year period, corresponding to an increasing trend in that wintering population (G. Mittelhauser, unpubl. data).

CONCLUSIONS

Our finding of low proportions of immature Harlequin Ducks on the wintering area in the Strait of Georgia, British Columbia, is cause for concern. If these age ratios are accurate, then recruitment would not be compensating for annual adult mortality and the population was declining during the period of our study. Of our three hypotheses, one needs more detailed investigation: Do immature males aggregate in some areas, resulting in higher proportions of immatures wintering beyond our study area?

While our age ratios provide an index of recruitment, true recruitment only occurs when new individuals enter the breeding population (Cooke and Francis 1993). This may be confounded by delayed breeding, which is common in sea ducks (Goudie *et al.* 1994). If birds breed in the first year of life, the proportion of immature males is a good reflection of the proportion of recruits. With delayed breeding, however, immature birds experience several additional seasons of mortality prior to breeding (Cooke *et al.* 1991), and thus the actual recruitment rate

Table 4. Number of Harlequin Ducks observed in the Strait of Georgia, British Columbia, at various locations during a boat survey, 10-16 December 1998, by age and sex (F = females, M = males) class.

Location	Total	F[a]	M[b]	Adult male	Imm. male	Proportion[c]	95% CI
Gulf Is.	203	81	122	104	18	0.148	-0.012 to +0.307
Hornby Is.	499	203	296	286	10	0.034	-0.090 to +0.158
Denman Is.	416	171	245	226	19	0.078	-0.037 to +0.192
Quadra Is.	356	146	209	189	20	0.096	-0.026 to +0.217
Cortes Is.	257	114	143	120	23	0.161	-0.023 to +0.299
Total	1731	715	1015	925	90	0.089	0.051 to +0.127

[a]Adult and immature females.
[b]Adult and immature males.
[c]Proportion of all males that are immature.

of young Harlequin Ducks into the breeding population would be lower than the proportions recorded during our surveys.

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