Using the proportion of juvenile waders in catches to measure recruitment

JACQUIE A. CLARK, ROBERT A. ROBINSON, NIGEL A. CLARK & PHILIP W. ATKINSON

BTO, The Nunnery, Thetford, Norfolk IP24 2PU, UK. jacquie.clark@bto.org

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As it is difficult to collect data on the success of breeding in the high arctic, the proportion of juvenile waders in catches outside the breeding season has been used to provide a measure of recruitment. This paper considers different ways of assessing the proportion of juveniles among waders in the non-breeding season and recommends the use of an individual-based index using a generalised linear model.

INTRODUCTION

Counts of non-breeding waders allow workers to assess the size of the population outside the breeding season, monitor trends in numbers and distribution and to assess the importance of individual sites (Kershaw & Cranswick 2003, Pollitt *et al.* 2003, Rehfisch *et al.* 2003). The underlying causes of any changes in populations can be investigated using information on survival rates, productivity and dispersal, allowing any conservation action to be focused at the appropriate stage of the life cycle. For long-lived species, changes in demography may be identified before changes in numbers (Baillie *et al.* 1999). It is therefore important to monitor demographic factors as they may give the first warning of problems for a population that may lead to declines. However, for migrant birds, the collection of demographic data may pose problems as there may not be access to information from both the breeding and wintering areas. Survival rates can be calculated from ringing and subsequent reports (recoveries) of ringed birds recaught (at or away from the original site of ringing), resighted (for colour-marked birds) or found dead. Ringing and recovery data can also provide information on movements between wintering sites. The collection of extensive productivity data at breeding sites has proved problematic as many wader species occupy vast and often remote breeding ranges (Cramp & Simmons 1983) and wader chicks leave the nest shortly after hatching.

In recent years, information from various workers in the arctic describing and analysing breeding conditions has been gathered together in *Arctic Birds* (e.g. Soloviev & Tomkovich 2003). *Arctic Birds* gives reports from individual locations and summarises information on weather, rodent abundance, predators, distribution and numbers of breeding waterfowl and breeding success. However, figures for breeding success may only be available for a few sites. An alternative approach is to use the proportion of juveniles on the wintering grounds (i.e. recruitment into the wintering population) as a measure of productivity, which might provide a useful index. Using data from the non-breeding grounds has the advantage that all surviving offspring, that have completed migration, are included. This is particularly useful for precocial species where it is often difficult to estimate the numbers fledged directly (Crick & Baillie 1996).

Juvenile proportions have been obtained from counts (e.g. Summers & Underhill 1987, Fox *et al.* 1989, Fox & Gitay 1991, Ebbinge 1992, Ebbinge & Spaans 1995), wings returned from quarry species (e.g. Clausager 2003) and catches of waders (e.g. Summers & Underhill 1987, Underhill *et al.* 1989, Minton *et al.* 2003a, b). For a review, see Minton (2003). For example, adult/juvenile ratios for Red Knot *Calidris canutus* have been used to investigate the contribution of survival and recruitment to population trends (Boyd & Piersma 2001) and data for Red Knot and Eurasian Oystercatcher *Haematopus ostralegus* wintering on the Wash, England, have been used successfully in a population model which suggested that recruitment rather than any long-term changes in survival had tended to drive changes in the number of birds in the population (Atkinson *et al.* 2003).

Cannon nets can be used to catch a relatively large number of birds at one time; for waders this is usually at a high tide roost. Ringers catching birds in cannon nets in Britain are required to make a return to the British Trust for Ornithology (BTO) for each catch, giving the numbers of each species caught and indicating to what degree the birds had been disturbed before the catch. In order to gather information for a recruitment index, a form dividing the catch into adults, juveniles and birds of unknown age of each species was introduced in 1990. Since then, the proportion of juveniles in cannon net catches has been collected for 3,156 different samples of 124,669 waders. This paper uses the numbers of adult and juvenile Dunlin *Calidris alpina* in winter cannon net catches in Britain to explore the use of catch data and provides a recommendation on the analytical method to be used to produce an annual recruitment index using ringing data. However, these data are collected during ringing operations which are not designed to measure recruitment and therefore the catches are not made in a systematic manner. In order to provide more accurate information on recruitment into the wintering population, it would be necessary to move to more standardised catching aiming for similar sized catches at the same sites in the same time period each year (Minton 2003). This paper however explores how we can use the data which are currently being collected.

A factor that can complicate estimating the proportion of juveniles in a population from cannon net catches is that this may vary with catch size. Large catches are often made at preferred high tide roosting sites where dominant birds (usually adults) may exclude subdominants, mainly juveniles (Newton 1998) (or the juveniles, being less efficient feeders, continue feeding elsewhere over the high water period in order to fulfil their daily food requirement). Conversely, small catches tend to contain a higher proportion of juveniles

(Boyd & Piersma 2001, pers. obs.). This may arise because small samples are often minority catches in much larger catches of other species. These catches may be biased towards juveniles because they are made at less preferred sites for that species. Such biases may therefore confound any attempt to estimate the true proportion of juveniles in a population. Nevertheless, provided catch sizes do not change significantly from year to year, it should be possible to obtain a reasonably accurate measure of annual productivity.

METHODS

A total of 230 cannon netted samples comprising 14,267 Dunlin caught in the winter (November to March), are included in the analysis. At this time population mixing is reduced, with the population of Dunlin in Britain consisting almost entirely of the race *alpina*, and movement between sites is at its lowest (Wernham *et al.* 2002). It is likely that over-winter mortality is higher in juveniles than adults (Goss-Custard *et al.* 1995) so the proportion of juveniles might be expected to reduce during the winter, but this was not evident from the data (the regression of the proportion of juveniles (arcsine transformed) on date shows no significant trend ($r^2 = 0.007$, NS). As few data were collected in the early winters, data from winter 1992/93 to 2002/03 (11 winters) are used. All samples are included, as recent analysis has shown no significant effect of pre-catch disturbance on the proportion of juveniles caught (M. Collier in prep). Birds were aged using plumage characteristics (Prater *et al.* 1977), which are reliable throughout the winter. To investigate the possibility of biases associated with catch size, the proportion of juveniles was plotted against catch size.

Two methods of calculating juvenile proportions are examined: the 'Catch' index and the 'Individual' index.

The 'Catch' index

Each catch can be treated as a sampling of a population. Thus, each catch provides an independent estimate of the proportion of juveniles present at a site and an index can be constructed from the mean proportion in each catch. If, for example, small samples prove to contain a disproportionately large number of juveniles, these could be excluded when the index is calculated taking a cut-off level. However, this is somewhat arbitrary and would not use all the available data. Alternatively a weighting factor (proportional to catch size) could be used, which would allow the influence of individual catches in the analysis to vary with their reliability as sampling events.

To produce the 'Catch' index, the proportion of juveniles in each sample of Dunlin in a winter was calculated and then an overall mean taken. The calculation was repeated with catches of less than 10 and less than 20 excluded. A 'Catch' index with catch size weighting was also calculated ('Weighted Catch' index), again with all catches and with those of less than 10 and less than 20 excluded.

The 'Individual' index

An alternative approach is to consider each bird as an individual sample. Then the estimate of the proportion of juveniles in any one group is simply the total number of juveniles present divided by the total number of birds aged. This is the index presented by e.g. Minton *et al.* (2003a, b). Although they did not present error estimates, these can be calculated from:

$$\text{Variance} = p_{juv} * (1-p_{juv}) / (N-1)$$

where N is the total number of birds and p_{juv} the proportion of juveniles. Standard errors are simply the square root of this and (approximate) 95% confidence limits are 1.96 * standard error. However, this approach suffers three potential problems: 1) no account can be taken of factors influencing individual catches; 2) birds are known to flock together in an age-specific fashion, this will introduce extra heterogeneity into the data, meaning that the confidence limits will be underestimated and 3) calculation of the errors can lead to confidence limits for the proportion of juveniles which are negative, or greater than one, which is clearly nonsensical. To overcome such difficulties, linear modelling was developed (McCullagh & Nelder 1989, Crawley 1993). This technique allows most of the assumptions (such as complete random distribution of individuals) made by the simple statistics to be relaxed, thus providing a more efficient way of analysing the data, and giving more reliable results.

STATISTICAL METHODS

Both model approaches outlined above fit naturally within a framework of generalized linear models (Crawley 1993). We fitted these in SAS using Proc Genmod (SAS Institute 1997). In each case, the proportion of juveniles in a catch was modelled with a (categorical) year term to produce an annual index. Note because catches were made in winter this is not a calendar year.

For the 'Catch' index, Proc Genmod was used with an identity link function and normal errors (equivalent to a standard ANOVA), with each catch forming a sample. An arbitrary weighting term proportional to the common logarithm ($\log_{10}$) of the total number of birds in a catch was used in some models (using the SCWGT option in Genmod).

For the 'Individual' index, the 'events/trials' syntax in SAS was used, i.e. the proportion of juvenile birds in a catch was specified as 'number of juveniles/total number'. Additionally, a logit link function and a binomial error distribution were specified. The logit link function bounds the index between 0 and 1 (an essential property when dealing with proportions) and the binomial error term accounts for the fact that error in the estimates will vary with the proportion of juveniles in the catch (there is much less scope for variation if the 'true' value is close to 1 or 0 than 0.5, for example). As individual birds are not independent (i.e. they exhibit non-random flocking) there was a greater degree of variability in the data than would be expected from a simple binomial error distribution (which is assumed by the calculation of variance above). Consequently, a variance inflation factor (c-hat) was employed (using the PSCALE option – Pearson's Chi-square statistic divided by its degrees of freedom) to account for this over-dispersion. This has no effect on the mean parameter estimates, but increases the error estimates (and hence confidence limits) appropriately.

RESULTS

When the proportion of juveniles in each catch is plotted against catch size, there is no significant trend, but the slope is negative and all of the catches containing >70% of juve-

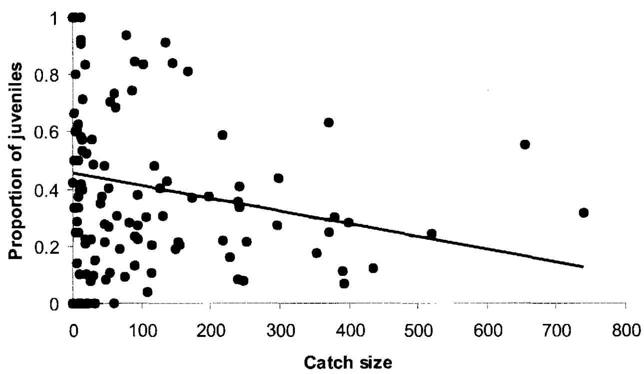

Fig. 1. Proportion of juveniles in 230 cannon net catches of Dunlin in the United Kingdom during November–March 1992/1993 to 2002/2003 plotted against catch size. The slope of the regression line is not significant (r^2 = 0.0161 with the dependent variable arcsine transformed).

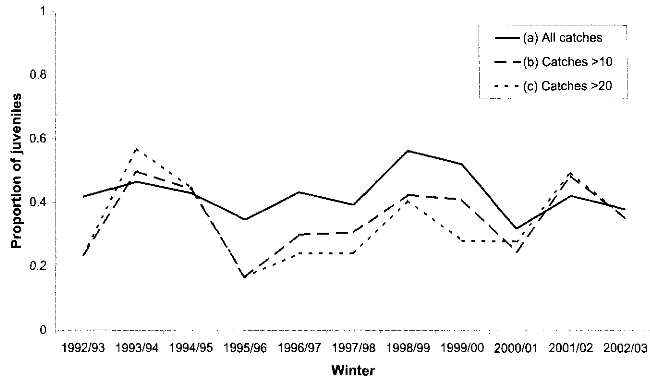

Fig. 2. 'Catch' index: proportion of juvenile Dunlin calculated by taking the mean proportion of juveniles from each catch: a) all catches; b) catches of >10 and c) catches of >20.

niles were of <170 birds (Fig. 1). Therefore it appears that although some small Dunlin catches contain a disproportionate number of juveniles, most do not. Moreover there is no evidence that large catches contain a disproportionately low number of juveniles.

The 'Catch' index with all catches included showed that the annual proportion of juveniles varied from 0.35 to 0.56 (Fig. 2). However, the small catches made a disproportionate contribution to the index. When small catches, of less than 10 or less than 20 birds, were excluded from the analysis the variation between years increased (<10 birds excluded: 0.17–0.50; <20 excluded: 0.17–0.57). For the 'Weighted Catch' index the three indices (for all Dunlin caught and when samples of less than 10 and less than 20 are excluded) are less disparate (all catches: 0.19–0.49; <10 excluded: 0.17–0.51; <20 excluded: 0.17–0.55) (Fig. 3.).

An 'Individual' index, using the overall proportion of juveniles amongst Dunlin when all samples in a winter are summed showed little difference between the results for all catches and those where small catches were excluded as small samples are contributing little to the result (All catches: 0.17–0.54; <10 excluded: 0.16–0.54; <20 excluded: 0.16–0.54). However, these data are over-dispersed, so confidence limits cannot be calculated accurately by hand. To avoid this problem, we recalculated the index using a linear model (see Statistical methods) (Fig. 4).

DISCUSSION

Investigations of different indices of proportion of juvenile Dunlin in cannon net catches in Britain have shown that an 'Individual' index using linear modelling (see Statistical methods) should be used. The 'Individual' index avoids the problem of over-representation of small catches, which tend to contain a higher proportion of juveniles, and allows statistical testing as well as allowing other factors to be taken into account.

Using a 'Catch' index (i.e. the mean of the proportion of juveniles in each catch in each winter) allows statistical testing but gives the same emphasis to all catches regardless of size, and is strongly affected if small catches are excluded. With the concerns about the age composition of small catches, this is therefore not ideal. A weighted 'Catch' index, which uses a weighted mean of the proportion of juveniles in each catch, overcomes both the problem of lack of confidence intervals and of over-emphasizing data from small catches. Figure 3 shows that, with weighting, there is little difference between the index calculated for all catches and those with catches of less than 10 and less than 20 excluded. However, the weighting of each catch is arbitrary.

An 'Individual' index, using all catches naturally emphasizes the data from large catches as each individual enters the analysis explicitly and thus avoids the criticism that small catches may be biased either by chance or biologically. How-

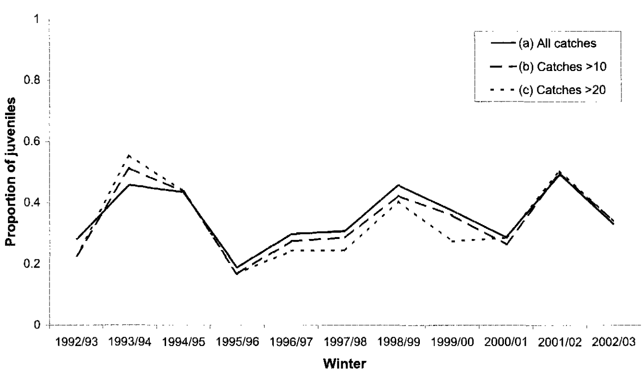

Fig. 3. Weighted 'Catch' index: mean proportion of juvenile Dunlin in catches weighted by catch size: a) all catches; b) catches of >10 and c) catches of >20.

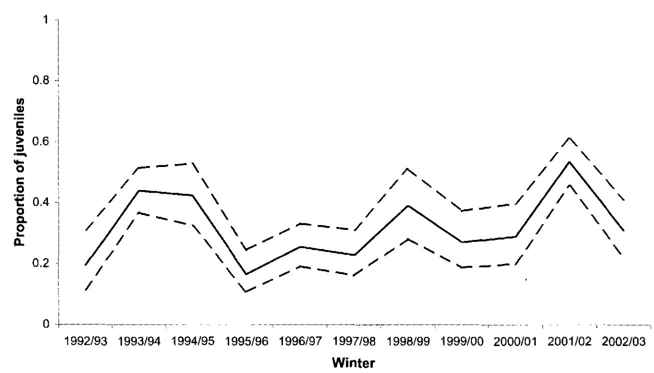

Fig. 4. 'Individual' index using linear modelling: mean proportion of juvenile waders in catches weighted by catch with 95% confidence limits (see Statistical methods for details).

ever, there are problems in assigning confidence limits to the data if they are over-dispersed and so a variance inflation factor needs to be employed. We would therefore recommend that this method should be used for the assessment of recruitment of waders into wintering populations. The 'Individual' index using linear modelling also takes into account the fact that birds may be distributed non-randomly.

While using juvenile ratios in non-breeding areas is a relatively easy method for monitoring changes in demographic factors acting on the breeding grounds, there are aspects of the birds' biology that must be considered if the results are to be interpreted correctly.

In many locations the non-breeding population of a species originates from one breeding area, but, in some cases, they may come from more than one breeding area, so that any index may be sampling multiple populations. Unless there are similar changes across different breeding populations this would make any changes difficult to detect. Also, the composite ratio from the non-breeding area may not correspond to the recruitment from any one breeding area.

On some sites, changes in the proportion of juveniles present may occur through the non-breeding period, for example autumn passage of juveniles tends to be later than adults. Thus it would be important to only compare samples from different years that were caught at the same time. The time period would have to be dictated by the behaviour of the birds, possibly with a narrow time frame in passage periods, but a wider time frame in the middle of the non-breeding season when populations tend to be more stable. Alternatively, if enough data are available, month or season terms could be added to the generalized linear model.

Although the Dunlin data do not show a strong effect of catch size on the proportion of juveniles, this may vary from species to species and from place to place. Certainly, in some species the proportion of juveniles present has been found to vary with habitat, adults usually being found in the preferred areas or at roost sites while the juveniles feed elsewhere (e.g. Clark 1983, Swennen 1984, , Ruiz et al. 1989, Durrell *et al.* 1996). Between year variation in catch location or size could also introduce sampling error. Care should therefore be taken to check that sampling biases are not affecting any productivity index.

The proportion of juveniles caught has also been found to vary with catching method; for example, more juveniles have been found in mist net than in cannon net catches (Pienkowski & Dick 1976, Goss-Custard *et al.* 1981, Insley & Etheridge 1997). Therefore catching methods should not be considered synonymous and data should not be lumped without testing for differences. In principle, data from different catching methods could be combined with the inclusion of a 'catching method' term in the model.

Differences in the distribution of adults and juveniles could also bias the proportions found. Such biases can occur at a macro (national or whole non-breeding area), local (within an estuary) or micro (within a flock) scale. Although many species of waders are faithful to the site or sites they use in the non-breeding season, latitudinal segregation according to age has been shown in Western Sandpiper *Calidris mauri* (Nebel *et al.* 2002), and Red Knot (Minton 2003). If this occurs, there will be areas with few juveniles where any changes are difficult to detect. These biases may also occur due to the non-breeding distribution of the species involved, the type and quality of habitats available in an area or the distribution of birds within a flock. For example, juvenile Redshank *Tringa totanus* in Scotland have been found to occupy less favoured habitats where they are more susceptible to predation while feeding over the high tide period (Hilton *et al.* 1999). Also, juvenile birds tend to be on the periphery of flocks (Clark 1983, Minton 2003, Harrington this volume). Age ratios in conjunction with migration analyses may detect temporal changes in the distance that a population migrates (e.g. Eurasian Oystercatcher, Lapwing *Vanellus vanellus* – Siriwardena & Wernham 2002) which could potentially lead to changes in the proportion of juveniles present in an area over time. The inclusion of site and/or region terms in the binomial model may alleviate some of these problems.

Further work also needs to be carried out to compare the juvenile ratios calculated from data collected on the non-breeding grounds with information gathered on the breeding grounds to establish the relationship between breeding productivity and recruitment to the non-breeding population.

The 'Individual' index using linear modelling (with a logit link, binomial error and variance inflation correction) provides an estimate that takes catch size into account and gives confidence limits, it also allows the addition of other factors such as site, season or catch method, to be accounted for, better representing the nature of the data involved. This should therefore be the method of choice to calculate and develop the calculation of juvenile recruitment into the wintering population.

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APPENDIX: SAS CODE USED

```
proc genmod data=dunli;
        class winter disturb represent area;
        title 'Winter CN catches of Dunlin predicted values – binomial';
        model juvs/totaged = winter /error = binomial link=logit type3 obstats pscale;
        ods listing exclude obstats;
        ods output obstats = dindex;
run;

data dindex1;
        set dindex;
        if juvs = .;
        USE = (Upper – Pred)/1.96;
        LSE = (Pred – Lower)/1.96;
        keep winter Pred Upper Lower;
        run;
```