

Mass and wing length of young Black-headed Gulls *Larus ridibundus* as predictors of age and survival

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Abstract

This study of Black-headed Gulls aims at finding methods for estimating the condition of gull chicks at the colony level, a measure that could be used to identify colonies exposed to poor and good feeding conditions, respectively. In enclosed parts of two colonies in South Central Sweden, we ringed hatchlings and measured wing length and mass of chicks throughout their pre-fledging period (≤ 25 days old). Chicks with a high mass relative to age were more likely to survive between visits to the enclosures suggesting that this measure can be used to estimate condition. From the age of two weeks wing length is a relatively accurate predictor of age and from this time mass relative

to wing length and mass relative to age are closely correlated. We therefore propose that one can obtain data on the condition of chicks from a single visit at a colony, by estimating individual condition as the deviation in mass from that expected from the chick's wing length. This is important in that many colonies can be studied with relatively little effort.

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The drastic decline of the Swedish population of Black-headed Gulls *Larus ridibundus* in the last two decades (Jönsson & Karlsson 1990, Källander 1996) and recently also in the Baltic countries (Viksne et al. 1996) calls for estimates of population parameters, i.e. reproductive success and adult survival rates. Within regions in Sweden, certain colonies have increased in numbers of pairs whereas most other colonies have decreased dramatically or even disappeared (Källander 1996). Scattered observations have documented colonies with remarkably low reproductive success (Bensch 1992). This suggests a source and sink scenario (e.g. Pulliam 1988); in certain colonies reproductive output balances mortality and emigration whereas birds in other colonies seem to experience permanently reduced breeding success. In order to investigate whether there are any physical or biological factors in the surroundings of a colony that influence its "health", we first need to identify a number of colonies with poor and sufficient reproductive success, respectively.

Black-headed Gulls typically breed in large colonies and already a few days after hatching their young may leave the nest, especially if the colony is disturbed by a potential predator (Goodbody 1955).

Hence, it is often not possible to monitor the survival of individual chicks up to independence and so the reproductive success of individual pairs cannot be estimated. The aim of the present study was to search for a quick indirect method to estimate the feeding conditions of a colony. This would enable the parallel study of several colonies.

The mass of chicks may reveal the general food condition for birds in a colony. Since the mass of chicks increases with age, one first needs to know the age of a weighed chick in order to determine its condition (i.e. mass corrected for age). For this a measurement that predicts the age of chicks independent of mass is necessary. In Black-headed Gulls, the length of the developing wing may fulfil this criterion (Heránová & Klima 1963). Hence, we can construct a measure of condition by relating mass to age, as estimated from wing length, and then investigate whether this measure predicts survival. Such a study can only be accomplished with individually marked chicks. To study individual young we therefore enclosed parts of colonies (see Viksne & Janaus 1990) to which we made repeated visits from hatching until fledging.

Methods

The study was carried out in South Central Sweden at lakes Kvismaren and Tysslingen, 25 km apart, from April to June in 1993 and 1994. By counting incubating individuals in early May 1993, we found 650 pairs of Black-headed Gulls breeding at Kvismaren and 1000 pairs at Tysslingen. Similar figures were obtained in 1994. At Kvismaren, all pairs bred in a part called Rysjön, where they nested on tussocks of iris *Iris pseudacorus* and sedge *Carex* spp. that are scattered in the shallow water. The colony is therefore formed of many subunits (1–50 pairs), the number of pairs in each subunit mainly depending on the size and density of tussocks. At Tysslingen, the colony is mainly located on three "floating" islands at the northern end of the lake, one bigger (500 pairs) and two smaller (250 pairs each).

We selected the areas for the enclosures approximately one week before the start of hatching. These were fenced in with chicken net (height=0.5 m, mesh size=10 mm) making sure that chicks could not escape below the net. Three enclosed areas in 1993 (A–C) were approximately 50 m² and four areas in 1994 (D–G) were 30 m² each (Table 1). We chose the smaller area in 1994 because we preferred to reduce the time needed for processing the chicks at each

visit. The much higher loss of chicks from the enclosures in 1994 than in 1993 was due to predation by mink *Mustela vison* (Table 1).

From start of hatching, the fenced areas were visited at least every second day until the hatching of the last chick. Hatchlings were ringed with an aluminium ring, and weighed with a Pesola spring balance (50 g or 300 g). At least once a week all chicks within the fence were collected, registered, weighed and their wing length measured (method 2, Svensson 1992).

Masses of young were fitted by logistic equations (Ricklefs 1967, 1984) of the form

$$M(t) = \frac{A}{1 + e^{-K(t-I)}}$$

where $M(t)$ is the mass (g) at age t days, A is the asymptote (g) of the growth curve, K is a constant describing the daily rate at which the asymptote is achieved, and I is the age (days) at the inflection point of the growth curve [$M(I) = 0.5A$]. Equations were fitted to data by a nonlinear least-square method (SYSTAT). The same procedure was used for estimating the relationship between wing length $W(t)$ and age (t). Analyses of survival between periods were done in the SYSTAT logit module.

Table 1. Breeding parameters of Black-headed Gulls within fenced areas at Rysjön (Rysj) and Tysslingen (Tyss).
Häckningsparametrar för skratmåsarna i hägnen i Rysjön (Rysj) och Tysslingen (Tyss).

Enclosure Hägn	A	B	C	D	E	F	G
Year År	1993	1993	1993	1994	1994	1994	1994
Lake Sjö	Rysj	Tyss	Tyss	Rysj	Rysj	Tyss	Tyss
Number of nests <i>Antal bon</i>	39	40	32	18	10	23	15
Mean hatching date <i>Medeldatum för kläckning</i>	30 May	28 May	29 May	30 May	30 May	30 May	28 May
Number of hatched young <i>Antal kläckta ungar</i>	74	87	79	36	14	44	31
Number surviving to day 13 (% of hatched) <i>% av kläckta ungar som överlevde till dag 13</i>	34 (46%)	47 (54%)	55 (70%)	16 (44%)	5 (36%)	21 (48%)	8 (26%)
Number surviving to day 23 (% of hatched) <i>% av kläckta ungar som överlevde till dag 23</i>	26 (35%)	40 (46%)	44 (57%)	0 (0%)	3 (21%)	0 (0%)	0 (0%)

Results

Relations between age, mass and wing length

Using young that survived until at least the age of 23 days, mass shows a sigmoid relationship with age (Fig. 1). A similar relationship is obtained between wing length and age (Fig. 2).

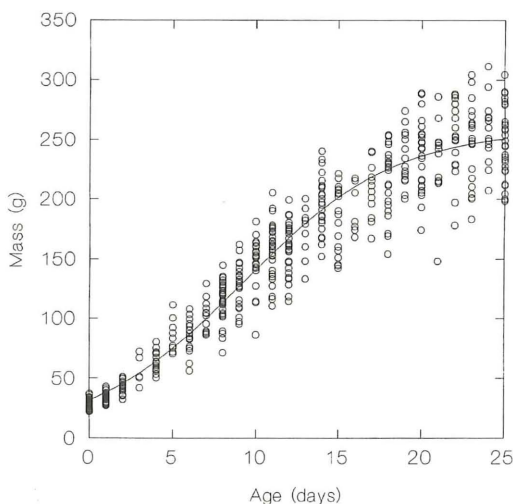


Fig. 1. Body mass in relation to age (hatching=day 0) of young Black-headed Gulls surviving up to at least 23 days. Chicks older than 25 days were excluded from the analysis. $Y=259.48/(1+\exp(-0.214*(x-9.20)))$, $r^2=0.939$, $N=618$.

Sambandet mellan skrämmåsingars vikt och ålder (kläckningsdagen = 0) för ungar som överlevt åtminstone till dag 23. Ungar äldre än 25 dagar utesluta.

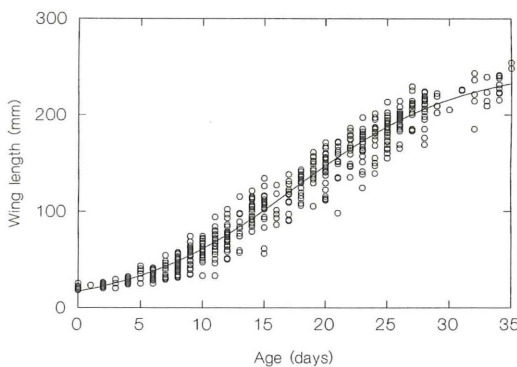


Fig. 2. Wing length in relation to age (hatching=day 0) for young Black-headed Gulls surviving up to at least 23 days. $Y=249.47/(1+\exp(-0.149*(x-17.55)))$, $r^2=0.96$, $N=552$.

Sambandet mellan skrämmåsingars vinglängd och ålder (kläckningsdagen = 0) för ungar som överlevt åtminstone till dag 23.

In order to estimate age from a measured character, a linear model would be desirable. From the age of one week until start of fledging (day 25), both mass (Fig. 1) and wing length (Fig. 2) could be approximated by a linear model. Using linear regression, including also young that disappeared before fledging, mass explains 73.3% of the "variation" in age

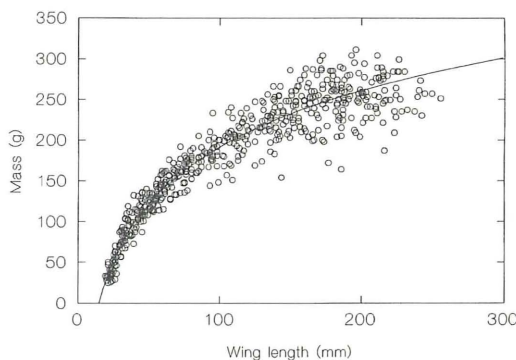


Fig. 3. The relationship between wing length and mass in Black-headed Gull chicks. All chicks are included. $Y=-269+100*\ln(X)$, $r^2=0.95$, $N=951$.

Sambandet mellan vinglängd och vikt hos skrämmåsingar beräknat på samtliga ungar.

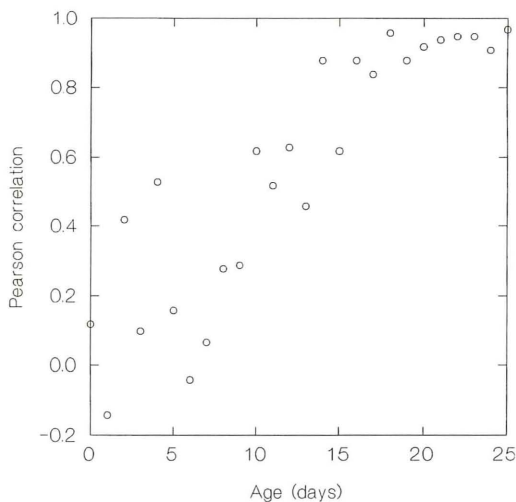


Fig. 4. Pearson correlation coefficients between the two measures of residual mass, RSA and RSW, each day from hatching to day 25.

Korrelationskoefficienter för sambandet mellan två mått på residualvikt, RSA och RSW (beräknade från Fig. 1 och 2) från kläckning till dag 25.

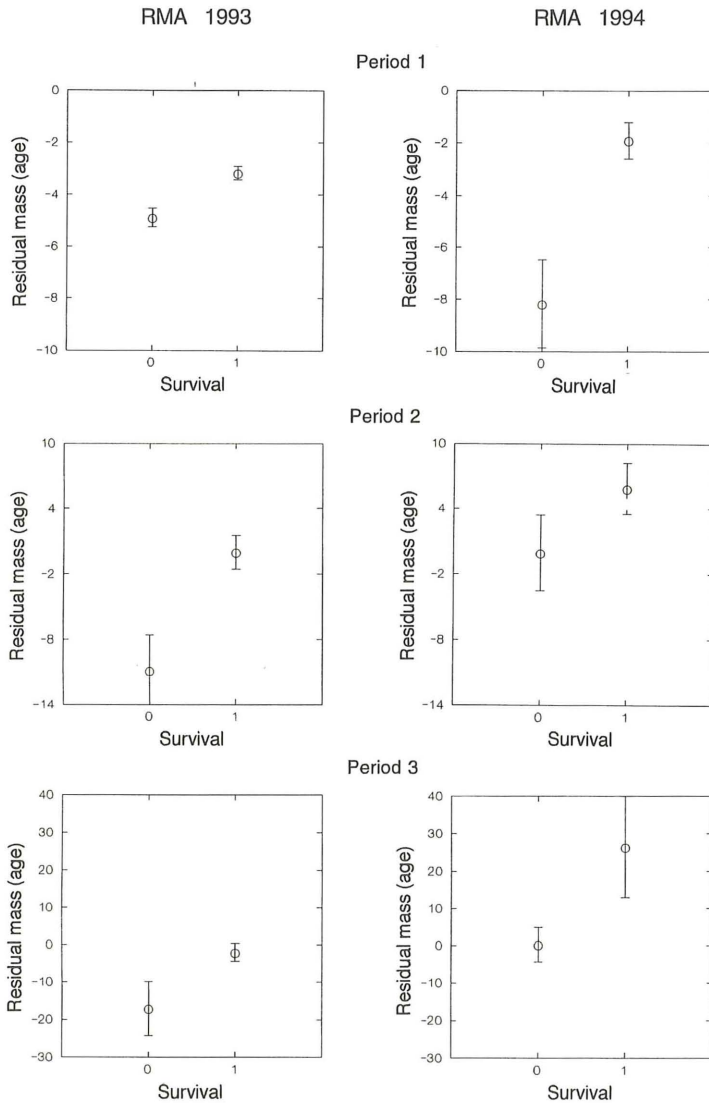


Fig. 5. Residual mass relative to age (RSA) in period i for chicks that survived (1) and disappeared (0), respectively, to period $i+1$. Period 1 (days 0-2), Period 2 (3-12), Period 3 (13-21). Bars represent SEs. Differences in RSA between surviving and disappearing chicks were tested with logistic regression (Period 1 1993, $\chi^2=12.91$, $P<0.001$; Period 1 1994, $\chi^2=12.21$, $P<0.001$; Period 2 1993, $\chi^2=9.51$, $P=0.002$; Period 2 1994, $\chi^2=1.99$, NS; Period 3 1993, $\chi^2=5.68$, $P=0.017$; Period 3 1994, $\chi^2=1.51$, NS).

Avvikelsen i vikt mot den för åldern förväntade (RSA) i period i för ungar som överlevde (1) respektive försvann (0) till period $i+1$. Period 1=dag 0-2, period 2=3-12, period 3=13-21. Vertikala linjer anger SE. Skillnader i RSA mellan ungar som överlevde och ungar som försvann testades med logistisk regression (se engelska figurtexten).

($Y=0.085X-0.733$, $r^2=0.733$, $N=524$). Wing length explains as much as 91.0 % of the variation in age ($Y=0.109X+3.80$, $r^2=0.910$, $N=524$). From a partial correlation, it becomes clear that wing length is the best predictor of age (partial $r=0.823$, $N=524$) since mass cannot predict the age of chicks when wing length is held constant (partial $r=-0.178$, $N=524$).

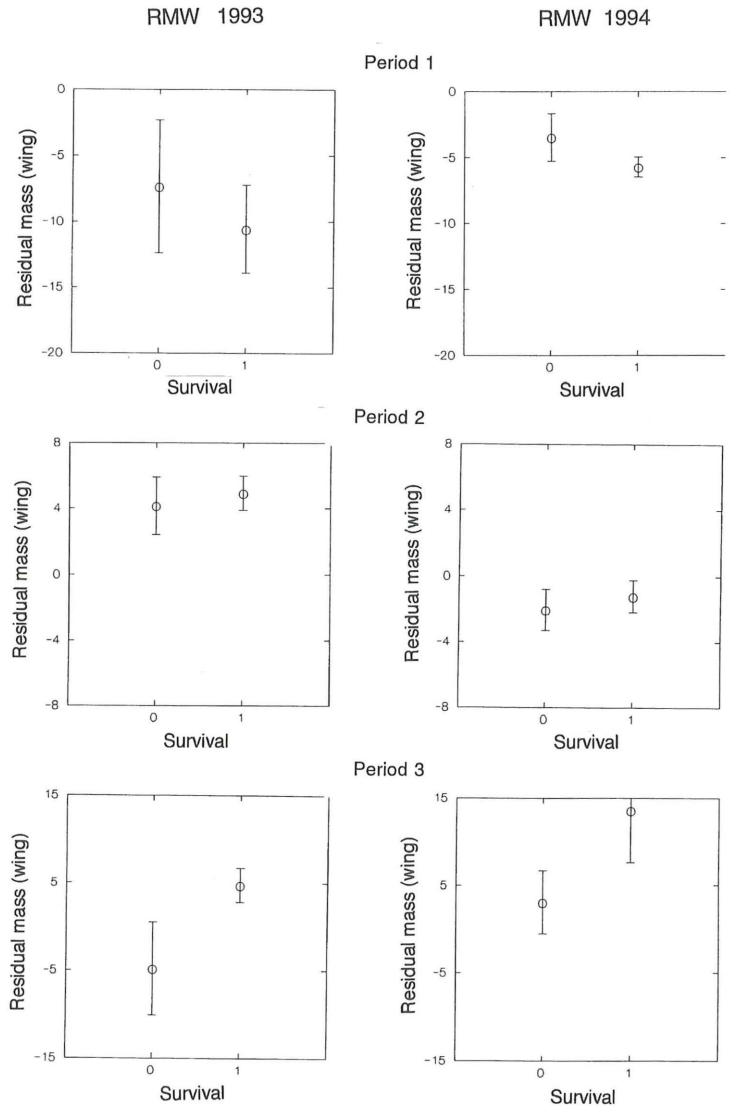
We created two estimates of condition. First, the logistic function in Fig. 1 shows the expected mass for a given age. Each time a chick was handled, we calculated the deviation in mass from the mass

expected from its age (i.e. the residual mass relative to age; RMA). Second, the relationship between mass and wing length is described by a logarithmic function (Fig. 3). Hence, we calculated the deviation in mass from the mass expected from a young's wing length (i.e. residual mass relative to wing length; RMW).

In order to investigate how these two estimates of condition are related we calculated the Pearson correlation coefficient between RMA and RMW (Fig. 4). During the days following hatching, the

Fig. 6. Residual mass relative to wing length (RSW) in period i for chicks that survived (1) and disappeared (0), respectively, to period $i+1$. Period 1 (days 0-2), Period 2 (3-12), Period 3 (13-21). Bars represent SEs. Differences in RSW between surviving and disappearing chicks were tested with logistic regression (Period 1 1993, $\chi^2=0.36$, NS; Period 1 1994, $\chi^2=1.14$, NS; Period 2 1993, $\chi^2=0.12$, NS; Period 2 1994, $\chi^2=0.27$, NS; Period 3 1993, $\chi^2=3.84$, $P=0.05$; Period 3 1994, $\chi^2=0.41$, NS).

Somfigur 5, men med avvikelsen i vikt från den för vinglängden förväntade (RSW). För testresultat, se den engelska figurtexten.



correlation is weak, gradually strengthening until chicks reach an age of approximately two weeks, whereafter the correlation coefficient remains above 0.80.

Predicting survival

The pre-fledging period was divided into four periods (P1-P4), days 0-2, 3-12, 13-22 and 23-25, respectively. The periods were selected to represent hatching (P1), first half of linear growth (P2), second

half of linear growth (P3) and the period of asymptotic mass (P4). For each period and chick we calculated the average residual masses, RMA and RMW. Because the mortality within the enclosures was much higher in 1994 than in 1993 (Table 1), we present data for the two years separately. In general, chicks that survived between period P_i and P_{i+1} had a higher residual mass relative to age (RMA) in period P_i than young disappearing (Fig. 5). Thus residual mass relative to age seems to predict survival in each of the first three pre-fledging periods. For



Eftersom vingen tycks tillväxa normalt även vid dåliga näringsförhållanden, bör en unges vikt i relation till dess vinglängd ge ett gott mått på ungens 'kondition'. Vingsträckning hos halv vuxen skrattnåsunge. Foto: Hans Källander.

Because the wing seems to grow relatively normally also in poor conditions, the relationship between mass and wing length of gull chicks should be a useful index of feeding conditions.

Table 2. Logistic regression on survival between periods with residual mass relative to age (RSA) and hatching date as independent variables. Each chick is only included once in each period. P-values obtained from log likelihood ratios.

Logistisk regressionsanalys av överlevnad mellan perioder med residualerna från regressionen vikt mot ålder och kläckningsdatum som oberoende variabler. Varje unge endast inkluderad en gång i varje period. P-värden från log-likelihoodkvoter.

Period and year	Variable	Estimate	S.E.	P
Period 1 1993	Constant	6.49	1.41	
	Hatching date	-0.17	0.048	<0.001
	Residual mass	0.13	0.051	0.009
Period 1 1994	Constant	9.15	2.44	
	Hatching date	-0.223	0.079	0.005
	Residual mass	0.093	0.047	0.049
Period 2 1993	Constant	7.94	2.07	
	Hatching date	-0.228	0.071	0.001
	Residual mass	0.007	0.010	0.470
Period 2 1994	Constant	8.75	2.71	
	Hatching date	-0.304	0.094	0.001
	Residual mass	0.007	0.010	0.470
Period 3 1993	Constant	3.411	2.17	0.117
	Hatching date	-0.065	0.078	0.403
	Residual mass	0.017	0.008	0.026
Period 3 1994	Constant	13.41	14.44	0.353
	Hatching date	-0.647	0.577	0.262
	Residual mass	0.06	0.048	0.209

the first two periods (P1 and P2) residual mass relative to wing length (RMW) is not correlated with survival into the subsequent period (Fig. 6). Chicks that survived from period P3 to P4, however, had a higher residual mass relative to wing length (RMW) than young that disappeared (Fig. 6).

Since RMA is a better predictor of survival than RMW, we restrict the following analyses to RMA. Hatching date was negatively correlated with residual mass relative to age (Period 1, $r=-0.187$, $P<0.001$, $N=360$; Period 2, $r=-0.224$, $P<0.001$, $N=265$; Period 3, $r=-0.129$, $P=0.086$, $N=179$; Period 4, $r=-0.102$, NS, $N=69$). This raises the possibility that the reduced survival of chicks with low residual mass could be caused by a late hatching date. In order to examine whether there was an independent effect of residual mass on survival, we performed logistic regressions with survival as the dependent variable and hatching date and RSA as independent variables (Table 2). In three of the six combinations of periods and years, both hatching date and residual mass had a significant effect on survival.

Discussion

This study shows that the deviation in mass from the expected relationship between mass and age can be used to predict the survival of young Black-headed Gulls. Thus, as in other species (e.g. Magrath 1991), part of the variation in mass at a given age seems to reflect condition. Similar to e.g. Daan et al. (1988) we also found that the date of hatching was negatively correlated with chick survival.

It has recently been demonstrated that variation in growth parameters between populations is partly genetically determined (Starck et al. 1995). Thus, some of the variation in mass relative to age might be adaptive. Klaassen et al. (1992) found that a slow growth rate may reduce the total gross energy intake (kJ during the pre fledging period) in chicks of Common Terns *Sterna hirundo* and Sandwich Terns *S. sandvicensis*. Thus, a slow growth rate may reduce the food requirements and improve the chances of successful fledging. Importantly, however, in the present study a significant part of the variation in mass relative to age seems to have fitness conse-

quences and is thus an indicator of condition of chicks at a given point in time.

As found in other studies of the same (Heránová & Klíma 1963) and other species (Ricklefs & White 1981, Moss et al. 1993, Monaghan et al. 1989) wing length can be used to predict age. However, because the flight feathers do not start emerging until approximately ten days after hatching (Heránová & Klíma 1963) most of the variation in wing length up to then is due to measurement errors. Accordingly, the other measure of condition, mass relative to wing length (MRW), shows higher correlations with mass relative to age (MRA) towards the second half of the pre-fledging period. The reason for the poor fit between the two estimates of condition during the first weeks after hatching is likely that at this time wing length is a poor predictor of age. Note that mass relative to wing length does not predict survival during the first two periods.

Estimating condition of chicks at colonies

A study that aims at estimating body condition of chicks at many ($N > 10$) colonies would be facilitated if this could be done without enclosures. In Arctic Terns *Sterna paradisaea*, Monaghan et al. (1989) found that in a colony where chicks had low masses relative to wing lengths, pairs fledged fewer young than in a colony where masses were higher relative to wing length. Similar results were obtained in a study of Red Grouse *Lagopus lagopus scoticus* when comparing variation in a body condition index and breeding success between years (Moss et al. 1993).

In Black-headed Gulls, condition could be measured at single visits during two different periods of the gulls' breeding cycle by using two different methods. First, at the time of hatching, chicks can be ringed and weighed. The mass of hatchlings predicts their survival and can hence be used as a measure of body condition at the colony level. If a substantial fraction of the chicks are ringed as hatchlings, a single visit later during the breeding season may enable a calculation of mass relative to age from the equation given in Fig. 1.

Second, when chicks are from two to four weeks old, their mass relative to wing length is highly correlated with mass relative to age. By choosing a time when most chicks are expected to be two to four weeks old, one can, from a single visit at a colony, obtain estimates of body condition from the relationship between mass and wing length as given in Fig. 3.

Conclusion

The above results suggest a method by which the well-being of chicks can be monitored with relatively little effort in a substantial number of colonies. However, the condition of chicks may depend not only on the feeding situation. For example, high mortality due to predation may reduce brood size and result in more food being delivered to the remaining young. Hence, it is possible that pairs in colonies with low fledging success due to predation, will produce young in better condition than pairs in colonies in which most chicks are fledged and intra-brood competition for food is high. Thus, a measure of condition is more valuable if the fledging success at the colony level can also be obtained.

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Sammanfattning

Vikt och vinglängd för unga skrattnåsar Larus ridibundus som indikatorer på ålder och överlevnad

En fågelunges vikt vid en given ålder bör normalt spegla de rådande näringsförhållandena, dvs om ungar är lätta för sin ålder indikerar detta att föräldrarna haft svårigheter att täcka ungarernas energibehov. Att väga ungar skulle således kunna ge viktig information under förutsättning att ungarernas ålder är känd. Detta kräver emellertid att man bestämmer kläckningsdag och för borymmande ungar dessutom att man märker dem individuellt, så att de kan identifieras vid ett senare vägningstillfälle. Om man därför genom någon indirekt metod kunde uppskatta en unges ålder med tillfredställande noggrannhet, skulle detta avsevärt minska såväl arbetsinsats som störning. Man skulle kanske med blott ett eller några få besök i en tarn- eller måskoloni under ungarernas uppväxttid kunna få en uppfattning om näringssituationen för kolonins fåglar. Flera undersökningar har visat att vingarnas tillväxt är mindre känslig för variationer i näringsförhållanden än ungarernas vikt. Vinglängden skulle således eventuellt kunna användas för att uppskatta en unges ålder med tillfredställande noggrannhet.

Syftet med denna undersökning var just att försöka fastställa sambanden mellan ålder och vinglängd, ålder och vikt samt vinglängd och vikt hos ungar av skrattnås *Larus ridibundus*. Förhoppningen var att kunna presentera en kurva över sambandet mellan vinglängd och vikt, som kunde tjäna som referens vid framtida studier i olika skrattnåskolonier.

För att exakt kunna bestämma skrattnåsungarnas ålder, inhägnades 1993 och 1994 delar av skrattnåskolonier i Rysjön (Kvismaren) och Tysslingen med kycklingnät (0,5 m högt, 10 mm maskor) ungefär en vecka före beräknad kläckning så att ungarerna inte kunde smita ur hägnet. Var och en av inhägnaderna var cirka 50m² 1993 och 30 m² 1994. Det senare året utsattes hägnen för betydande predation av mink (Tabell 1). Från kläckningsstarten och framåt besöktes hägnen åtminstone varannan dag tills den sista ungen kläckts. Nykläckta ungar ringmärktes och vägdes. Under ungarernas uppväxttid besöktes sedan hägnen minst en gång i veckan, varvid samtliga ungar vägdes och deras vinglängd mättes (metod 2, Svensson 1992). Ungarnas viktutveckling beskrevs sedan med hjälp av logistiska ekvationer (Ricklefs 1967, 1984).

För de ungar, vilka överlevde de första 23 dagarna, har sambandet mellan vikt och ålder en sigmoid form (Fig. 1), liksom sambandet mellan vinglängd och ålder (Fig. 2). För bestämning av ålder är emellertid ett linjärt samband att föredra; ett sådant samband med ålder råder för både vikt och vinglängd från det att ungarerna är ungefär en vecka gamla. Sambandet är speciellt starkt mellan vinglängd och ålder och kvarstår när vikten hålls konstant i en partiell korrelation, medan sambandet mellan ålder och vikt försvinner om vinglängden hålls konstant. Detta innebär att en unges vinglängd är ett gott mått på dess ålder.

En unges kondition kan ses som avvikelser från kurvan i Fig. 1: punkter under linjen representerar ungar som är lätta för sin ålder. För att direkt kunna se sambandet mellan vinglängd och vikt har Fig. 3 konstruerats. Som synes ökar spridningen i punkterna med ökande vinglängd hos ungarerna (dvs ju äldre ungarerna är). Från det att de uppnått en vinglängd av 100 mm (vilket svarar mot en ålder av 15 dagar) faller lätta och tunga ungar väl ut i diagrammet. Det bör påpekas att vingpennorna börjar spricka ut på tionde dagen och att vinglängdsmätningarnas noggrannhet därvid sannolikt ökar. Från den punkten bör alltså den presenterade kurvan kunna användas som en måttstock vid mätningar i skrattnåskolonier på olika håll i landet.

Vi undersökte också i vilken utsträckning vikt relativt ålder resp. vinglängd kunde förutsäga ungarernas överlevnad. På grund av minkpredationen 1994 presenteras data separat för de två åren. Ungperioden indelades i fyra perioder (dag 0-2, 3-12, 13-22 och 23-25). För varje unge och period beräknades den genomsnittliga viktavvikelsen från de båda kurvorna, som beskriver sambandet mellan ålder och vikt

samt vinglängd och vikt. I grova drag kan sägas att ungar som hade låg vikt för sin ålder överlevde sämre till den efterföljande perioden än ungar med hög vikt (Fig. 5). Vad gäller viktavvikelse i relation till vinglängd så fanns inga statistiskt säkerställda skillnader för de två tidigaste perioderna men väl från den tredje till den sista perioden (Fig. 6).

Sammanfattningsvis kan sägas att två sätt står till buds för att med rimlig arbetsinsats indikera näringssituationen för en skrattmåskoloni. Antingen bör ett besök göras just då majoriteten kullar kläcks, varvid de nykläckta ungarna vägs och ringmärks. Eftersom kläckningsvikten tycks förutsäga ungar-
nas överlevnadschanser, är den troligen något slags

mått på näringsförhållandena. Om tillräckligt antal ungar märks och återfångas vid ett senare besök, kan deras vikt relateras till kurvan i Fig. 1. En mindre arbetsintensiv metod är att välja en tidpunkt då de flesta ungarna i den studerade kolonin är 2-4 veckor gamla. Genom att mäta deras vinglängd och vikt vid ett enda besök och utnyttja det samband som presenteras i Fig.3 bör ett mått på näringssituationen under ungarnas botid erhållas. Ligger punkterna för de enskilda ungarna ovanför kurvan är situationen god, ligger de under indikerar detta födobrist. Detta är en enkel och föga arbetsintensiv metod som borde prövas i ett större antal kolonier.