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Food of the white-tailed eagle Haliaeetus albicilla in Greenland

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Six nests of white-tailed eagles in the southernmost Greenland were watched during the nestling period and food items recorded photographically by remote controlled cameras. The species composition of the food was representative even for the adult eagles' diet. Fish made up a major part of 90%, various bird species and arctic fox pups the remaining 10%. The total intake of an eaglet amounted to 50 kg from hatching to fledging. The daily requirements of fledglings, some 800 g fish food, are equal to previously reported values for older birds. The rate of food consumption of eaglets is constant through most of the nestling period.

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Introduction

Information on the feeding ecology of the white-tailed eagle's *Haliaeetus albicilla* arctic outpost in Greenland has until recently been meagre. Kampp and Wille (1979) presented a rather extensive material, together with a summary of earlier records, but the method used was considered somewhat unreliable. The results presented here, gathered during the years 1976–80, are based on direct observation of the birds and should closely reflect the food habits during summer for the southernmost range of the species in Greenland.

The study also has aspects concerning conservation. The white-tailed eagle's population in Greenland is small and, therefore, vulnerable, and although legally protected since 1973 persecuted to some degree (Hansen 1979). As in many other places the eagle has been accused of killing lambs by sheep-farmers, and one of our aims has been to elucidate the frequency of such incidents and the circumstances under which they are likely to occur.

A preliminary account of the results for the years 1976–78 has been published earlier (Wille 1979). A few minor errors in the table of that report have been corrected here.

Methods

The material has been obtained during a general investigation of the eagle's ecology and behaviour, initiated by FW in 1975. The study area lies within the sheep-farming areas of South Greenland, approximately identical to 'area I' in Hansen (1979). The main part of the material consists of a complete record of the food items brought to a total of six nests during part of or the whole nestling season. In addition, a number of other observations concerning food have been made at these and other nests during the incubation, nestling and fledging stages of the breeding cycle.

The recording of food items brought to the eaglets was made photographically by motorized cameras placed near the nest and released from a hide via a cable – this we judge more reliable than releasing by radio, and furthermore the equipment used (Leicaflex SL Mot or Leica R3) sends a return signal to the releaser unit, triggering the counter and telling the observer if anything goes wrong. The cameras were mounted in weather- and sound-proof boxes permanently placed for the whole period. At most nests the cameras covered the nest itself and the space immediately above and in front of it, and the arriving birds were photographed

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Fig. 1. Project photo, uncut copy from the original colour slide. The fish is a bull rout.

just before alighting (Fig. 1). To be sure of getting at least one satisfactory picture, two cameras were used in tandem, with different setings and focal lengths. At one eyrie, due to the character of its immediate surroundings, a single camera had to be placed 60 m away from and somewhat above the nest, equipped with an 800 mm lens.

The observation hide was built of glass-fiber modules and therefore firm, weather-proof and reasonably comfortable, but still also transportable. The observer could stay for several consecutive days, which is a great convenience when observing an extremely shy species and wishing to reduce disturbance as far as possible. Routine activities has mostly been to replace observer and films every second day. Often this could be done in half an hour; late in the season, when it was dark by night, replacement could be done in darkness without disturbing the birds at all.

Comments on the method

Food composition of birds of prey has usually been studied by means of food remains and pellets collected at nests and roosts. It is widely realized, however, that materials thus obtained give biased estimates of the species and size distributions of food animals, due to the varying durability of the remnants (see e.g. discussion and references in Tjernberg 1981). This difficulty is especially grave in a species like the white-tailed eagle, which like its congeners eats a mixture of fish and bird prey, together with occasional mammals. Fish will often be wholly eaten and have no fur or feathers to form pellets, and what small parts which may remain are much less durable than bird and mammal bones. Consequently, fish will be underrepresented in food remain materials (Glutz et al. 1971; see also Kampp and Wille 1979).

In later years investigations by observation of live birds have been carried out for several raptor species, either directly or by use of time-lapse photography (e.g. Green 1976, Häkkinen 1977, Newton 1978). Often only a part of the nesting season has been covered, or the food brought to the nest during the whole period has been sampled. In eagles food deliveries are infrequent, and continuous observation during several weeks is necessary in order to make the material sufficiently extensive for reliable qualitative and quantitative assessments.

Our method clearly provides the desired results concerning food, and also a wealth of information on the behaviour of the eagles. It has, however, some disadvantages. First, it sets some limitations as to which nests can be studied, since it must be possible to place the hide as well as the cameras in a suitable way. Besides, the observer should be able to overlook the surroundings in order to achieve information on activities of adult birds. Secondly, while eagles easily accept the presence of a hide, not all pairs tolerate the cameras, in most cases placed less than 15 m from the nest. Adult white-tailed eagles are extremely wary; at one nest we had to stop the observation because the female refused

to alight on the nest, and at another we suspect that our activities gravely influenced the behaviour of the female. In both cases the chicks later fledged normally.

Thirdly, the technique requires time and manpower. There have been no difficulties in getting assistance from quite a number of helpers, but not all observers had relevant experience, and the number of persons involved has made the observation journal somewhat heterogeneous. However, this hardly influences the record of food items. Another point is, that even the experienced observer cannot be constantly alert, and where the observer occasionally has failed to activate the cameras in time we must rely on the journal alone. A few food deliveries may even have been totally missed, but normally the arrival of an adult will be announced by screams from the chicks.

Finally, of course, the equipment must be very reliable under these circumstances. Difficulties have mostly been solved by uncomplicated repairments in the camp and, as far as possible, by having duplicates of key items.

Results

It has generally been easy to identify delivered food items from the photos (Fig. 2). Fish can usually be identified to species. Birds involve difficulties, plucked as they are when brought to the nest, and occasionally they have been identified from remains during film replacement.

Identities and numbers of food items delivered to the six study nests are listed in Tab. 1. All other food records, from the same sites concerning food not brought to the nests and from elsewhere, are compiled in Tab. 2.

A few comments on the nests in Tab. 1 may be of interest in evaluating the data:

Nest I was situated on a large island at the outer coast. The possibilities to observe the adults away from the nest were very limited; otherwise the nest was ideally placed.

Nest II was situated by a large fiord. It had to be abandoned after a couple of weeks because the female eagle, as mentioned above, suddenly refused to return to the nest.

Nest III was placed by an almost circular inner fiord 2–3 km across. Fish, especially cod, were very abundant, and the eagles even used a nearby stream with char as a source of food. The nest was suited for observation, so far as the cameras could be conveniently placed and the opportunities to watch activities of the adult birds were excellent. On the other hand the hide had to be placed much lower than the nest.

Nest IV was placed by a large fiord, with aggregations of non-breeding gulls. A stream running right beneath the nest spread out as a delta. However, the stream was devoid of life, and even the delta, lacking proper tidepools, was of little significance as a food-source for the eagles (compare nest V). The nest was not very suited for observation, as the cameras could not be properly placed. The records from most of the season therefore only consist of the observers' notes. Observations were

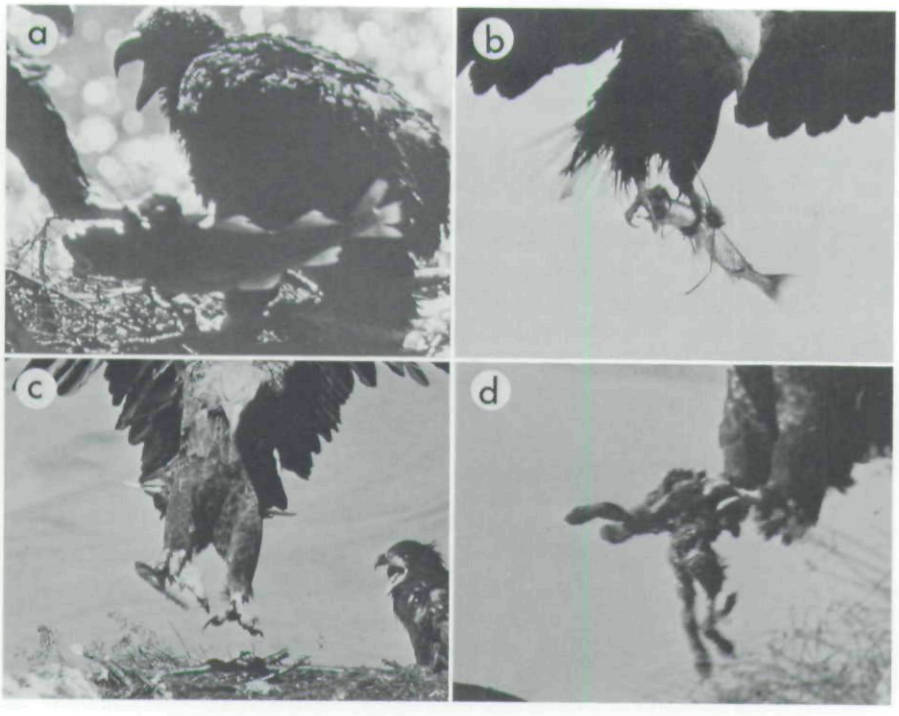

Fig. 2. Details of project photos showing the prey. Even in black-and-white the identifications are readily made: a) cod; b) char; c) long rough dab; d) arctic fox.

Tab. 1. Numbers (n) and percent of total (%) of food items brought to the nests. In all nests two chicks hatched, but in I, IV and VI the youngest died within one or two weeks. English names of prey species are given in Appendix 2.

Nest No. (Year) Number of days observed	I (1976) 33		II (1977) 15		III (1977) 49		IV (1978) 66		V (1978) 74		VI (1979) 71	
	n	%	n	%	n	%	n	%	n	%	n	%
FISH												
Clupea harengus	–	–	–	–	–	–	–	–	–	–	1	0.7
Salvelinus alpinus	–	–	2	8.7	22	22.4	30	26.3	95	44.0	32	21.5
Mallotus villosus	–	–	–	–	–	–	–	–	6	2.8	–	–
Gadus morhua	4	6.7	1	4.3	16	16.3	14	12.3	2	0.9	42	28.2
Gadus ogac	15	25.0	2	8.7	1	1.0	14	12.3	36	16.7	9	6.0
Gadus sp.	31	51.7	1	4.3	3	3.1	4	3.5	5	2.3	28	18.8
Sebastes marinus	–	–	–	–	–	–	2	1.8	–	–	–	–
Myoxocephalus scorpius	2	2.3	–	–	10	10.2	–	–	23	10.6	7	4.7
Cyclopterus lumpus	–	–	–	–	5	5.1	4	3.5	2	0.9	8	5.4
Hippoglossoides platessoides	–	–	–	–	–	–	2	1.8	32	14.8	1	0.7
unidentified fish	–	–	14	60.9	33	33.7	27	23.7	10	4.6	8	5.4
Total fish	52	86.7	20	87.0	90	91.8	97	85.1	211	97.7	136	91.3
BIRDS												
Gavia stellata	1	1.7	–	–	–	–	–	–	–	–	–	–
Lagopus mutus	1	1.7	–	–	–	–	–	–	–	–	–	–
Larus hyperboreus	–	–	1	4.3	–	–	3	2.6	–	–	–	–
Larus sp.	–	–	–	–	–	–	2	1.8	–	–	–	–
Rissa tridactyla	–	–	–	–	–	–	6	5.3	–	–	–	–
Cepphus grylle	–	–	1	4.3	–	–	–	–	–	–	–	–
Corvus corax	–	–	–	–	–	–	–	–	–	–	4	2.7
unidentified birds	5	8.3	1	4.3	1	1.0	1	0.9	1	0.5	1	0.7
Total birds	7	11.7	3	13.0	1	1.0	12	10.5	1	0.5	5	3.4
MAMMALS												
Alopex lagopus	–	–	–	–	4	4.1	–	–	3	1.4	8	5.4
Total mammals	–	–	–	–	4	4.1	–	–	3	1.4	8	5.4
UNIDENTIFIED PREY	1	1.7	–	–	3	3.1	5	4.4	1	0.5	–	–
TOTAL	60	100	23	100	98	100	114	100	216	100	149	100

continued because they could easily be done parallel to those towards nest V.

Nest V was placed by a broad inner fiord near a large estuary with shallow tide-pools which offered excellent and much frequented feeding places for the eagles. Also char going up the stream here were exploited. The nest was very suited for observation.

Nest VI was an alternative nest of 1979 for the pair which had nest III in 1977, lying at the same inner fiord. It was easier to place a hide here, but cameras had to be placed far from the nest. This problem was solved by using an 800 mm lens which covered the nest itself, rather than the space in front of it. Prey items were accordingly photographed lying on the nest rather than hanging in the talons of the adults; this has made the identification slightly more difficult than otherwise.

The average frequencies of food deliveries to the nests are given in Tab. 3. The variation through the season is shown in Fig. 3 for nests IV, V, and VI, which were covered for the whole nestling season except for the first week. In nest IV the frequency of food deliveries was slightly lower after mid-July than before, the difference being just significant (χ^2-test, $P = 0.03$), whereas no trends are discernible for nests V and VI.

The mass of the food brought to the nests has been estimated for nests V and VI, where the photographic

Tab. 2. Food (number of items) not included in Tab. 1, i.e. not brought to the chicks of the six study nests. All such records through the years 1976–80 are included.

	Fate of food			Total
	eaten by nestlings or fledglings	eaten by adults	not known	
Fish	87	54	27	168
Birds	3	2	2	7
Mammals	4	1	0	5
Unidentified	12	1	2	15
Total	106	58	31	195

Tab. 3. Mean frequency of food deliveries to the nests.

Nest	I	II	III	IV	V	VI
Chick-days	38	30	89	66	140	77
Food items per chick per day	1.6	0.8[a]	1.1[a]	1.7	1.5	1.9

a. presumably too low owing to investigator-caused disturbances and, possibly, missed food deliveries.

record is almost complete. Food items visible from suitable angles were measured on the photos. The lengths were converted into biomass using weight-length relationships for fish caught by us. Since only a sample of the prey could be measured, mean values had to be used to assess the total mass of food brought to the nests. This should, however, be justified since the measurable fishes seem to be quite representative. The accuracy of the result is, however, difficult to assess. The major source of error lies in the very broad mass distributions of fishes caught by the eagles (Fig. 4), with standard errors generally lying between 10% and 20% of the means. The overall inaccuracy is probably somewhat less, judged from photos of fishes not measured.

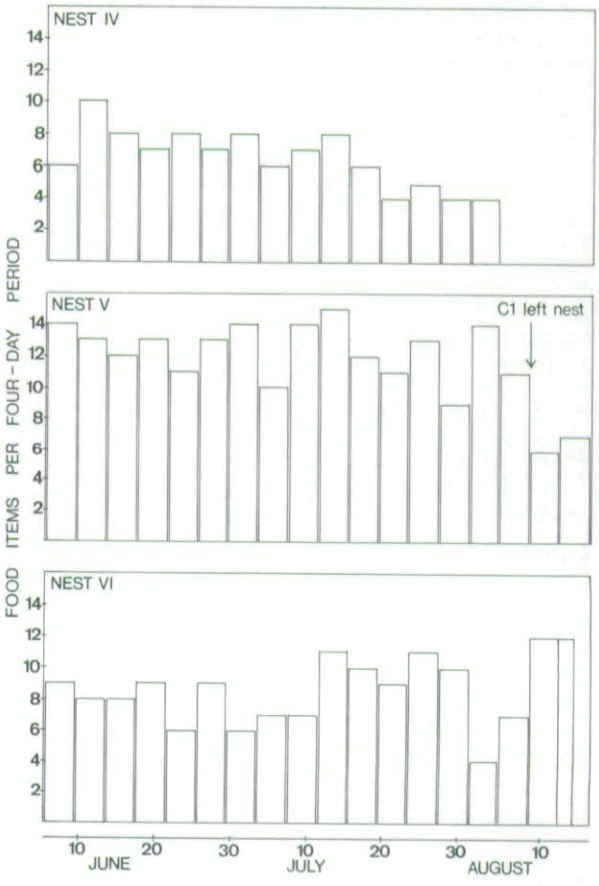

Fig. 3. Number of prey per four day period brought to nests IV, V and VI, with one, two and one eaglets, respectively. The oldest young left nest V on 9 August.

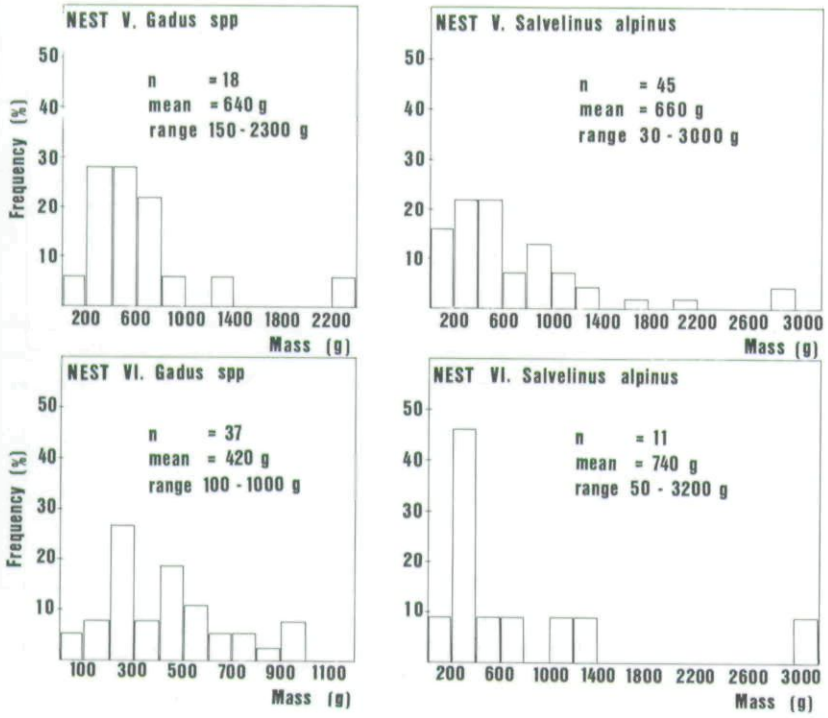

Fig. 4. Biomass distributions of fish caught by the eagles at nests V and VI.

Tab. 4. Biomass of food brought to nest V and VI and food intake of the chicks. The figures for nest VI concern the surviving nestling alone; it was excessively supplied with food late in the season and some was wasted.

Nest	Chick-days	food brought to nest (kg)	total food per chick[a] (kg)	Food per chick per day (g)	
				whole period	last five weeks only
V	140	116	52	740	820
VI	71	72	63	890	1180

a. corrected for amount eaten by adults.

Errors in length determination and length-weight conversions are of minor importance. Accordingly, we consider the values of total mass brought to the nests accurate to within 10% or a little more.

The live weight of the prey had to be corrected, as items delivered were often partly eaten by the parent birds. For fishes, this usually implied that the head was missing, and the proportion of decapitated fishes varied considerably between species and between nests. For *Gadus* spp. it was 25% at nest V and 45% at nest VI, for *Salvelinus alpinus* 20% and 25%, respectively, while extremes were *Hippoglossoides* (more than 90%) and *Myoxocephalus* (less than 10%). A further reduction of 5% at nest V and 10% at nest VI has been made to account for prey brought as small remains and a few prey removed by the parent birds later on. The weights thus corrected are given in Tab. 4. Some of the food, however, was eaten by the adults on the nest during the first part of the season. We estimated this to be 20% of the food brought before 10 July. The rest was available to the chicks and normally almost completely consumed. In nest VI, during the late part of the season, the chick was occasionally so lavishly supplied with food that a considerable proportion was wasted. Its consumption was probably comparable to that of the chicks in nest V (Tab. 4).

Discussion

Choice of prey

Although Tab. 1 concerns food of nestlings, the figures in Tab. 2 suggest that the results are representative of the summer diet of the entire population, not of nestlings alone. This conclusion is supported by the fact that prey often are partly eaten when delivered to the nests.

The figures clearly indicate that the white-tailed eagle in this region primarily subsists on fish in the nesting season. Probably this is the most highly fish dependent population of the species to be found anywhere. This is not surprising: birds, including water-birds, which make up a considerable part of the eagle's diet elsewhere (see Glutz et al. (1971) for a review), are scarce in these parts of Greenland. This fact is probably due to the unpredictable climate and ice conditions, caused by the variable amount of floating ice arriving with the East Greenland current each spring and summer (Salomonsen 1950–51, Nørrevang 1973). Further north birds are much more numerous and may form a larger part of the eagle's diet (Kampp and Wille 1979).

Tab. 1 shows some differences between the pairs. This reflects rather closely the availability of different prey species in different types of nesting localities, although individual habits of the birds could influence the picture to some degree. Roughly speaking three types of localities are apparent:

(1) Skerries (nest I): fish, mostly *Gadus*, make up some 90% of the food items; char rarely being available. The rest of the food consists of various water-birds.

(2) Larger fiords (nests II and IV): fish make up some 90% or a little less; *Gadus*-species important, while char may or may not be available. The rest consists mainly of birds, especially gulls.

(3) Inner fiords (nests V and III/VI): fish make up 90% or more. *Gadus*-species are again important; char may or may not be available. The rest consists of pups of the arctic fox, and sometimes land-birds, in any case the raven.

This classification of habitats roughly corresponds to the zones A, B and C of Christensen (1979) determined by the distance from the outer coast. In our scheme, about 20% of the at present active nest sites are found in localities of type (1), 45% in type (2) and 35% in type (3). The whole eagle population in the area then should eat, by numbers, about 90% fish (20% *Salvelinus alpinus*, 65% *Gadus* spp. and 5% others), at most 10% birds (mostly gulls) and 1–2% arctic foxes.

No sheep or lambs whatsoever were brought to any of the nests, although sheep wool occasionally was brought as nest lining. This is hardly surprising, as the lambing mainly occurs in early May; some of the lambs are born already in early April. In the nestling season the lambs obviously are too heavy for an eagle to carry, and probably to kill; a white-tailed eagle carries about 4 kg as an absolute maximum (own observations). If lambs are brought to the nests they have to be taken as carrion. An eagle should physically be capable to take a lamb in its first week or so, but presumably will do so only under special circumstances. The sole incident we have witnessed concerned a lamb about 2 d old and occurred on 9 April 1980, after the weather had deteriorated seriously with frost and heavy snow.

Food quantities

From Tab. 4 it appears that about 50 kg fish is needed to rear a white-tailed eagle chick to fledging. Late in the season the daily requirements are 800 g, approximately. The chicks in question appeared to be well nourished.

Most previous records of the daily food requirements concern adult or immature birds whose needs might

differ somewhat from that of a fledgling. Furthermore, in comparing food weights its nutritive values must be taken into account. This cannot be done very precisely, but in the following the average energy content of fish food is set equal to 5 kJ g^{-1}, while for birds and mammals 8 kJ g^{-1} is used. Figures in the literature generally cluster around these values. In addition, equal digestibility of the various food types has been assumed.

Uttendörfer (1939), using data from Heinroth and Heinroth (1927), gives 500 g clean meat as the food requirements of an adult white-tailed eagle. Since this refers to rat meat it should correspond to about 800 g fish. Willgohs (1961) mentions a case where the adults and their chicks daily got 625 g each, of a composition corresponding to a little less than 800 g fish (supposing that all was eaten), but during the period in question the chicks lost weight. Willgohs (1961) also refers to a captive immature male which ate 500 g d^{-1} of unspecified food through several months, during which its weight varied only slightly between 5.0 and 5.3 kg. For seven captive immatures, Love (1979) reported from 409 to 618 g food daily, which were 8.0–11.0% (mean 9.4%) of the body weight. The food was 50% mammal and 25% each of bird and fish, which should correspond to 600–900 g fish daily (14% of body weight). In conclusion, there is no apparent difference between fledglings and older birds, the daily requirements being a gross intake of nearly 4000 kJ, and presumably a little more for free-flying birds. Incidentally, it seems a little puzzling that the white-tailed eagle should need more food, relative to body weight, than the golden eagle *Aquila chrysaethos* (figures in Fevold and Craighead 1958), although the latter is a smaller bird.

A remarkable feature of the food intake of eaglets is the constancy in time. The rate at which food is brought to the nest varies little by season. This is shown in Fig. 3 as regards numbers of prey and will roughly hold true even for food mass. In the first couple of weeks after hatching an eaglet's requirements are naturally relatively small; a hand-reared chick (Helander 1978 and pers. comm.) ate 375 g d^{-1} (fish constituting at most 25%) as average during its first 5 weeks, increasing from 20 to 500–600 g over the three first weeks and thereafter roughly constant. The food surplus during the first weeks is eaten by the parent birds; one of these is almost constantly present anyway (the chicks are brooded for about 4 weeks).

While the adults evidently do not regulate the rate of food deliveries according to their chicks' requirements early in the season, they rather precisely do so according to the number of chicks, as clearly shown in Fig. 3 and Tab. 3.

The approximately constant food requirements of eaglets are probably a consequence of the growth pattern, with the inflexion point of the growth curve lying early (i.e. before half the asymptote weight is attained), implying that the food demands for growth are largest when the maintenance requirements are small. A growth curve thus skewed accordingly leads to a smaller peak demand at the cost of an increased total food demand, when compared with a symmetrical growth curve. The effect is rather small, however. A simplified calculation (see Appendix 1) gives a reduction in the peak value of 8% and an increase in the total cost of 13%, compared with a hypothetical logistic growth pattern. The adaptive significance of a skewed growth curve, with its emphasis on rapid initial growth, should rather be seen in the light of the intense competitive regime under which eaglets grow up (cf. O'Connor 1978).

It should be added that the above-mentioned calculation predicts a total food consumption of 152000 kJ, or about 30 kg of fish. With allowance for incomplete food digestion and energy used in exercise this figure is consistent with our finding of a total amount near 50 kg.

Conclusions

The white-tailed eagle in South Greenland is primarily a fish-eater in the summer; other prey species are waterbirds (especially gulls), raven and arctic fox, but altogether these make up only 10% (by numbers) of the food. The minor differences between pairs in diet can mostly be attributed to food availability in the feeding areas. The amount of food needed to rear an eaglet to fledging is approximately 50 kg of fish. The rate at which food is brought to the nests is almost constant through the season and in the first weeks, when the needs of the chicks are small, the adult birds eat the surplus.

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Appendix 1

The energy requirements during growth were estimated as the sum of energy going to maintenance and energy going to growth. Maintenance requirements were calculated as existence metabolism at 0°C according to Kendeigh (1970). The growth was modelled by a Gompertz type curve (Ricklefs 1968) which has the form $W = A\exp(-B\exp(-Kt))$, where W is the mass of the

eaglet. Based on figures found in various publications and a few weighings of eaglets by ourselves, the following parameter values were used: A = 5500 g, B = 4 and K = 0.072 d^{-1}. They are not necessarily very accurate but will suffice for a rough calculation like this. As proposed by Dunn (1975) a linearly increasing caloric density of the chick, from 2.9 kJ g^{-1} at hatching to 8.4 kJ g^{-1} at fledging, has been used. The logistic growth curve used for comparison has the form W = A/(1 + Bexp (–Kt)), where parameters were chosen to give the same values of initial mass, asymptote and t_{10-90} (see Ricklefs 1968) as the Gompertz type curve: A = 5500 g, B = 55 and K = 0.102 d^{-1}.

Appendix 2

English names of prey species.

Clupea harengus ..... Herring
Salvelinus alpinus ..... Arctic char
Mallotus villosus ..... Capelin
Gadus morhua ..... Cod
Gadus ogac ..... Greenland cod
Sebastes marinus ..... Norway haddock, redfish
Myoxocephalus scorpius ..... Bull rout
Cyclopterus lumpus ..... Lump-sucker
Hippoglossoides platessoides ..... Long rough dab
Gavia stellata ..... Red-throated diver
Lagopus mutus ..... Ptarmigan
Larus hyperboreus ..... Glaucous gull
Rissa tridactyla ..... Kittiwake
Cepphus grylle ..... Black guillemot
Corvus corax ..... Raven
Alopex lagopus ..... Arctic fox

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