weights increased following a change from feeding on submerged aquatic vegetation to field feeding.

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WEIGHT CHANGES IN *CYGNUS OLOR*

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Introduction

Since 1968 a considerable number of biometric data on Danish *Cygnus olor* have been collected in connection with the swan investigations of the Zoological Museum in Copenhagen. Most of these data have been transferred to magnetic computer tape but not yet analysed. More than 10 000 data on weight are included. The present paper includes only a few chosen aspects concerning the weight of *C. olor* and the possible reasons for some of the differences in weight which have been found. The significance of the weight in relation to mortality will be shown with some examples.

It can be assumed that the growth period of the young and the moulting period represent periods when quality and quantity of food will have great effect on swan weights. The winter period, with frequent food limitation, is also of great significance for the survival of the swans, and the weight development in ice-winters will be dealt with, too.

The Danish breeding population

The Danish population of *C. olor* has increased considerably. In 1925 there were only 4 to 5 pairs but today at least 4000 pairs breed. There are two main types of breeding habitat: freshwater lakes with solitary breeding pairs and brackish or salt shallows with swans breeding in colonies on isles. The number of colonial swans has been increasing over the last 20 years. In 1978 there were 1500 to 2000 pairs breeding in colonies. The biggest colony is on Klaegbanken in Ringkøbing Fjord, Jutland, and consists of 662 pairs. Apart from this one the majority of colonies are situated in southeastern Denmark (Andersen-Harild and Preuss 1978).

Weight conditions in young of solitary breeding pairs

An area in Copenhagen and northern Sjaelland, where on average about 60 pairs breed, was investigated. The population of this area has been more or less constant since investigations started in 1966. Most of the swans are familiar with humans and it is relatively easy to catch the broods by feeding them. Most of the breeding pairs in this area get part of their food from humans but naturally growing plants are still the most important food source.

The area investigated has a much bigger number of vacant potential breeding places for *C. olor.* For the period 1966 to 1975, 95 localities are known where at least for one year a nest was built and eggs laid. However, on average only 44% of these are used.

Examples from two localities show how the plant food available affects the weight of the young:

– (i) Gentofte Lake, in the northern vicinity of Copenhagen, is a eutrophic lake about 1.0 km long and 0.4 km wide. It is very shallow (0.5 to 2.0 m deep) and along the western side there are a number of reedy islets where each year four to eight pairs of *C. olor* nest. Some of these pairs, normally birds without experience, are usually chased away and the remaining pairs split the lake into territories. Originally the submerged vegetation in the lake consisted of a dense growth of *Ceratophyllum, Myriophyllum* and *Potamogeton pectinatus.* In the late summer of 1975 an excavation for a main sewer was started along the eastern side of the lake. This excavation resulted in large amounts of particles being suspended in the water. The water became turbid and the submerged vegetation almost disappeared. The work lasted for about a year and not until the winter 1976/77 was the area re-established. Since then the transparency of the water has increased slowly and water plants, especially *Potamogeton pectinatus,* are once more common.

How these changes affected the weight of the swans is shown on Fig 1. Until 1974 the lake produced big and healthy swans, with females weighing 7 to 8 kg at an age of three months, and males 8 to 9 kg. When captured on 30 August 1975, two of the three broods showed a normal weight, whereas the third, whose territory was in the part of the lake where excavation had started, weighed considerably less. In 1976 the weight of all young was low, about 5 kg. Since then weights have increased slowly so that they were nearly normal again in 1979.

– (ii) Viemose, the other breeding locality, is a reservoir for surplus rainwater, some 150 x 75 m in size. This locality had an extremely dense submerged vegetation of *Elodea canadensis* which is obviously one of the swans' favourite plants. From 1966 to 1968 some big broods with heavy young were produced, weighing about 10 kg at an age of three and a half to four months. For unknown reasons the vegetation was partly spoiled in 1969 and the weight of the young decreased to

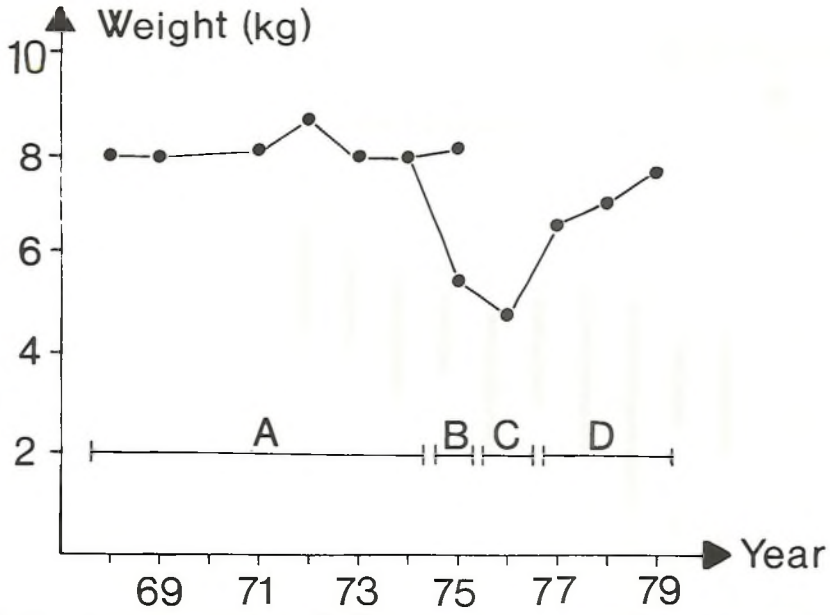

Fig 1. Average weight of *Cygnus olor* cygnets in Gentofte Lake around 1 September, 1968 to 1979.

A: Dense submerged vegetation. B: The submerged vegetation is being spoiled in the southern part of the lake. C: The submerged vegetation of the whole lake is spoiled. D: The submerged vegetation is slowly re-established.

less than half. In 1970 the vegetation of the lake was strongly reduced and the bottom consisted of stinking mud. The cygnets had no chance of going ashore to graze, as the lake is surrounded by a fence. During 1970/71 no swans bred, and in 1972 attempts to breed were unsuccessful. Broods produced in 1973 and 1974 had young weighing 4 to 5 kg by September. In 1974, which was the last year with breeding swans here, a male cygnet weighing only 3.9 kg was caught in the beginning of October.

These two examples illustrate clearly the importance of submerged vegetation for swans. From 1968 to 1975 all weights of birds caught in the period 24 August to 8 September have been examined to see how often the locality in question had been used as a breeding place (Fig 2).

The result is that the less a locality is used, the lower the weight of the young produced there. The picture is distorted to some extent by the fact that at some localities, especially those used least, extra food, eg grain and grass, is given by people living close by, who feel sorry for the poor small young. The picture is further distorted because we tend to avoid catching the lightest broods around 1 September, as their tarsi are often so small that the rings fall off. If these two

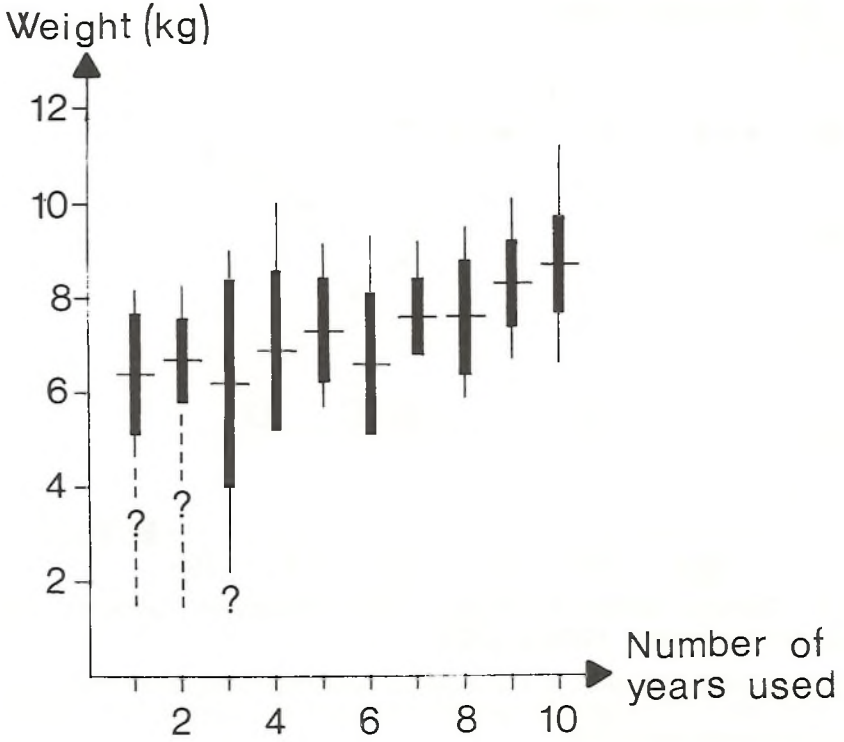

Fig 2. The average weight of young from an area of North Zealand and Copenhagen around 1 September, related to how often the locality has been used as a breeding place.

Average, standard deviation and range of variation are shown. Question marks indicate that there have been broods with low weights which have not been caught.

facts were taken into consideration, the differences would be still more marked.

When botanical conditions, especially submerged vegetation, are investigated, it becomes clear that some of the following conditions are characteristic for bad swan localities:

- acid water with consequent poor vegetation;
- deep lakes with steep shores;
- polluted lakes with poor transparency and consequent absence of submerged plants;
- few opportunities of grazing ashore.

Good swan localities are characterized by some of the following conditions:

- neutral or basic water;

– shallow eutrophic lakes with rich vegetation of *Elodea canadensis, Potamogeton* sp, (eg *P. pectinatus* and *P. gramineus*), *Myriophyllum, Ceratophyllum, Chara* sp;
– growth of *Phragmites;*
– opportunities of grazing ashore;
– feeding by man.

The size of the lake seems to be of minor consequence. Several ponds situated close to each other can be used by the same swan pair.

Weight conditions in swans breeding in colonies

Young were caught in two areas:

– (i) Roskilde Fjord is a mesohaline, shallow fjord, about 40 km long, and about 30 km west of Copenhagen. There are now several swan colonies in this area, with altogether around 200 breeding pairs. The biggest colony is situated on Langholm, an island about 500 m long, and has 50 to 90 pairs. When the breeding season is over, the broods spread evenly over the whole fjord. The submerged vegetation consists mainly of *Zostera marina* and *Ruppia maritima* as well as *Potamogeton pectinatus* and *Ulva lactuca* in some areas. *Zostera* in summer is overgrown by large amounts of epiphytic algae. Apart from breeding birds, there are in summer 1500 to 2000 non-breeding swans and in winter up to 3500 birds on the fjord. The young fledge from the end of September and are usually caught in the last part of September. Generally they are not as well developed as birds from lakes in Copenhagen and North Sjaelland (see Table 3).

There are rather distinct differences from year to year in the weight of the young (Table 1). These differences are not caused by changes in the breeding time, as this varies only a few days from year to year, with the spring of 1979 an exception.

Table 1. The weight of *Cygnus olor* cygnets in Roskilde Fjord.

Year	Date	Average weight (kg)	Average brood size	Survival up to 1 June in 2nd calendar year (%)	Number of days with ice in Danish waters in the first winter
1971	11–12 September	7.9	4.0	?	39
1972	20–22 September	8.5	3.6	76	4
1973	11–12 September	6.7	3.1	46	3
1974	21 September	8.4	3.3	79	1
1975	17–18 September	8.7	3.7	87	17
1976	17 September	7.5	3.0	29	26
1977	23–25 September	8.1	3.5	22	18
1979	29–30 September	6.7	3.3	?	83

It has not been possible to ascertain important changes in the submerged vegetation in the brackish areas.

– (ii) Bredningen, Guldborgsund, is situated between Lolland and Falster in southern Denmark. The conditions in the fjord are rather like those in Roskilde Fjord but the area is more exposed to wind. There are two big swan colonies with a total of about 100 breeding pairs (Clausen and Lind *in litt).* The area is an important wintering place for *C. olor,* whereas there are only a few moulting swans. Swans have been captured here for four years (Table 2).

Table 2. The weight of *Cygnus olor* cygnets in Guldborgsund.

Year	Date	Average weight (kg)	Average brood size	Survival up to 1 June in 2nd calendar year (%)
1973	23 September	7.8	4.8	94
1975	21 September	8.1	3.4	25
1976	18 September	6.1	2.3	5
1977	18 September	6.5	2.9	19

Causes of differences in weight

The swan broods most often stay in rather shallow water and the small young can often be seen pecking at the water surface. It can be assumed that small invertebrates, eg *Idotea, Gammarus,* are of importance, and possibly mysids and other crustaceans usually found in big numbers in the vegetation.

When the wind is strong it is more difficult for the young to seize these small animals, and at the same time the water level often rises, making the vegetation more difficult to reach. In addition, the wind forces the young to use more energy and their down may get soaked so that they become chilled and eventually die. The development of the survivors will be retarded.

Information about wind and wind speeds in Roskilde Fjord has been obtained from the meteorological station at Risø (M Frederiksen *in litt).* Strong winds in June have a particularly negative impact on the autumn weight of the cygnets. In years where the wind speed exceeded 9 m/sec for 20% to 25% of the time, the cygnets had relatively low weights as compared with calmer years. The first half of June, when the cygnets are 0 to 3 weeks old, appears to be a critical period. Thus in 1973, wind speeds exceeded 9 m/sec for 25% and 12 m/sec for 14% of the time in that period and the average weight of the cygnets in September was only 6.0 kg. In contrast, the weight of the cygnets averaged 7.4 kg in September 1975. June that year was very calm, with wind speeds above 9 m/sec for only 14% of the time.

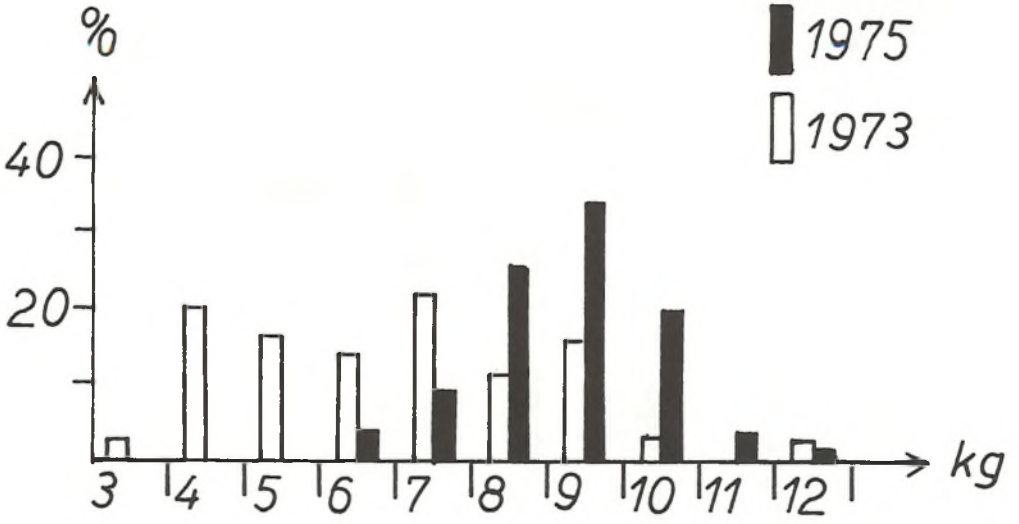

Fig 3. Variation in weight of young *Cygnus olor* in Roskilde Fjord in 1973 and 1975.

Fig 3 shows clearly that, apart from the difference in average weight, the weight variation among the young was largest during the windy year (1973). This is because some of the broods live in more sheltered areas, whereas the 'territory' of others is more exposed to the wind. During calm years, the importance of territory selection for the development of the young will be less.

The average brood size is positively correlated with the average autumn weight of the cygnets (Table 1).

Young from other localities also show significant differences in average weight.

Table 3. Average weight of *Cygnus olor* cygnets caught on different localities.

The weight has been calculated for 1 September, irrespective of differences in day of catching. The data from Tipperne are from 1977, the others from 1973.

Locality	Calculated weight (kg)
Tipperne, west Jutland (brackish water)	5.7
Roskilde Fjord, Sjaelland (brackish water)	6.1
Guldborgsund, Falster (brackish water)	6.6
Takern, Ostergotland, Sweden (fresh water)	6.2
Lakes in northern Sjaelland (fresh water)	7.7

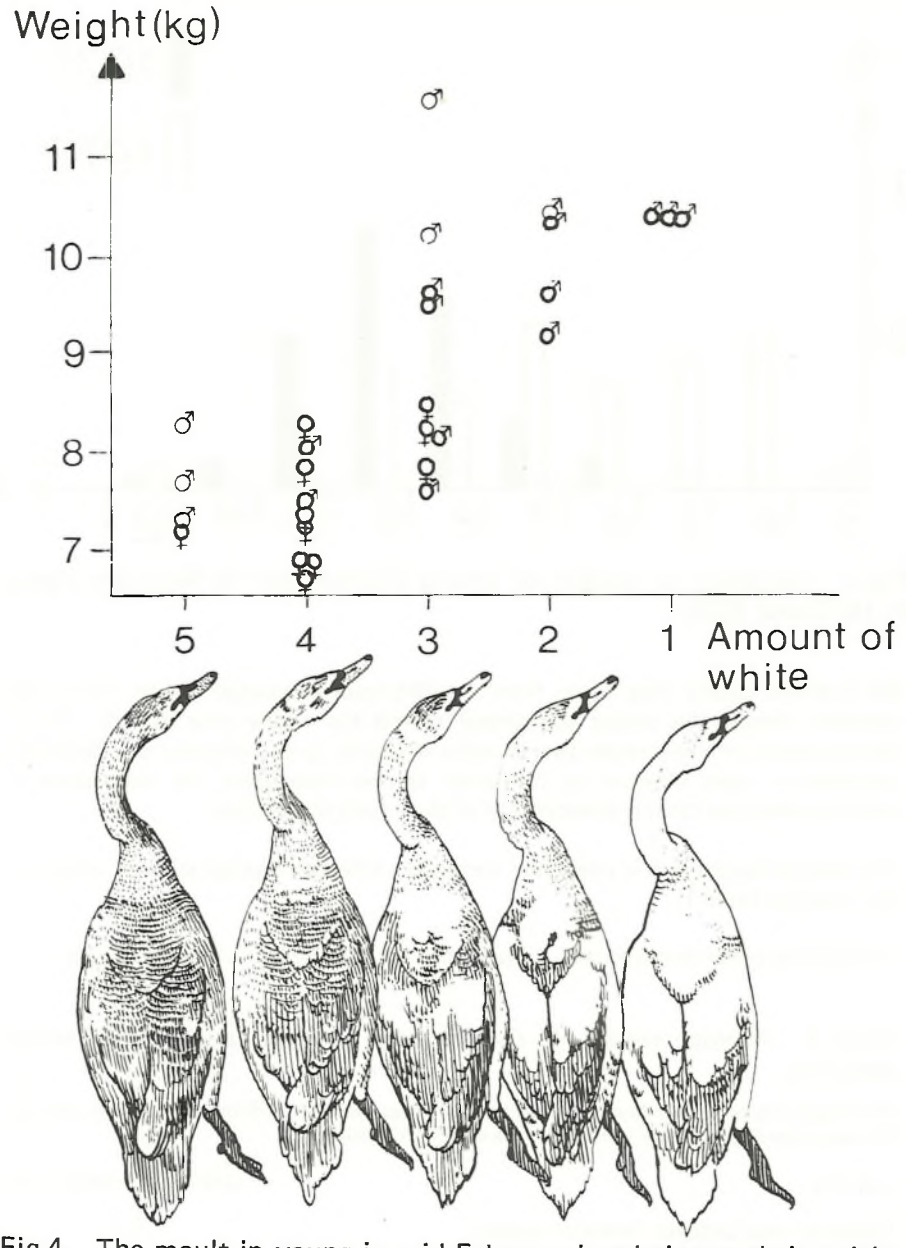

Fig 4. The moult in young in mid-February in relation to their weight around 1 September.

The figures at the bottom show the degree of moult: 1 = intense and early moult; 2 = intense but later moult; 3 = medium moult; 4 = little moult; 5 = none or only a few white feathers.

The moult of young in relation to weight

The moult of young starts during their first winter. The first birds with single white feathers are usually seen in October when the birds are four and a half to five months old. After that the birds gradually grow more and more white feathers but there are very big individual differences. In February and March all states can be seen from completely drab to very variegated young, where neck, upper back and tail coverts are white.

It is evident that during the coldest time of the year the growth of new feathers, which takes a lot of energy, can be carried out only by young which are in a good food situation. Fig 4 shows the relation between the weight of the young in September and their moult by mid-February.

The importance of weight for survival

Tables 1 and 2 and Fig 5 show how large a proportion of the young from Roskilde Fjord and Guldborgsund is known to have survived the first winter. A striking

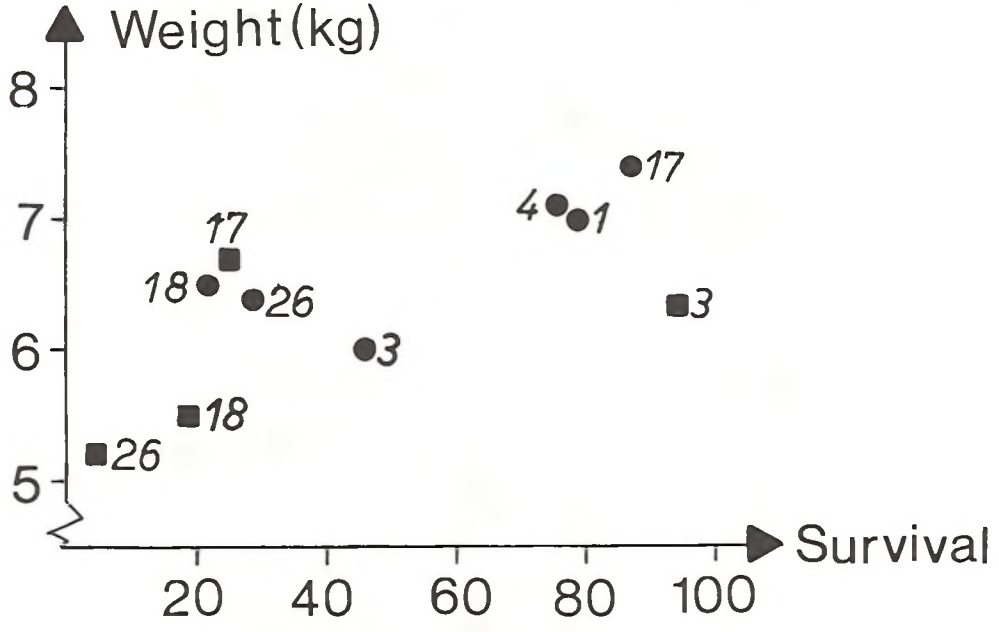

Fig 5. Correlation between the weight of cygnets in September and their survival from the time of ringing to 31 May in their second calendar year.

Circles indicate data from Roskilde Fjord – squares from Guldborgsund. The numbers indicate the number of days with ice in inner Danish waters.

relationship is apparent with the weight of the young, but severity of the winter is also involved. The survival rates are minimum values, as they originate from young ringed with neck-collars, seen after 1 June in their second calendar year. Some young may have lost the neck-collar or may have escaped notice.

Differences in weight in moulting swans

About 35 000 to 40 000 non-breeding *C. olor* stay in Danish waters (including the Swedish coast of Øresund) from June to September (Andersen-Harild 1971). These swans come from the entire Baltic area (Andersen-Harild 1981b) and assemble in certain places to moult their wing feathers. This lasts 6 to 7 weeks. Thereafter the birds leave the moulting places and go to good feeding areas nearby. The moult of body feathers continues through the autumn.

About 9000 birds were caught and a high number were weighed. The investigations have, besides other things, shown that the moult starts in the heaviest individuals.

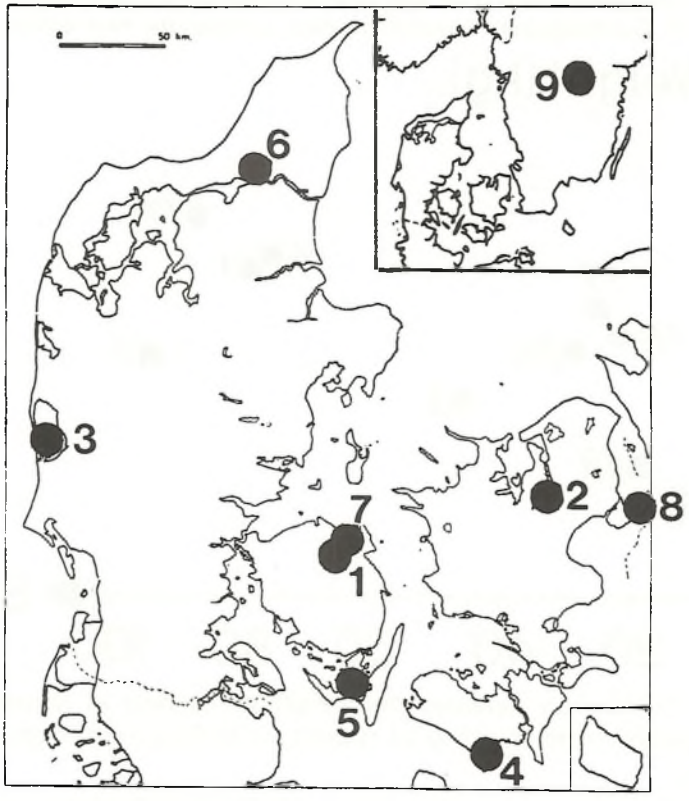

Fig 6. Situation of moulting places.

From year to year there may be a difference in time of onset of the moult but usually not more than one week. During moult the birds can lose up to 20% of their weight.

Description of some moulting places (Fig 6)

– 1 Seden Strand, Funen. The area is a very shallow brackish water area inside Odense Fjord. The renewal of water is poor and the area is influenced by sewage. In the past the fjord was overgrown by *Zostera* but because of sewage pollution this vegetation has gone and is replaced by *Ulva lactuca.* This change started at the end of the 1960s and the number of moulting *C. olor* increased from about 500 in 1968 to 2300 in 1974. *Ulva* is most probably the only summer food for swans in this area.

– 2 Roskilde Fjord has been described on page 363. The main food of the moulting swans is *Zostera* (with epiphytic algae) and *Ulva.* The swan population increased from about 600 in 1968 to 1700 in 1974 and has since then been more or less stable.

– 3 Ringkøbing Fjord, Jutland, is a brackish water area of about 295 km^2. The majority of swans remain on shallows in the southern part of the fjord. These areas, which are less than 1 m deep, are overgrown with *Ruppia* with a dense admixture of *Ulva;* besides there is some *Ranunculus* sp. The growth is very dense. The population of swans increased from 1300 in 1968 to 2500 in 1974.

– 4 Rødsand, south of Lolland, is the biggest moulting place for *C. olor.* The population increased from 4800 in 1968 to 7000 in 1974. The area is shallow with abundant growth of *Zostera, Ruppia* and *Chara.*

– 5 Strynø. The birds in this archipelago feed on the shallow areas off Tasinge or close to Bredholm. The vegetation here is mainly *Zostera.* The population increased from 2800 in 1968 to 4800 in 1974.

– 6 Ulvedybet is a shallow inshore area at Limfjorden in North Jutland. The area is brackish, fringed by extensive growth of *Phragmites.* The submerged vegetation is mainly *Fucus.* The area has a small population of swans – 300 in 1968 increasing to 700 in 1974.

– 7 Odense Yderfjord, Funen, is an area without especial importance for moulting swans, only a few birds staying here. This area is overgrown mainly with *Fucus* sp.

– 8 Saltholm in the Oresund near Copenhagen has long been known as a moulting place for swans. The population in this area decreased from 2300 in 1968 to 1100 in 1974. The majority of the birds stay along the eastern and southern

coast of the island, where the bottom is mainly sandy. There is no particularly rich growth of *Zostera* and *Ruppia,* but lots of *Fucus.*

– 9 Lake Takern, Ostergotland, Sweden. This is a big freshwater lake of about 50 km^2, surrounded by reeds. It is shallow and lightly alkaline, with an exceptionally rich vegetation of *Chara tomentosa, Myriophyllum* and *Potamogeton crispus.* The population of swans increased from about 1100 in 1968 to about 2700 in 1974.

Thus the ecological conditions differ considerably between the localities used as moulting places, ranging from open seas to estuaries, from inshore brackish water areas to big freshwater lakes. What they all have in common is that they are shallow and that the birds can find shelter from the wind. The vegetation in the areas varies considerably in species composition and density.

However, it seems that there is enough food available. The swans of Roskilde Fjord will, for example, be able to eat only a few percent of the available standing stock of *Zostera,* which is in accordance with the conditions on moulting places along the Swedish west coast (Mathiasson 1973).

Comparison of weights from different localities

When the weights of birds from different localities are compared (Table 4), it is obvious that birds feeding on *Ulva* have the highest weight. As growth of algae,

Table 4. Average weight for male *Cygnus olor* after second calendar year, caught on different moulting places around 1 August.

Moulting place	Average weight (kg)	Main food
Roskilde Fjord	11.6	*Zostera* (with epiphytic algae), *Ulva*
Seden Strand	11.5	*Ulva*
Takern	11.1	*Chara*
Ringkøbing Fjord	10.9	*Ruppia, Ulva*
Rødsand	10.6	*Zostera, Ruppia, Chara*
Strynø	10.5	*Zostera*
Odense Yderfjord	10.4	*Fucus*
Ulvedybet	10.3	*Fucus, Phragmites?*

favoured by sewage, has increased during recent years, there is no doubt that the increased pollution in this case has favoured the species.

Next to *Ulva,* it seems that *Zostera* and the epiphytic algae on it, which may weigh just as much as the *Zostera* itself, *Ruppia* and *Chara* are of high food value for swans, whereas *Fucus* is of less value.

To avoid possible differences in age composition of swan flocks influencing the average weight, only data from localities where the age composition has been roughly equal are included.

The birds from Saltholm originate from eastern Denmark and southern Sweden (Andersen-Harild 1981b). The breeding population of this area is stagnating or slowly decreasing, which has probably led to a lower average age of the moulting population.

The average weight for swans in this area has decreased over the last ten years. In the period 1969 to 1972 the average weight for males after their second calendar year was about 11 kg, but subsequently the weight has decreased to about 10 kg. It is possible that the reason for this decrease is a different age composition of the population but it might also be that the submerged vegetation has changed.

Weight changes in winter

Denmark is a very important wintering area for *C. olor.* In cold winters the population may reach 70 000 birds, whereas in mild winters the Danish population remains at around 45 000 birds (Joensen 1974). The maximum occurs at the end of January and in February.

The mean January temperature in Denmark is close to 0°C, but from time to time there are winters with lower temperatures, and shallow areas may then be covered with ice for up to three months from December to March (Table 5).

This ice cover causes severe food limitation for feeding swans. Cold weather migration brings birds from other parts of the Baltic to Denmark, but only a few Danish birds leave Denmark for northern Germany and Holland.

Grazing on land, which is commonly seen in *Cygnus cygnus cygnus,* does not occur in *C. olor* in winter. Instead *C. olor* gathers in big numbers in openings in the ice, which are kept free by currents or sewage effluent. At some places the hundreds of hungry swans attract the attention of the public, who feed them bread, grain, etc. However, it must be kept in mind that such places offer space to only about 25% of the population. The rest stay in openings in the ice far from land, where they are not fed.

The value of a high weight at the beginning of the winter can be illustrated by calculating the theoretical loss of weight during starvation (Kendeigh 1970). The necessary metabolized energy (EE) in Kcal per day includes energy for basal metabolism and limited locomotory activity, and this resembles fairly closely the conditions when the swans sleep on the ice at the beginning of a period of hard weather. The formula is:

$$EE_0 = 4.337 \times W^{0.53}$$

where EE_0 is the energy requirement at a temperature of 0°C and W is the weight of the bird in g.

Table 5. Data on the winter climate in Denmark 1959/60 to 1978/79.

Winter	Numbers of days with ice in inner Danish waters	Mean temperatures (°C)	
		January	February
1959/60	36	−0.3	−1.0
1960/61	11	0.0	3.3
1961/62	21	2.0	1.3
1962/63	99	−5.3	−4.5
1963/64	27	0.7	0.2
1964/65	21	1.4	−0.4
1965/66	54	−2.2	−1.7
1966/67	6	0.3	2.3
1967/68	24	−0.8	−0.5
1968/69	53	0.4	−2.5
1969/70	95	−2.7	−3.6
1970/71	22	0.5	2.3
1971/72	39	−1.5	0.5
1972/73	4	1.4	2.3
1973/74	3	2.9	3.2
1974/75	1	4.5	1.5
1975/76	17	0.4	0.2
1976/77	26	−0.3	0.0
1977/78	18	1.5	−1.9
1978/79	83	−4.0	−4.0

The mean December weight of male *C. olor* after their second calendar year is about 11.6 kg. For them, therefore, EE^0 = 619 Kcal per day. The metabolized energy for fat is about 9.5 Kcal per gram and therefore 619/9.5 = 65 gram fat per day should be necessary for a swan under these conditions..

It is estimated that a swan in normal weight conditions has fat reserves of 2.0 to 2.5 kg. Thereafter it will be necessary for the swan to metabolize proteins (muscles) which have a much lower energy content. The fat reserves will last for a maximum of about one month and it is estimated that a swan can starve for one and a half to two months at maximum.

Of course, the actual energy need for a swan will be considerably greater, as locomotory activity is greater and weather conditions (wind, temperature) much more unfavourable. The survival of swans therefore depends very much on their ability to find suitable feeding places. The three coldest recent winters enabled masses of

swans to be ringed, and a substantial amount of data on weight and changes in weight was collected.

The winter of 1978/79

The winter started at the end of December 1978 with a period of strong winds from the northeast and a simultaneous drop in temperature to -10^{o} to 15^{o}C. All shallow areas froze over within a few days, even most of the traditional current openings. In the beginning the swans stayed sleeping on the ice but during the first part of January they assembled in numbers at the gaps in the ice. The temperature stayed below zero and in the middle of February there was another period with strong wind and very low temperatures. At the end of February the weather became milder and from about 1 March temperatures were generally close to zero. The ice disappeared from most areas in the last part of March (see Fig. 7).

Just before the ice period, a small number of swans weighed in the vicinity of Copenhagen had normal weights, namely 11.6 kg average for males and 9.2 kg for females. The first big catch of swans was on 13 and 14 January 1979, at Mariager Fjord in East Jutland. Here the wintering swans originate mostly from Jutland and western Sweden.

Fig 8 shows the weight of the swans. The normal variation with age is quite obvious.

There had been only an insignificant decrease from 'normal' winter weights. Control weighing later in the winter was rather limited, as the birds were so well-fed by the people that they did not come close in order to take food, and so could not be caught. In this area, of an estimated population of 1500 birds only 50 to 100 died, the majority being young.

The condition in the eastern part of Denmark was very much grimmer. Here the population is so big and widespread that adequate artificial feeding of all birds is impossible. Fig 9 shows the change in weights during the winter. It is obvious that the weight of the birds decreased less at places where the birds were fed than at those where there was no feeding.

In many places organized feeding did not start until early February. It was noticed at several of these feeding places that the decrease in weight stopped and some of the birds even increased in weight. At places without feeding, mortality was enormous. In Stavreby, where more than a hundred swans were ringed at the end of January, half of them were found dead by the end of February.

Large-scale mortality of swans occurred from the beginning of February. In January mostly drab second-year birds died; the white birds (in their third calendar year or more) began to die on a larger scale only later. The Zoological Museum and the

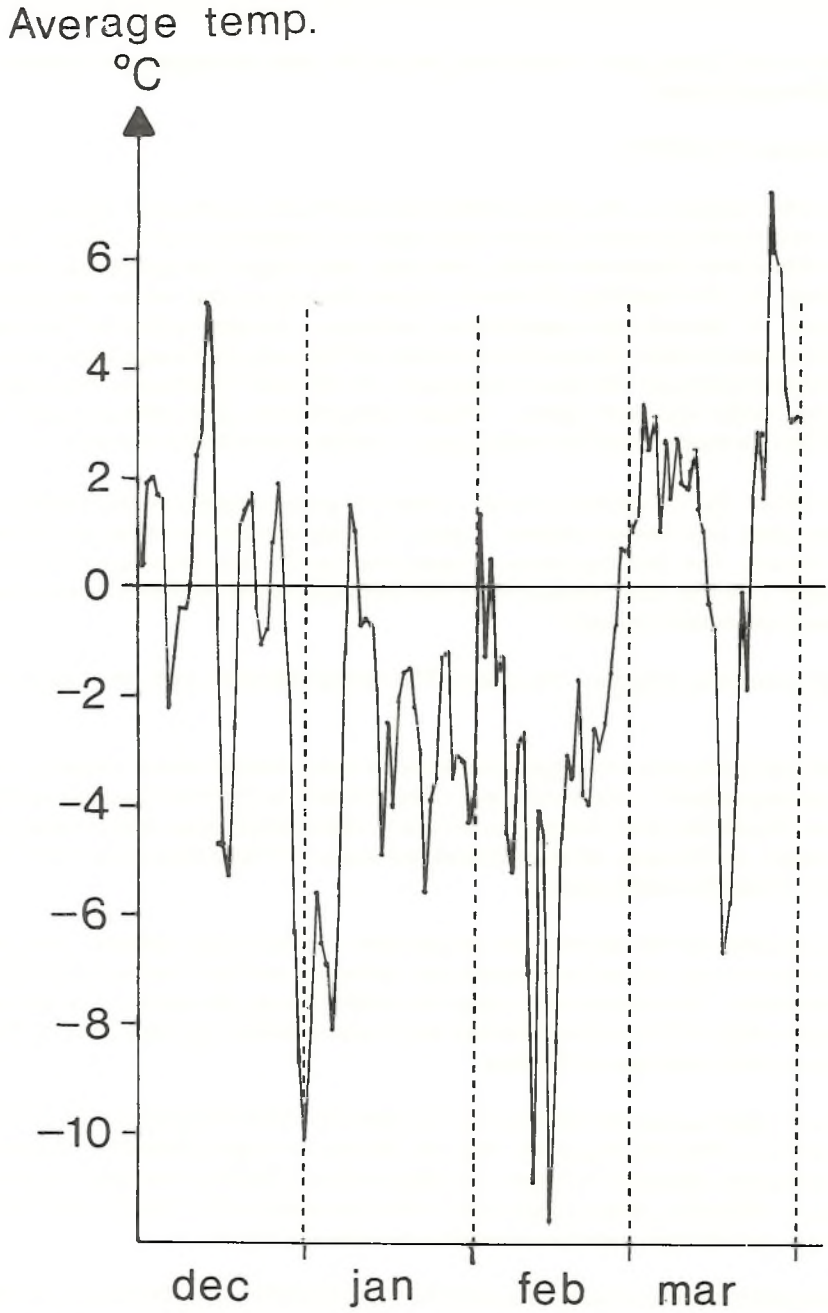

Fig 7. Average temperatures in Roskilde Fjord (Risø) during the winter of 1978/79.

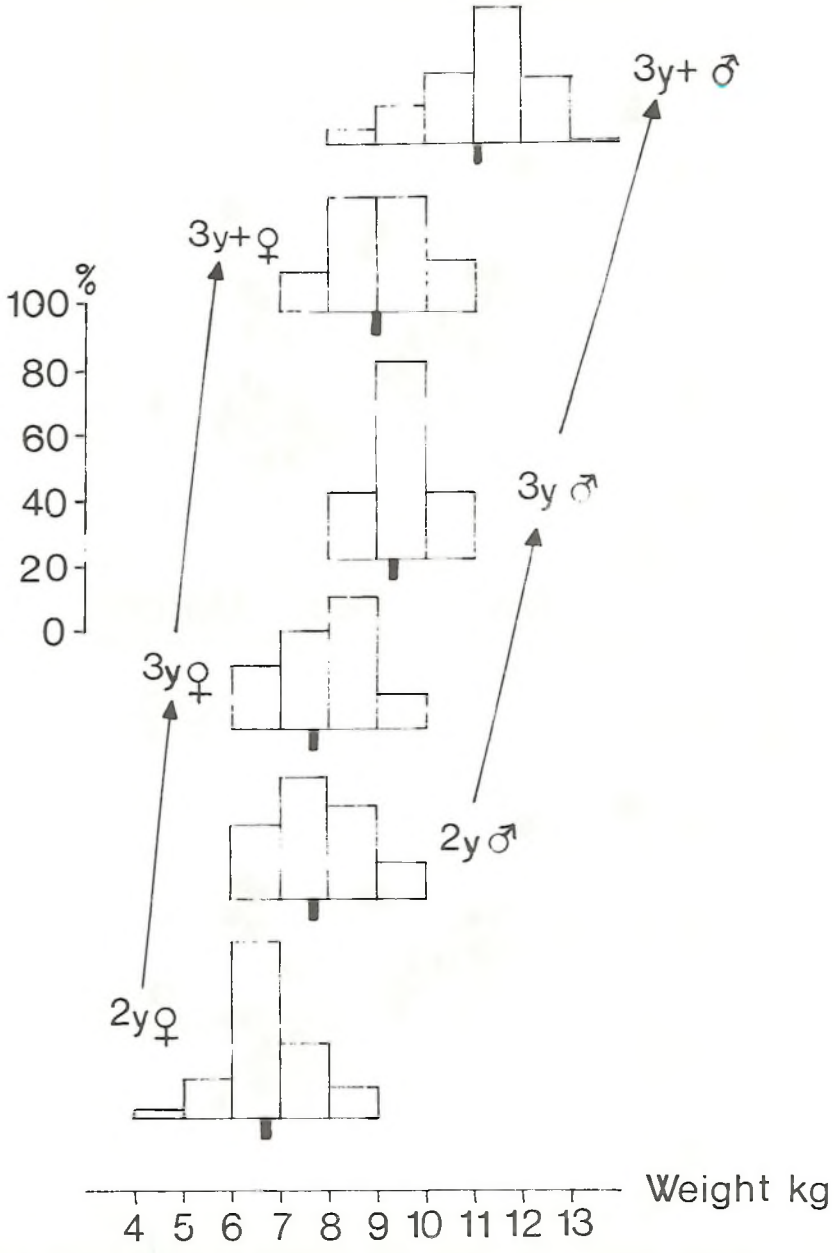

Fig 8. Weights of *Cygnus olor* of different sex and age caught in Mariager Fjord, Jutland, on 13 to 14 January.

2y = swans in their second calendar year etc.

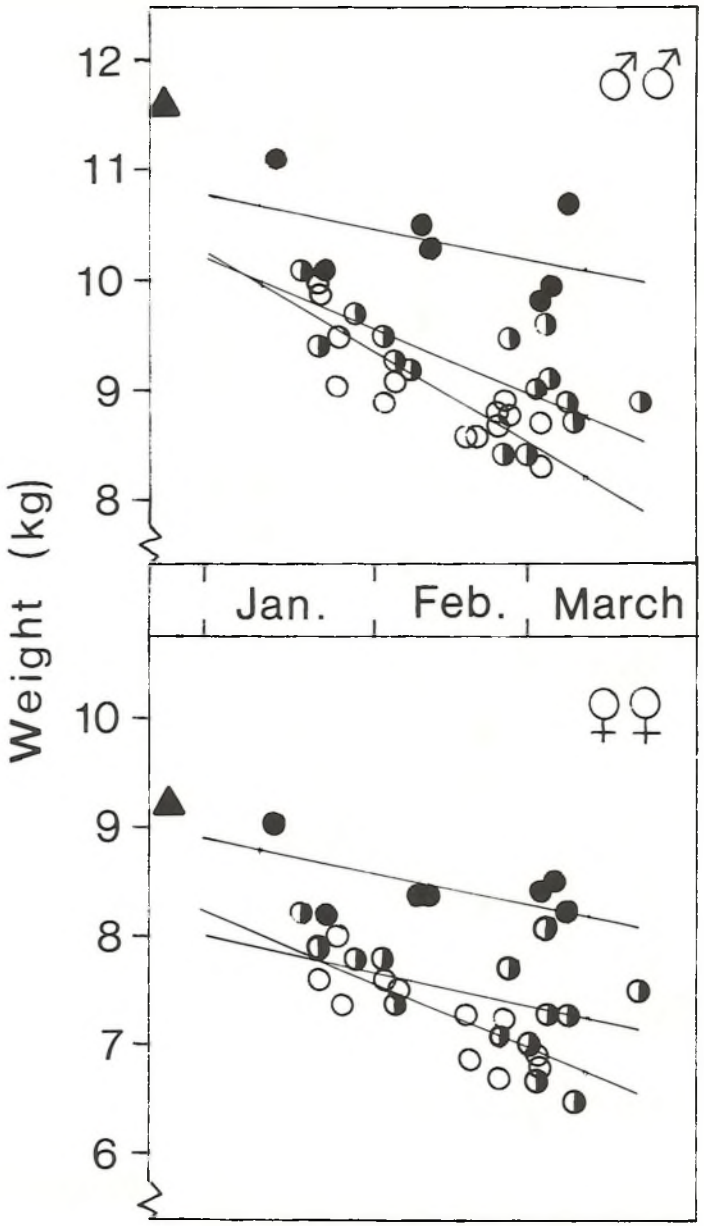

Fig 9. Average weights for males and females of *Cygnus olor* after their third calendar year during the winter of 1978/79.

Shaded circles indicate localities with intensive feeding; half-shaded circles localities with some feeding; unshaded circles localities with no or little feeding. Only localities and days on which at least 50 birds were weighed are included. The triangles indicate the average weights just before the ice period.

Veterinary Serum Laboratory collected about 2700 dead swans.

Survival in relation to weight

The average weight of males dying from starvation was 6.8 kg, of females 5.9 kg (only birds after their second calendar year used). By the end of February and the beginning of March 1970, males surviving the winter weighed 7.5 to 10.3 kg, average 8.1 kg. The corresponding weights for females were 6.5 to 8.5 kg, average 7.4 kg. The weight of birds which were found dead later in the ice-winter was 6.2 to 8.6 kg (average 7.6 kg) for males and 6.0 to 7.2 kg (average 6.6 kg) for females. In severe winters a large number of swans die from starvation if their weight decreases to two-thirds of the normal average weight.

Concluding remarks

The weights of *C. olor* vary greatly, and weight variations may be of decisive importance for survival. Even relatively small decreases in weight will result in increased mortality.

First of all accessibility of food, especially submerged plants, is decisive for the weight. Weather conditions are of great importance for the accessibility of the food but even pollution may play some role.

The stabilization in swan populations in southern Swedish and eastern Danish lakes is probably connected with the fact that, owing to extensive pollution, some lakes no longer have the necessary amount of food to raise 'strong' swans. The observed shift in breeding habitats from lakes to salt and brackish water areas, with establishment of colonies, has involved exposure to rougher physical conditions. Cygnets from coastal sites generally weigh less than those from lakes notwithstanding a generally rich supply of food. This may at some point put a ceiling to further population increases.

The summer weights of moulting swans show modest differences and there are no clear indications of limitations owing to feeding conditions at this time of the year. On the other hand, severe winters result in serious food shortage for the swans, and after such winters the population may decrease by 30%. Hitherto such winters have occurred at long intervals, so that the population has had no difficulties in recovering.

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Summary

The paper reviews some aspects on variations in weight noted in 10 000 records of *Cygnus olor* weighed in Denmark and their significance in relation to mortality.

Quality of submerged vegetation affects the weight of cygnets of solitary breeding swans, which require non-acidic water, rich submerged vegetation, *Phragmites* stands, opportunities to graze and artificial feeding. In colonially nesting *C. olor,* exposure to wind severely reduces cygnet weights, so that choice of a sheltered territory is important. Moult in the first winter is also governed by physical condition and hence weight.

For *C. olor* moulting in late summer, the heaviest individuals are the first to moult. Although ecological conditions differ considerably between moulting sites, birds feeding on *Ulva* are heaviest, followed by *Zostera,* then *Ruppia* and *Chara.*

Calculations are made of the energy requirements and fat reserves of *C. olor* in winter. Large numbers die in the occasional ice-winters if their weight decreases to two-thirds of normal weight.

Relatively small decreases in weight result in increased mortality and it is suggested that pollution of lakes, by affecting vegetation, has prevented further increase in some *C. olor* populations.

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