NOT EVERYTHING IS BLACK AND WHITE. ABUNDANCE AND HEAD COLOUR OF GREAT CORMORANTS *PHALACROCORAX C. CARBO AND P. C. SINENSIS* ON HELIGOLAND, GERMANY

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SUMMARY – The island of Heligoland is the only place in Germany where great cormorants of the *carbo* and *sinensis* subspecies are regularly present in significant numbers. The last estimates of their abundance date back to the winters of 1996/1997 and 2000/2001, when subspecies were identified using head colour. We counted great cormorants in breeding plumage over a thirty day period in February and March 2019 and recorded their head colour. While the proportion of black-headed birds had decreased only slightly compared to 1996 (5%), the total number of wintering *carbo* had decreased by 58 % due to a general decrease of great cormorants on the island. To estimate the error rate of identification using head colour, we photographed 75 great cormorants in breeding plumage, measured their gular pouch angle (GPA) and noted whether they were white- or black-headed. Our data indicate that head colour is not diagnostic for identifying subspecies in single great cormorants, but can be used to infer proportions in large groups. Therefore we believe that the decline of *carbo* on Heligoland in winter is real. Possible causes are a decline of *carbo* populations, or an increase of the wintering population of *sinensis* in Central Europe, especially in Norway.

The great cormorant *Phalacrocorax carbo* is common and widespread in both coastal and inland water bodies from eastern North America to South-east Asia. Five subspecies have been recognized by Gill *et al.* (2021), only two of which regularly occur in Europe: *P. c. carbo* and *P. c. sinensis* (Gill *et al.* 2021). European *carbo* and *sinensis* show some marked differences in their breeding sites and ranges. *Carbo* breeds along rocky coastlines from North-east North America to Norway and North-west Russia, while *sinensis* prefers nesting in trees on both coastal and inland waters, from continental Europe to South-east Asia (Bregnballe *et al.* 2014, del Hoyo *et al.* 1992). Although *carbo* and *sinensis* generally breed in separate colonies, hybridisation is known to occur (Goostrey *et al.* 1998).

Cormorants on Heligoland prefer to keep their distance. Südwest-Mole, Heligoland, Germany, 14 March 2019. Foto: Nicolás Ordax Sommer

Aalscholvers op Helgoland blijven graag op afstand.

In Germany, the status of *carbo* is poorly known. Although it is considered a vagrant everywhere except for the coast, it has been reported to co-occur with *sinensis* in several inland colonies (Deutsche Seltenheitenkommission 2010). The only place in Germany where it is regularly recorded is the North Sea island of Heligoland (Dierschke *et al.* 2011, Flore & Hüppop 1997). *Sinensis*, on the other hand, is a common breeder, migrant and wintering bird in most parts of Germany (Dierschke *et al.* 2011, Gedeon *et al.* 2014). Ring recovery data show that most birds wintering along the German North Sea coast breed in the Baltic, Denmark and The Netherlands (Bairlein *et al.* 2014, Bønløkke *et al.* 2006, Fransson & Pettersson 2001), which are known breeding areas of *sinensis*. In Germany there are fourteen ring recoveries of *carbo* from breeding areas in Norway and North-west Russia, of which five were found on Heligoland (four from Norway, one from Russia; Bairlein *et al.* 2014). British great cormorants are not recorded regularly in Germany, as they tend to winter along the Atlantic and North Sea coasts from Spain to The Netherlands (Wernham *et al.* 2002) and none of thirteen ring recoveries from Britain to Germany can be attributed to *carbo* (Bairlein *et al.* 2014).

Great Cormorants were rare on Heligoland at the beginning of the 20th century, becoming more common in the late 1970s, parallel to their increase in the Central-European populations (Flore & Hüppop 1997). They are present throughout the year, peaking during migration, but there is also a small contingent present during summer and usually some hundred birds winter on the island (Dierschke *et al.* 2011). Flore & Hüppop (1997) reported a proportion of ca. 60% *carbo* on Heligoland during February 1996, which decreased to only 33% by mid-March. Similar results were obtained by Liebert (2000). However, these results are based on identification using head colour of birds in breeding plumage as the main criterion, with white-headed birds being assigned to *sinensis* and black-headed to *carbo*. This method has been criticised and is widely considered unreliable (Marion 1983, Millington 2005, Newson 2005, D. Gruber pers. comm.).

Our goal was to test whether the frequency of the two European subspecies on the island of Heligoland has changed over the last two decades. To do so, we compared bird counts mainly from 1996 and 2019, which used head colour as an identification criterion for the subspecies. Additionally, we tested whether head colour was a good predictor of subspecies by comparing it with a known reliable criterion, the gular pouch angle (GPA; Newson *et al.* 2004, 2005), in a photographic dataset from 2019. Since *carbo* populations across Europe have been declining since 2006 (Bregnballe *et al.* 2014) and *sinensis* has become more common in winter in Central Europe (Gerlach *et al.* 2019, Maumary *et al.* 2007), we expected a decrease in the proportion of birds identified as *carbo* from 1996 to 2019.

MATERIAL & METHODS

STUDY AREA

Heligoland is a small island in the North Sea, approximately 50 km from the German coast (54° 11’N, 7° 53’E). Unlike the rest of the German North Sea coast, Heligoland has a rocky coastline, consisting mostly of red sandstone cliffs, and several breakwaters. Cormorants roost mainly on these breakwaters, preferring the north-western and south-western ones.

HEAD-COLOUR COUNTS

Birds in breeding plumage were counted on ten occasions between February 21st and March 20th 2019, on two of the island’s breakwaters. Birds were considered to be in breeding plumage if they had a completely white thigh patch (figure 1). Birds of which the thigh area was not visible were excluded. Birds in breeding plumage were classified according to their head colour: those with a mostly white head and

figure 1. A - typical black-headed carbo *with very little white hue on neck sides, GPA=40, December 31 2018; B - intermediate-headed* carbo *with white on head-sides but black crown, GPA=50, March 9 2019; C -* carbo *with quite some white, especially on crown; GPA=59, December 31 2018. All pictures were taken on Heligoland.*

A - *carbo* met weinig wit op zijkant van nek, GPA=40, 31 december 2018; B - *carbo* met intermediaire hoeveelheid wit op kopzijde maar met zwarte kruin, GPA=50, 9 maart 2019; C - *carbo* met veel wit, vooral op kruin, GPA=59, 31 december 2018. Alle foto's zijn op Helgoland gemaakt.

figure 1. D - black-headed sinensis*, GPA=87, March 28 2019; E - typical white-headed* sinensis*, GPA=73, March 14 2019; F - white-headed* sinensis *with some black patches on head sides and hindneck, GPA=87, March 9 2019.*

D - zwartkoppige *sinensis*, GPA=87, 28 maart 2019; E - karakteristieke witkoppige *sinensis*, GPA=73, 14 maart 2019; F - *sinensis* met zwarte plekken op kop en nek, 9 maart 2019.

those a mostly black head. Intermediate birds were excluded (n=9). The abundance of white-headed and black-headed birds was compared to the data published by Flore & Hüppop (1997) during the same time window in 1996, using the same methodology.

Because the abundance of the two head colour types has varied within the previous counting season (Flore & Hüppop 1997), we divided the counts into three intervals: 21-28 (29) February, 1-10 March and 11-20 March. Within each interval all counts were pooled. In total, this left 913 birds for 1996 and 309 birds in 2019.

PHOTOGRAPHIC COUNTS

In addition to the counts, we photographed a total of 460 birds between January 19th 2018 and March 28th 2019 on the south-western breakwater and the main harbours of the island. The photographs were analysed using ImageJ software (Schneider *et al.* 2012) in order to measure the GPA (Newson *et al.* 2004). Photographs of low quality, or in which the birds were not in a relaxed posture with the bill parallel to the ground, were discarded. We cannot exclude the possibility that some individuals might have been counted or photographed more than once, since they were not individually marked. However, the double counts should not affect the proportion of the subspecies in our analyses.

Photographs of 75 birds in breeding plumage could be assigned to subspecies on basis of the GPA. Birds with a GPA of less than 66° were considered *carbo*, birds with an angle over 72° *sinensis* (Newson *et al.* 2004). Plumage status and head colour of the individuals was determined the same way as in the head colour counts, except that intermediate-coloured birds were not removed from the analyses.

***WINTERING POPULATION OF** CARBO*

To estimate the number of great cormorants wintering on Heligoland from 1988 onwards, we used data from waterbird counts, which are performed twice a month. As wintering population we assumed

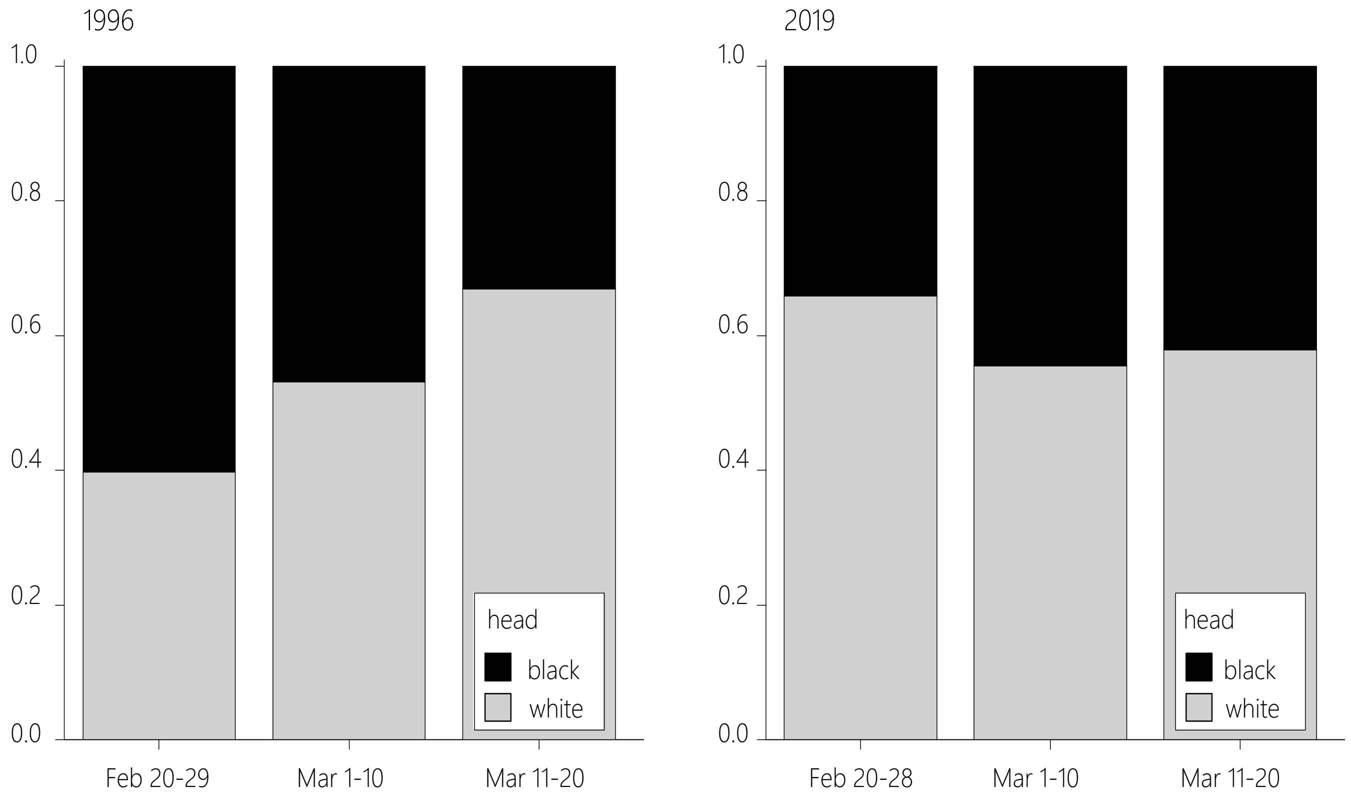

figure 2. Proportion of white and black-headed great cormorants on Heligoland in 1996 and 2019, for each year subdivided in three periods.
Aandeel wit- en zwartkoppige aalscholvers op Helgoland in 1996 en 2019, opgedeeld in drie periodes.

figure 3. Proportion of birds classified as P. c. carbo *and* P. c. sinensis *on Heligoland in 2019, according to their GPA on photographs relative to their head colour. Both groups labeled 'a' are not statistically different from each other, but they differ from 'b' (p<0.05).*
Aandeel grote en gewone aalscholvers op Helgoland in 2019 volgens hun GPA (mondhoek) op foto's in vergelijking met de kopkleur. Steekproeven met letters 'a' verschillen niet significant van elkaar, maar beide verschillen wel van groep 'b' (p<0,05).

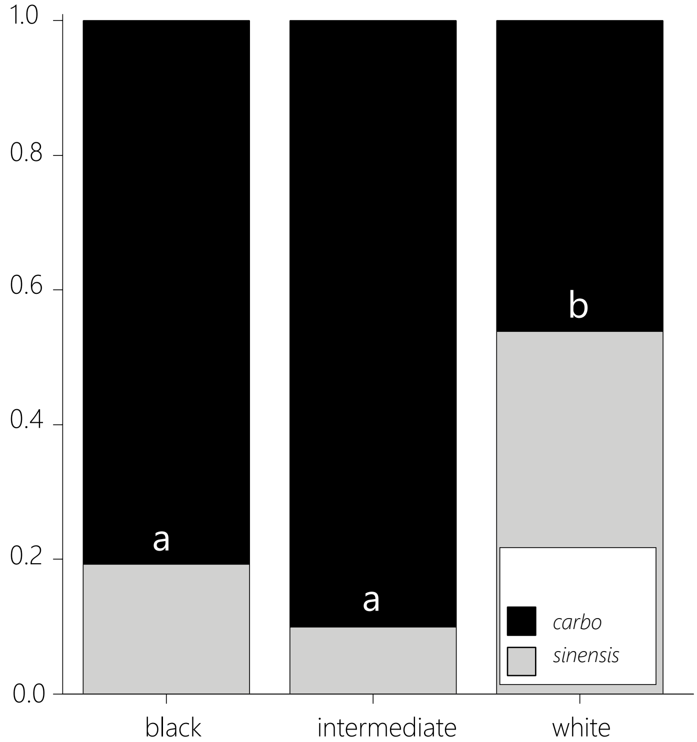

table 1. Generalized linear model fitted to the head count data of 1996 and 2019. The coefficients are followed by the standard error of the mean in brackets. Location controls for differences between the two different breakwaters sampled.
Generalized linear model toegepast op voorkomen van beide kopkleuren in 1996 en 2019. Gegeven zijn de berekende coëfficient en de standaarfout van het gemiddelde (tussen haakjes). De factor 'location' corrigeert voor verschillen tussen beide pieren op Helgoland.

	dependent variable probability of white head	
year 2019	0.614	(0.339)
March 1-10	0.546**	(0.199)
March 11-20	1.123***	(0.224)
location	-1.021*	(0.403)
year 2019 x March 1-10	-0.518	(0.422)
year 2019 x March 11-20	-1.065**	(0.392)
intercept	0.603	(0.441)
observations	1222	

*p<0.05, **p<0.01, *** p<0.001

table 2. Generalized linear model comparing subspecies as identified using GPA with head colour of the photographed individuals. Location is added to control for differences between sampling sites.
Een generalized linear model waarin gefotografeerde exemplaren van carbo en sinensis worden vergeleken aan de hand van kopkleur en mondhoek (GPA). De factor 'location' corrigeert voor verschillen tussen beide pieren op Helgoland.

	dependent variable probability of sinensis	
intermediate head	-1.226	(1.242)
white head	1.402*	(0.635)
location	-1.878**	(0.631)
intercept	0.023	(0.698)
observations	75	
log likelihood	-37.965	
Akaike information criterion	83.930	

*p<0.05, **p<0.01

the average of the number of great cormorants between November and March. For the years 1996, 2000, 2001 and 2019 we could also estimate the proportion of *carbo* in the wintering population by multiplying the average winter count with the proportion of black-headed birds. Published counts were obtained for February and March 2000 (Liebert 2000) and December 2000 and January 2001 (Dierschke *et al.* 2011).

STATISTICAL ANALYSES

i) head colour in 1996 versus 2019

We fitted a generalized linear model (GLM) in the form of a logistic regression with a logit link function, with each of the 1222 counted individual's head colour as the response variable, and year and date interval as predictors. Date interval was included as a 3-level factor to test for changing frequencies of black and white-headed birds throughout the study periods within the years. The year in which the counts were performed was treated as a 2-level factor, as there were only sufficient data available for 1996 and 2019. Location of the counts was added as a 2-level factor to account for possible non-independence of the data within counting spots. The model was fitted with and without an interaction term between counting interval and year, and these two models were compared using ANOVA.

ii) subspecies versus head colour

We fitted a logistic regression with a logit link function with each of the 75 individual's subspecies assignment as the response variable, and head colour as the predictor. Location was again added as a 2-level factor to account for possible non-independence of the data within counting spots.

All models were fitted using R version 3.6.1 (RStudio Team 2015) and the 'glm' function. The significance threshold was established at 0.05.

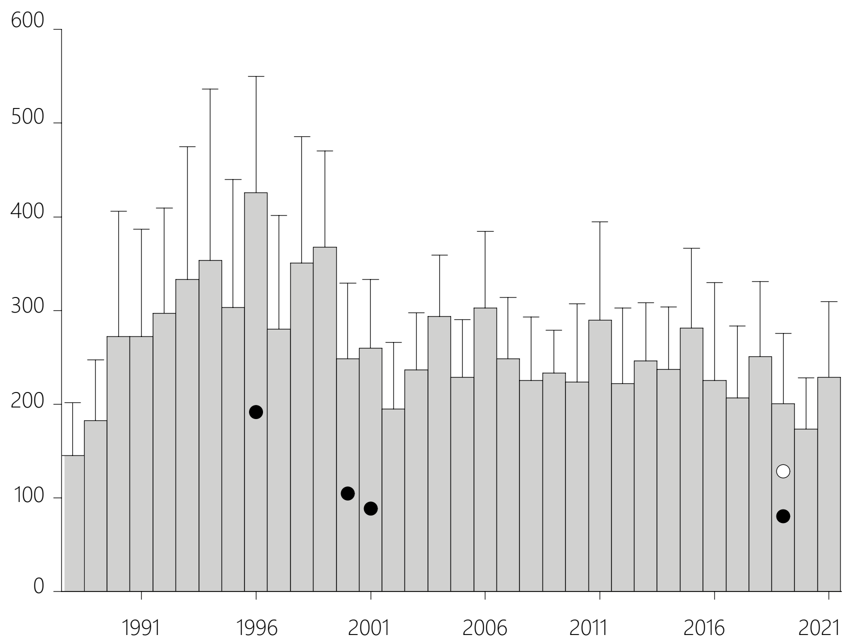

figure 4. Average number of great cormorants between November and March on Heligoland between 1988 and 2021. The bars indicate the standard deviation. Year = start of winter; n=339 counts/88,557 birds. Black dots show the calculated number of carbo by plumage, the white dot calculated by GPA in 2018/19.
Aantal aalscholvers op Helgoland van 1988 tot en met 2021 in november-maart. De standaarddeviatie is boven de staven aangegeven. Jaar = begin van de winter; n=339 tellingen/88.557 exemplaren. De zwarte stippen zijn het op kopkleur berekende aantal *carbo*, de witte stip is berekend op basis van de mondhoek (GPA) in winter 2018-2019.

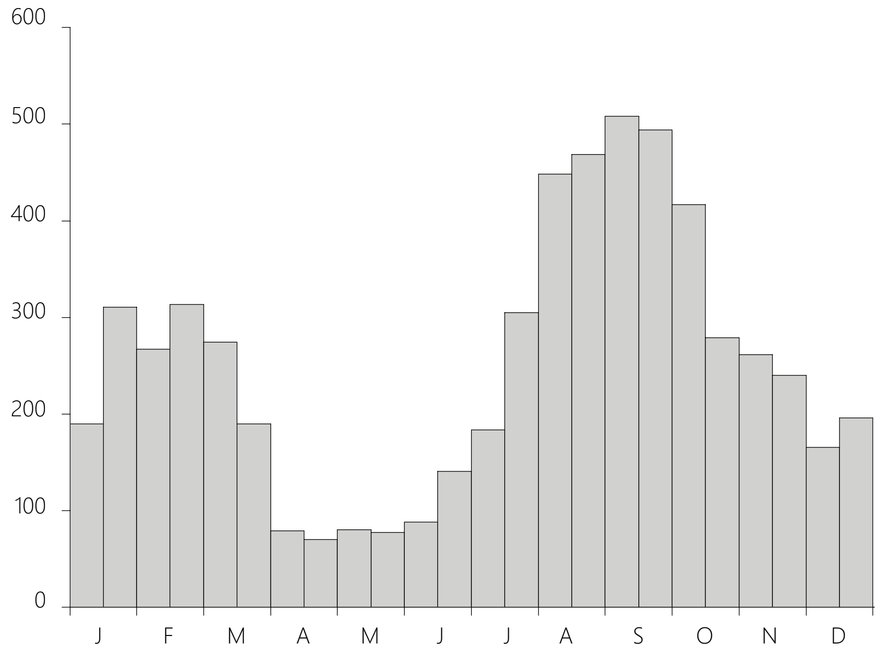

figure 5. Average number of great cormorants per half month from 2010-2019 (n=62,864).
Gemiddeld aantal aalscholvers per twee weken, van 2010-2019 (n=62.864).

RESULTS

HEAD COLOUR

In total, 913 birds in breeding plumage were counted in February/March 1996 and 309 in February/March 2019. Of these, 45 % and 40 %, respectively, were black-headed and therefore assumed to be *carbo*. The model accounting for interaction between year and counting period performed slightly better based on the results from the ANOVA (df=2, deviance=7.99, $p<0.05$), so the interaction was kept in the model.

The overall proportion of black-headed birds has decreased from 1996 to 2019, (figure 2, table 1). There was, however, also a significant interaction between period and year (figure 2, table 1), which means that there was a gradual decrease in the proportion of black-headed birds within 1996, but not in 2019 (figure 2). Hence, the largest difference in proportion of black-headed birds was in late February.

GPA VERSUS HEAD COLOUR

Of the 75 cormorants photographed in 2019, 48 (64%) were identified as *carbo* by GPA, and 27 (36%) as *sinensis*. Birds with a white head were more likely to belong to *sinensis* than black-headed and intermediate birds (table 2). However, only about half of the white-headed individuals belonged to *sinensis* (figure 3). More than 80% of birds with black or intermediate heads were identified as *carbo* by their GPA (figure 3) and almost 40% of individuals identified as *carbo* by their GPA showed a substantial amount of white in the head, while about 20% of *sinensis* had a black head despite being in breeding plumage. This means that a black head is a good predictor of subspecies, but a white head is not. Birds with intermediate colour were predominantly classified as *carbo* by their GPA.

WINTERING NUMBERS

Wintering numbers of great cormorants increased from the late 1970s onwards, peaked in the 1990s and have been stable or slightly decreasing on a lower level since (Dierschke *et al.* 2011, figure 4). Maximum counts from November to March were 18 in the 1960s, 28 in the 1970s, 400 in the 1980s, 655 in the 1990s, 373 in the 2000s and 271 in the 2010s. Using the percentage of black-headed birds in breeding plumage in February/March from the average number from November to March as proxy for the number of *carbo* in winter, numbers are 191 for 1995/96, 104 for 1999/2000, 88 for 2000/01 and 80 for

2018/19. Therefore the number of *carbo* has strongly decreased from 1995-2000 and has stabilized since. The decrease from 1995/96 to 1999/2000 is 46 %, from 1999/2000 to 2018/19 23 % and from 1995/96 to 2018/19 58 %.

The GPA results from 2018/19 indicate a higher percentage of *carbo* in the winter population than the head colour counts, and it is calculated that 128 *carbo*'s must have been present in that winter (figure 4).

DISCUSSION

SUBSPECIES IDENTIFICATION BY HEAD COLOUR

We compared our results for 2019 with those of Flore & Hüppop (1997) and Liebert (2000) using the same method, and found differences in the abundance and phenology of white-headed and black-headed birds. The abundance of black-headed birds decreased from 1996 to 2019, mostly due to a decrease in late February (figure 5). The decrease in black-headed birds in March 1996 did not occur in 2019.

Changes in the relative abundance of white-headed and black-headed birds could be caused by an increase in *sinensis*, a decrease of *carbo*, or a combination of these. One explanation is the decline of *carbo* populations in Europe over the last decades (Bregnballe *et al.* 2014). However, this does not explain why the proportion of black-headed birds in February 2019 was much lower compared to the second and third counts in that year. There could also have been an increase of wintering *sinensis*. The wintering numbers of *sinensis* have increased in Central Europe (Gerlach *et al.* 2019, Maumary *et al.* 2007), which we expect to see reflected on Heligoland, too. However, as cormorants have decreased as a wintering bird on Heligoland (figure 4), this seems not likely. The two hypotheses are not mutually exclusive and may both be contributing to the change in abundance and phenology on Heligoland. A change in departure dates of *carbo* could also be responsible for the observed changes but seems unlikely to us and so far there is no indication for that in Norway (T. Anker-Nilssen pers. comm.).

The use of head colour as a tool for identifying the subspecies of individual birds has been questioned. Stokoe (1958) found that at least 15% of birds in British *carbo* colonies were white-headed, and Marion (1983) discovered that early breeding individuals from *carbo* colonies in France present extensive white on the head, which tends to quickly disappear after incubation has started. In our study, almost 20 % of black-headed birds were identified as *sinensis* using GPA, while for black-headed birds the proportion of *carbo* was around 50 %. As expected, head colour was a poor indicator of subspecies and using head colour to identify individual birds therefore is not advisable, especially if *carbo* is rare. However, establishing the proportion of white-headed and black-headed birds in late winter is a useful method to obtain rough estimates on the subspecies' proportion in large groups of both subspecies, as done on Heligoland in 1996, 2000 and 2001, considering black-headed birds mostly concerned *carbo*. However, our results indicate that the frequent occurrence of white-headed *carbo* and black-headed *sinensis* lead to an overestimate of the proportion of *carbo*. Therefore, the proportion of black-headed versus white-headed birds is useful to track trends in abundance of subspecies over time, but is unsuitable to estimate absolute numbers of each subspecies.

RELIABILITY OF THE GPA FOR IDENTIFICATION IN THE FIELD

GPA is mostly regarded as a reliable identification criterion, especially when measured directly on dead birds of known sex (Newson *et al.* 2005). Its validity in the field, however, has yet to be properly tested, even though rarity committees in Europe often use this feature. GPA can vary substantially with a bird's posture (Newson *et al.* 2005) and there can be inconsistencies even between measurements in hand and on photographs of the same bird (M. Illa pers. comm.). This means that although GPA is currently our best tool for subspecific identification, it should be used with caution and results should be interpreted carefully. We only analysed photos where the birds held their heads parallel to the ground to avoid possible distortion of the GPA, and we had to discard pictures of which the quality did not permit proper measuring of angles.

Another factor to consider is the possible occurrence on Heligoland of hybrids between *carbo* and *sinensis* and birds belonging to *P. c. norvegicus*, a taxonomic group occurring in the Baltic Sea. This possible subspecies has not yet been accepted by Gill *et al.* (2021), and no formal description has been published so far (Marion & Le Gentil 2006). The phenotypes of either are unknown and could therefore pose a further identification problem. The presence of *norvegicus* in northern Norway, the White Sea, and the Swedish Baltic coast (Marion & Le Gentil 2006) make it plausible that *norvegicus* occurs on Heligoland, as there are ring recoveries from all three regions on Heligoland (Dierschke *et al.* 2011), More data on the morphology and status of this taxon are therefore needed.

WINTERING NUMBERS OF CARBO *ON HELIGOLAND*

Heligoland is the only place in Germany where great cormorants of *carbo* regularly appear in sizeable numbers, and mostly in winter. The data on abundance of great cormorants gathered by Flore & Hüppop (1997) and Liebert (2000) suggested that more than half of the wintering birds on Heligoland are black-headed, with their proportion decreasing as spring approaches. This decrease in black-headed birds was attributed to the departure of wintering *carbo* individuals. In total, the proportion of black-headed birds fluctuated slightly from 45 % in 1995/96 (Flore & Hüppop 1997) to 42 % in 1999/2000 (Liebert 2000), 34 % in 2000/01 (Dierschke *et al.* 2011) to 40 % in year 2019 (this study). In accordance with the decreasing numbers of *carbo* elsewhere (Bregnballe *et al.* 2014), the wintering population of *carbo* on Heligoland had decreased considerably between 1996-2000, as did the total number of cormorants, and our data from 2019 using the same method (head-colour) indicate a further, though smaller, decrease since. The 2019 GPA-data, however, suggest that the proportion of *carbo* in winter is higher than previously thought and may consist of up to 130 birds - more than half of the wintering great cormorants. This high proportion of *carbo* was also confirmed by measurements from corpses in the 1990s (Flore & Hüppop 1997, Liebers 2000), but no recent data are available. The high proportion of *carbo* is remarkable, as this subspecies is supposed to be rare in the southern North Sea. However, Van Bemmelen (2020) found 27 % *carbo* at IJmuiden, The Netherlands, indicating that *carbo* is also more common there than previously thought. The high proportion on Heligoland might also be attributed to the presence of cliffs, which are unique in the southeastern North Sea and may be more attractive for this cliff-breeding subspecies. As great cormorants were scarce or even rare until the late 1970s, both subspecies have colonized Heligoland as a wintering site since. Due to the increase of *sinensis* in Central Europe and the decline of *carbo* in Norway (Bregnballe *et al.* 2014) we expected a strong decrease in the proportion of *carbo* on Heligoland. However, this decrease was moderate for black-headed birds, and habitat choice of *carbo* may be an important explanatory factor.

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SAMENVATTING – NIET ALLES IS ZWART EN WIT. AANWEZIGHEID EN KOPKLEUR VAN AALSCHOLVERS *PHALACROCORAX C. CARBO* EN *P. C. SINENSIS* OP HELGOLAND, DUITSLAND

Net als elders in de Noordzee komen ook op Helgoland beide ondersoorten van de aalscholver voor, de Atlantische of grote aalscholver *Phalacrocorax c. carbo* en de continentale aalscholver *P. c. sinensis*. Geen van tweeën is zeldzaam, maar ook op Helgoland worstelen waarnemers met de herkenning en is het voorkomen van beide dus niet goed bekend. De laatste schattingen van voorkomen dateren uit de winters van 1996-1997 en 2000-2001. Uit ringmeldingen blijkt dat de meeste overwinterende aalscholvers uit het Oostzeegebied, Denemarken en Nederland komen. Van *carbo* zijn uit Duitsland maar veertien ringmeldingen bekend; deze komen uit Noorwegen en Rusland. Vier hiervan zijn op Helgoland gevonden. Britse *carbo* zijn nooit uit Duitsland teruggemeld. De soort komt het hele jaar op Helgoland voor en er overwinteren een paar honderd vogels. Een schatting dat 60% *carbo* betreft is gebaseerd op de overwegend zwarte kopkleur in broedkleed. Inmiddels is bekend dat kopkleur vanwege de grote variatie niet betrouwbaar is voor bepaling van de ondersoort. De hoek die de naakte keelhuid bij de mondhoek maakt wordt vooralsnog betrouwbaarder geacht. In deze studie wordt gecheckt of het aandeel overwinterende *carbo* door de tijd heen is veranderd. Hiertoe zijn 75 vogels gefotografeerd en is op de foto's de mondhoek met behulp van software gemeten. Van deze vogels is ook de kopkleur genoteerd, om vergelijking met gegevens uit het verleden mogelijk te maken. Kopkleur van individuele vogels is onbetrouwbaar voor ondersoortbepaling, maar lijkt wel bruikbaar om een indruk te krijgen van het aandeel van een ondersoort in een grotere groep. Het aandeel *carbo* op Helgoland is sinds de jaren 1990 met maar liefst 58% gedaald. Een ogenschijnlijke voor de hand liggende verklaring lijkt dat de populatie van *carbo* is gedaald, maar omdat de populatie van *sinensis* is gestegen, levert dat een alternatieve verklaring voor de daling.

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