Population structure, philopatry and mortality of Cory's Shearwater *Calonectris d. diomedea**

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A colony of Cory's Shearwater has been studied on a small rocky island in the southern Aegean Sea since 1975. Ringing results show a very high degree of philopatry for males, and site tenacity and mate fidelity for breeding birds. The importance of these findings has to be discussed in relation to gene flow and formation of subspecies. In addition approximations for other population parameters are given (productivity, juvenile and adult mortality, longevity, age of first breeding). There are indications that irregularities in mortality figures could correspond with changes of the sea water temperature in the South Atlantic (El Nino effect).

Key words: *Calonectris diomedea*, philopatry, mortality, site tenacity.

Zusammenfassung

Ristow D., F. Feldmann, W. Scharlau & M. Wink (1990): Populationsstruktur, Geburtsortstreue und Mortalität des Gelbschnabelsturmtauchers *(Calonectris d. diomedea)*. – Vogelwelt 111, 172-181.

Eine Brutkolonie des Gelbschnabelsturmtauchers, die sich auf einer kleinen Felseninsel der südlichen Ägäis befindet, wurde seit 1975 intensiv untersucht. Beringungsergebnisse und Wiederfangdaten zeigen eine ausgeprägte Geburtsortstreue für die Sturmtauchermännchen, und eine hohe Nest- und Partnertreue für die Brutvögel an. Schätzwerte für die Produktivität, die Jugend- und Adultmortalität, die Lebenserwartung und das Erstbrüteralter werden angeführt. Die Bedeutung der hohen Brutorts- und Nesttreue in bezug auf Genfluß und Unterartbildung wird diskutiert. Unregelmäßigkeiten in den Wiederfangraten der Jung- und Altvögel scheinen mit den Veränderungen in der Meerestemperatur der Südhemisphäre (El Nino-Effekte) korreliert zu sein.

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1. Introduction

Cory's Shearwater breeds in the Mediterranean *(C. d. diomedea)*, in the Cape Verde Islands *(C. d. edwardsii)* and in the Atlantic islands, such as Selvages, Madeira, the Azores and the Canary Islands *(C. d. borealis)*. The shearwaters spend the winter months in the South Atlantic (Cramp & Simmons 1977).

Cory's Shearwaters return to their breeding grounds, usually small rocky islands, in March. Like other Procellariidae this shearwater breeds colonially. Nest burrows are often found under rocks (in the Mediterranean) or bushes (in the Selvage Islands). At the end of May the female lays a single egg which is being incubated for 53 days. The young hatch in July and fledge in October (for review see Cramp & Simmons 1977, Wink et al. 1982, Mougin et al. 1984, Zino et al. 1987). As compared to other Procellariidae knowledge of the breeding biology, population structure and demography of Cory's Shearwater is largely incomplete. The subspecies best studied is *C. d. borealis* from the Selvage Islands, because there they breed in the open and can be caught quite easily, moreover the birds are rather abundant on these islands (Jouanin et al. 1977, Mougin et al. 1984, 1985, 1986, Zino 1971, Zino et al. 1987). The Mediterranean breeding colonies of Cory's Shearwater are comparably small, and usually situated in uninhabited rocky islands, which are difficult to visit. Furthermore, since many shearwaters are often inaccessible in their nest burrows, it is difficult to monitor a large number of birds and in consequence to study their population biology. For this reason, the number of studies on this subspecies is small and our general knowledge very scanty (Fernandez 1985, Massa & Lo Valvo 1986; Zammit & Borg 1987; Ristow & Wink 1980; Ristow et al. 1981, Wink & Ristow 1979; Wink et al. 1979, 1982, 1987a, b).

We have studied the population biology of the Mediterranean subspecies, *C. d. diomedea*, on a small island in the southern Aegean Sea almost every year since 1975. In this communication we report on the results of this long-term study with emphasis on productivity, juvenile and adult mortality, age of first breeding, longevity, philopatry, site tenacity and mate fidelity. Because of the difficulties mentioned above, the number of birds which could be ringed and retrapped is rather small as compared to other species, e. g. Manx Shearwater *(Puffinus puffinus)* and some of our data must still be considered preliminary. They are published here since no better data are available at all for *C. d. diomedea*.

2. Material and methods

It is difficult to ascertain the size of the shearwater colony studied (island size. 300 × 1000 m; its name and location are not given for reasons of conservation), but we estimate from the number of burrows found that 1000 pairs are present. Typical distance between individual nests is 10-20 m but at locations of high density it can

decrease to 3 m. A limited number of breeding sites and nest burrows are accessible, but it is often difficult to catch the birds in their burrows which lie hidden deep under rocks. We therefore concentrated our efforts on 2 study plots of 1000 m^2 (A) and 6000 m^2 (B) size where burrows are only up to 2 m deep. In these plots we monitored all nest burrows, and especially in A we regularly ringed all adult birds and their respective young. In plot B, intensive ringing and retrapping were carried out in 1978, 1985 and 1989, meaning that about 100 nest sites were marked individually and monitored during egg-laying and incubation period. We tried to capture both partners of a breeding pair and ringed their nestlings later in the autumn. Between 1977 and 1988 723 fledglings and 470 adults were ringed. Field work was carried out by 2-4 persons/session (often in dark moonless nights) and overall we spent more than 250 days on the island studying Cory's Shearwater. Since we were living directly within the colony (plot A), we were able to record many behavioural and other aspects of the life of this nocturnal shearwater (e. g. Ristow & Wink 1980; Ristow et al. 1981; Wink & Ristow 1979, Wink et al. 1979, 1982, 1987a, b). Our presence did not seem to disturb the birds, which were returning to the same place sometimes every night, although we controlled their ring numbers regularly.

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3. Results and Discussion

3. 1. Productivity

The productivity of *C. d. diomedea* was determined in 1985 and 1989 by monitoring 253 nests in June, the time of egg-laying and again in Sep/Oct, the time of fledging. Fledging young were scored as successful breeding, and failed eggs, dead chicks or empty nests (where an egg had been recorded before in June) as breeding failure. 17-19% of all eggs fail to hatch, and a further 4-5% of nestlings do not fledge. Thus breeding success is 77% on average. Comparable figures have been recorded in other colonies: Malta 72% (Zammit & Borg 1987), Marseille Islands 79-82% (Fernandez 1985) and Selvage Islands 60-71% (Zino 1971, Zino et al. 1987). The lower productivity in the Selvage Islands may be due to increased predation, since nest sites lie in the open there and are thus vulnerable to gulls and other predators.

3. 2. Juvenile mortality

In a small subcolony of 12-14 pairs (within plot A) we have ringed more than 90% of all nestlings between 1975 and 1989 (with the exception of 1978) and have controlled the origin of the breeders in all these years. Out of 62 fledglings, which were ringed between 1977 and 1984 (we have omitted fledglings from later years, since they were not yet due to return by 1989), we were able to recapture 14 different birds in later breeding seasons, especially in 1985 and 1989. All birds were sexed by their beak size dimorphism (Wink & Ristow 1979; Ristow & Wink 1980) and 93% were males (Tab. 1). These data can be used to estimate the order of

magnitude of the mortality rate of males between birth and the time of first return to their natal island: Assuming an equal sex distribution, we start with 31 males. 13 of them were recaptured at a mean age of 6 years (no attempt was made to correct for the differential age of return because of the small sample size). A first and preliminary estimate for the geometric mean of the annual mortality of males is about 13% ($m = 1 - (13/31)^{0,167}$ or slightly lower as some males may have settled outside the control area and others born in 1983/84 may not have returned yet. The overall survival probability for young males between birth and first return is 41%. Female mortality is probably similar, but females show a much stronger dispersal (Tab. 1, 3), which makes a separate calculation impossible at present.

Tab. 1: *Recovery of C. diomedea in their natal colony. In a subpopulation (plot A), which consisted of up to 14 pairs, all young were ringed each year between 1977 and 1989 (except 1978). They were later retrapped in the same study plot. – Wiederfunde von* C. diomedea *in der Geburtskolonie. In einer Subpopulation (innerhalb von Probefläche A), die aus maximal 14 Brutpaaren bestand, wurden alle Jungvögel zwischen 1977 und 1989 beringt. Ein Teil dieser Jungvögel wurde in späteren Jahren an ihrem Geburtsplatz wiedergefangen.*

Year of birth	*Number of young ringed*	*Number of young controlled in later years*		
		males	*females*	*total*
1977	*12*	*3*	*0*	*3*
1978	*0*	–	–	–
1979	*9*	*2*	*0*	*2*
1980	*9*	*2*	*1*	*3*
1981	*8*	*0*	*0*	*0*
1982	*9*	*0*	*0*	*0*
1983	*6*	*4*	*0*	*4*
*1984**	*9*	*2*	*0*	*2*
	62	*13*	*1*	*14*

* *Years 1985 till 1989 are omitted since no birds had been seen until 1989 which derived from this group.*

3. 3. Adult mortality

In 1978 and in 1985 38 and 77 pairs of shearwaters were ringed, respectively and again monitored on their former nests in 1985 and 1989. Of 38 males present in 1978, 10 were still breeding in 1985 and 1 in 1989; of 37 females, 11 were recaptured in 1985 and 8 in 1989. Of 72 males and 77 females breeding in 1985 34 and 37, respectively, were observed in 1989. With respect to the high degree of site and mate fidelity (see 3.6 and 3.7) we assume that birds which could not be recaptured in these years had disappeared and probably died in the meantime or were on „sabbatical" (Mougin et al. 1984, 1985). An approximation for the annual adult mortality (calculation as for juvenile mortality), would be 16 - 17% for males

in the 4 and 7 year assessments and 13% for females in the 1978-1989 comparison. A similar figure has been obtained from Malta (Zammit & Borg 1987), but is in contrast with data from other shearwaters, which all have adult mortalities below 10% (Cramp & Simmons 1977). For *C. d. borealis* an annual mortality of 9.1% was obtained (Mougin et al. 1984). In the Selvage Islands it was shown that about 7% of all breeders interrupt reproduction and take an annual sabbatical leave (Mougin et al. 1985). We need to analyze whether Aegean shearwaters also take their „sabbatical" and whether it has influenced our mortality data.**

If we analyze the fate of the 1978 birds which were still present in 1989 (see above), a remarkable bias towards females is evident. These data imply that females tend to become older than males (see also Tab. 2). Taking into account that *C. diomedea* first breeds at an age of 7 (Tab. 2), we can assume, that males and females can live and reproduce up to an age of at least 20 years.

3. 4. Age at first breeding

We have recaptured the first young birds at the age of four in their natal colony, similar to the situation in *C. d. borealis* (Jouanin et al. 1977). The age of first recovery was 6.4 years on average (Tab. 2). First breeding was at 5 years for males and at 7 years for females, with an average of 7.3 y for males (n = 12) and 7.6 y for females (n = 3) (Tab. 2). In the Selvage Islands *C. d. borealis* breeds later for the first time with a mean of 9 years, but the authors do not distinguish sexes (Mougin et al. 1984, 1986). On Malta a male *(C. d. diomedea)* was found breeding at the exceptional age of 2 years (Zammit & Borg 1988).

3. 5. Philopatry

Cory's Shearwater which were ringed in plot A and B have not been found breeding in other colonies (for instance on Malta or in Italy, where larger numbers of *C. d. diomedea* have been controlled). Only one our shearwaters has been recovered away from the colony. It was a x + 3 − year old male and shot in Tunesia on migration in March. In contrast, of 280 fledgelings ringed in plots A and B between 1977 and 1984 26 were recaptured in their natal colony within the same area in later years. Fledglings from later years had not returned yet at the time of this evaluation (till 1989). Breeding sites up to 150 m away from the study plot A

** We have repeated the field analysis in June 1990 and compared the inhabitants of the nests studied in 1989 and 1985 with those of 1990. We now arrive at a mortality figure of 10-11% and have no evidence for any significant sabbatical leave (Ristow et al., in preparation). These mortality values are now in the expected range for shearwaters. We assume that the higher figures which we determined earlier were due to the El Nino effect (see below).

Tab. 2: *Age of first recovery, first breeding and maximal site tenacity and longevity of C. diomedea. – Alter von* C. diomedea *zum Zeitpunkt des ersten Wiederfangs und des ersten Brütens; ferner maximale Dauer der Ortstreue und die Lebensdauer.*

Age of first recovery: Time between birth and recovery, i.e. a bird born in 1980 and recaptured in 1984 was considered to be 4 y old. – Alter beim ersten Wiederfang: Berechnet wurde die Zeit zwischen Geburt und dem Zeitpunkt des Wiederfanges, z. B. ein Vogel der 1980 geboren und 1984 wiedergefangen wurde, gilt als 4 Jahre alter Vogel.

Age of first breeding: Calculated similarly to first recovery. Birds had been ringed as fledglings in the control area and were recaptured in the same area in a nest burrow in later years. (It is assumed that more females settled outside the control area). – Alter beim ersten Brüten: Berechnung wie beim Wiederfangsalter. Vögel wurden als Nestlinge in der Kontrollfläche beringt und später in derselben Fläche brütend registriert. (Wir nehmen an, daß sich die Weibchen außerhalb der Probefläche ansiedeln.)

Maximal site tenacity: Evaluation of all recapture data from 1975 to 1989. Calculation: e.g. a bird breeding in the same nest in 1980 and 1981 had a site tenacity of 2 years. – Dauer der Ortstreue: Auswertung aller Wiederfangdaten zwischen 1975 und 1989. Berechnung: ein Sturmtaucher der 1980 und 1981 in demselben Nest brütete erhielt eine Ortstreue von 2 Jahren.

Longevity: Maximal time interval between capture and latest recapture of shearwaters which had been ringed as adult birds (with a typical age of at least 7 y). Calculation: A bird ringed in 1980 and recaptured in 1989 was assigned a longevity of 9 y; its real age was probably at least 9 + 7 = 16 y. – Lebensdauer: Maximaler Zeitraum zwischen Beringung und der letzten Kontrolle, wobei nur Fänglinge berücksichtigt wurden, die bei Beringung bereits ca. 7 Jahre alt waren. Berechnung: Ein Vogel, der 1980 beringt und 1989 zum letzten Mal wiedergefangen wurde, erhielt ein Lebensalter von 9 Jahren; sein wirkliches Alter betrug vermutlich mindestens 9 + 7 = 16 Jahre.

M = males, F = females. – M = Männchen, F = Weibchen.

Years	Number of Shearwater First Recovery M+F	First Breeding M	First Breeding F	Max. Site Tenacity M	Max. Site Tenacity F	Longevity M	Longevity F
1	0	0	0	–	–	14	9
2	0	0	0	13	14	3	5
3	0	0	0	4	8	8	4
4	4	0	0	5	3	36*	35*
5	5	1	0	34*	24*	4	3
6	7	3	0	3	2	3	4
7	3	2	2	1	1	6	4
8	2	3	0	4	2	2	1
9	4	3	1	2	1	1	2
10	1	0	0	0	0	2	3
11	0	0	0	1	0	1	5
12	0	0	0	0	5	0	2
13	0	0	0	0	1	1	0
mean	6.4	7.3	7.6				

* biassed by 1985/89 studies.

were monitored regularly and no recaptures of ringed birds (from A) were obtained in those areas.

We have analyzed the dispersal patterns of the 26 recaptures (Tab. 3): 66% of all breeding males show a remarkable degree of natal philopatry and were found either in their natal nest or within a 20 m radius of it, for instance, just in the neighbouring nest (Tab. 3). The same is true for male „bachelors" [these birds were caught while sitting at the entrance of a burrow of which the two breeding birds had been controlled inside the burrow previously. Compare Zammit & Borg (1987) and Mougin et al. (1984)]. This high degree of natal site tenacity has never been recorded before for Cory's Shearwater or – as far we know – for any other Procellariidae (Cramp & Simmons 1977).

Tab. 3: *Distance between the natal nest and the site of first breeding or control in later years. – Entfernung zwischen dem Geburtsnest und dem Ort des ersten Brüters bzw. Wiederfangs.*

Distance in metres	Breeding birds		"Bachelors"	
	Males	Females	Males	Females
0	3	0	1	0
0.5-5	2	0	5	0
5-20	3	0	3	0
20-50	1	0	1	0
50-100	2	3	0	1
>100	1	0	0	0
Total	12	3	10	1

The few females that were recaptured (Tab. 1, 3) were observed 50-150 m away from their site of birth (4 birds, Tab. 3). These data suggest that most females will settle at greater distances, i. e. 150-500 m away from the study plots. Since we were not able to check these sites, these females could not have been retrapped. For the bachelors controlled in later years when they were classified as breeders, again male birds were found much closer to their natal nest than female bachelors. Manx Shearwater settle in their natal colony; in addition, part of the females seem to disperse to adjacent colonies (Harris 1966, de L. Brooke 1978). It is not known yet whether the same applies to female Cory's Shearwater.

3. 6. Site tenacity

Once the birds have occupied their breeding site, they show a high degree of site tenacity: A number of birds returned to the same nest site for up to 11 years (males) or 13 years (females) (Tab. 2). Of 33 males and 37

females recorded breeding in 1985 and recovered in 1989 28 (=85%) and 27 (=73%), respectively, were still in the same nest burrow. The other birds (15% or 27%, respectively) were breeding within 50 m. Similar findings have been obtained for other shearwaters (Cramp & Simmons 1977) and for *C. diomedea* (Zammit & Borg 1987, Mougin et al. 1984).

3. 7. Mate fidelity

It could be a consequence of this remarkable site tenacity that Cory's Shearwater also shows high mate fidelity: We could monitor a few pairs that had been breeding together for more than 8 years. In 1985 and 1989 we have controlled mate fidelity in a quantitative way: Out of 61 breeding pairs marked in 1985 only 20 (=32.8%) were recovered in 1989, of which both partners were still present. Of 23 pairs both partners (=37.7%) disappeared; of 8 and 9 pairs only the male or the female, respectively, was still present. About 95% of the 20 surviving pairs had maintained their partners for four years, only one pair (=5%) had separated and was now breeding with its former neighbours. Lifelong monogamous pair bond seems to be the rule in Procellariiformes (Cramp & Simmons 1977) and has been also recorded for *C. diomedea* before (Wink et al. 1982, Zammit & Borg 1987, Mougin et al. 1984).

3. 8. Inbreeding and its consequences

Once settled Cory's Shearwaters posses a marked site tenacity and return to their nest every year (see 3.6). Since young males come back to the nest of their birth, we have to assume that even close relatives interbreed in the colony (for instance mother and son) which would increase the number of homozygotic alleles. In captivity, repeated interbreeding of close relatives usually produces an enhanced number of deformed or otherwise damaged offspring. We suggest that the same happens on this island but that the affected offspring do not survive (see juvenile mortality). On the other hand the homozygotic birds would have the advantage that they would maintain gene-encoded specializations or adaptations to their particular breeding site and population structure, which would be lost easily if birds from outside with different genes or alleles would enter the colony regularly. At present we are analyzing the degree of relatedness within and between shearwater populations with the aid of DNA fingerprinting (Wink et al. 1990).

Allowing enough time and no change in the dispersal behaviour we speculate that this and other shearwater populations will develop into subspecies or species eventually, as described for the Darwin finches on the Galapagos archipelago (Lack 1947). For *C. diomedea* subspecies are already distinguished, which differ in their sizes (s. Introduction). Within the nominate groupe, *C. d. diomedea*, we observe a size gradient from west

to east, with the shearwaters in the Aegean being the smallest birds (M. Wink, D. Ristow, H. Witt in prep., Massa & Lo Valvo 1986). This implies that the island populations of the Mediterranean are already genetically separated for a prolonged period and it has to be discussed whether the shearwaters from different islands of the Mediterranean already deserve the status of specific subspecies at the present time.

3. 9. El Nino Effect

During our study there were two El Nino events when sea water temperatures in the southern hemisphere showed strong irregularities which had disastrous effects on southern seabird populations (Schreiber & Schreiber 1989). One El Nino started in Nov. 1982, the other in Jan. 1986. Some irregulrities in our retrap data seem to be correlated with these events, a dependence which might be possible since Cory's Shearwater visits the respective seas in winter: Whereas we had recoveries from ringed young shearwaters in most years (Tab. 1), the birds of 1981 and 1982 did not return. We had ringed 120 nestlings in 1985 and according to Tab. 2 four year old birds could have been expected in 1989. But in spite of intensive field work in 1989 we could not retrap a single bird from 1985. Adult mortality also seems to be affected by the El Nino, since the subpopulation (Tab. 1) had a low of 6 in 1983 and of 3 in 1986 (as compared to 11 in 1985 and 8 in 1987 and 1988).

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