

BIOMETRICAL AND BIOLOGICAL CONSIDERATIONS ON THE  
CORY'S SHEARWATER *COLONECTRIS DIOMEDEA*

Bruno Massa & Mario Lo Valvo, Istituto di Zoologia  
dell'Università di Palermo, 18 Via Archirafi, 90123 Palermo

Introduction

Today the Mediterranean distribution of Cory's Shearwaters is believed to be well known. New colonies may be discovered, but certainly the largest ones are known. Many data were published during the last ten years and we believe to have a satisfactory knowledge of their biology, though some problems, as the winter movements of each population, the first breeding age and the ratio immatures/adults are still to be examined carefully.

In this paper we examine only the following aspects:

- 1) the estimate of the Mediterranean populations;
- 2) a biometrical comparison between some populations of the Mediterranean basin and the Atlantic ones (ssp. *borealis*);
- 3) a comparison of the breeding cycle of previous populations.

Material and methods

The estimate of the populations and the biometrics have been drawn from the available literature. Some authors did not recognize the males and the females and their data probably are the mean of both sexes. We made the average of the males and females of all the populations in order to compare these data with those of the authors who did not recognize the sexes. Therefore we did not test the small homogeneous values and we used the *t* of Student only to compare populations of the same sex. We also took some measurements on skins collected along the coasts of Tuscany and Liguria (Tyrrhenian sea), probably coming from colonies of Corsica or Sardinia, and preserved in the Museum of Natural History of Milan. We also measured some

skins from I. Selvagen (Atlantic) (2 males and 1 female), I. Cabrera (Balearic Islands) (3 males and 2 females) and I. Dragonada (Crete) (2 males and 3 females), all taken in order to research chemical pollutants (Renzoni et al., in prep.). Original data on the breeding cycle were collected in the I. Linosa (Sicilian Channel) during research between 1981 and 1985.

● Numbers and distribution in the Mediterranean Sea

Fig. 1 shows all the colonies, according to contemporary authors.

Aegean Sea. Kumerloeve (1972) published a map in which he reported 12 confirmed colonies and 7 possible ones, but he did not estimate the population. Vaughan (1980) found a small unknown colony of about 50 pairs in the Aegean; he also stated that all the Aegean colonies were small, but those of Crete. Wink et al. (1982), who studied the colony of Paximada (Dionisiades, Crete), think that the largest colonies of the Southern Aegean exist in these isles holding about 1,600 pairs. Round & Swann (1977) had found 63 nests of Cory's Shearwaters in the I. Dragonada (Dionisiades) and probably that colony is constituted by some hundreds of pairs (Massa, unpubl.). James (1984) estimates 5,000 pairs all over Greece.

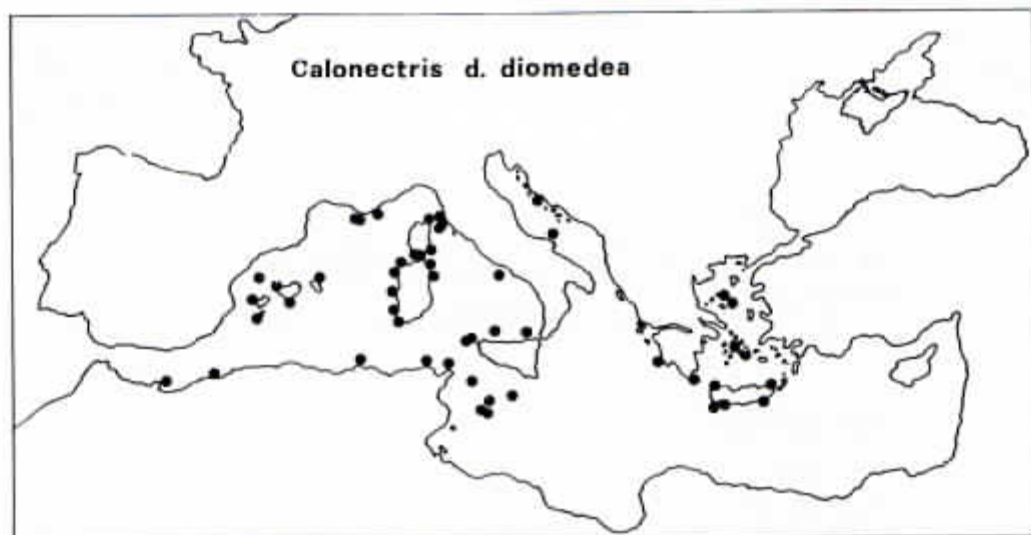


Fig. 1: Mediterranean distribution of the Cory's Shearwater.

Adriatic Sea. According to Matveiev & Vasic (1973) the Cory's Shearwater breeds certainly along the dalmatian coasts, where, according to Krpan (1962-64 in Vaughan, 1980) there should be only small colonies. The only Italian breeding site in the Adriatic is the I. Tremiti, from which the name "Diomedea" of this species came (Vaurie, 1965). Neither Di Carlo (1963) nor Spina (1982) estimate that population, but the latter makes us understand that it consists of hundreds of pairs. Census is difficult because of inaccessibility of the breeding site.

Sicilian Channel. Here we can find the largest colonies of the whole Mediterranean. Cachia Zammit & Sultana (pers.comm.) estimate about 8-10,000 pairs in the Maltese Islands. We have no data for the I. Pantelleria, but some observations at dusk in 1978, 1982 and 1985 make us think that at least 1,000 pairs breed there. In the I. Linosa (Pelagic Isles), where Vaughan (1980) estimated from 1,000 to 5,000 pairs, we censused at least 10,000 pairs with the capture-recapture method (see Appendix 1). It seems that a few pairs breed in the I. Lampedusa (Pelagic), whereas in Lampione, an islet off Lampedusa, at least 300-400 pairs still breed (Massa, unpubl.). Massa (1973) recorded it as abundant in the I. Egadi. The largest colony of these islets breeds on I. Marettimo; The colony is accessible, though with difficulties, and consists of hundreds of pairs. The largest colony of the Sicilian Channel lives on I. Zembra. Gaultier (1981) estimates this colony between 20 and 25,000 pairs.

Tyrrhenian Sea. The islets along the northern coast of Sicily are breeding sites of the Cory's Shearwater. It breeds on I. Ustica and I. Aeolian (small populations). There are no numbers for the populations of the islets of Tuscany and Latium (Brichetti, 1979), but it seems that while the Cory's Shearwater is plentiful in the Sicilian Channel, in the Tyrrhenian sea the Manx Shearwater (Puffinus puffinus) is more abundant.

Sardinia and Corsica. Schenk & Torre (1986) estimate 2,500-4,000 pairs in the islets and along Sardinian coasts. Guyot et al. (1985) estimate the whole Corsican population between 350 and 490 pairs.

Mediterranean French coasts. Breeding has been confirmed only in the islets of Marseille and Hyères, where Guyot et al. (1985) estimate a population between 460 and 570 pairs.

Mediterranean Spanish coasts. According to de Juana (1984) there is no evidence of breeding along the Spanish coasts. Therefore the only confirmed colonies are in the I. Columbretes (some hundreds of pairs) and in the Balearic isles (5,000-10,000 pairs, including those of Cabrera, where Araujo et al. (1976) censused about 300 pairs in 1974).

Coasts of Algeria and Morocco. Jacob & Courbet (1980) found two colonies, one in some islets near Collo and another in the I. Habibas near Oran. The former consists of about 20 pairs, while the latter is larger, but it has not been censused. Along the Moroccan coasts Berthon & Berthon (1984) report it only as



		SELVAGES	CHAFFARINAS	CABRERA	TYRRHENIAN SEA	ZEMBRA	LINOSA	MALTA	PAXIMADA
WEIGHT grams	males + females	945 n=52	664 n=29	641 (63.3) n=63	n.a.	639 n=121	623 n=375	606 n=43	552 n=211
	males	1014 (55.9) n=26	717 (65.6) n=13	629 n=3	n.a.	703 n=73	675 (59.4) n=187	n.a.	586 (58.7) n=113
	females	877 (61.6) n=26	622 (34.7) n=16	510 n=2	n.a.	575 n=49	577 (48.5) n=178	n.a.	514 (64) n=98
	males + females	361 n=31	355 n=27	351 (8.5) n=66	344 (9.2) n=19	349 (6.5) n=218	351 n=114	346 n=39	337 n=127
	males	363 n=20	361 (7.5) n=11	345 n=3	352 (2.4) n=8	355 (6.1) n=109	356 (9.3) n=59	n.a.	342 (7.6) n=65
	females	358 (4.5) n=11	351 (7.1) n=16	340 n=2	339 (8.4) n=11	343 (6.9) n=109	345 (9.6) n=55	n.a.	333 (8.4) n=62
TARSUS mm	males + females	55.7 n=113	55 n=21	51.9 n=66	47.7 (1.8) n=18	n.a.	53.2 n=114	54.6 n=34	52.7 n=73
	males	57 (1.2) n=52	56.8 (1.3) n=7	n.a.	48.4 (1.1) n=8	n.a.	53.6 (3.2) n=59	n.a.	53.4 (1.7) n=35
	females	54.6 (1.3) n=61	54.1 (1.1) n=14	n.a.	47.2 (2.1) n=10	n.a.	52.8 (2.1) n=55	n.a.	52 (1.2) n=38
	males + females	54 n=112	50.1 n=29	50.6 n=66	50.4 (2.1) n=18	48.8 (1.6) n=218	52.1 n=114	49.5 n=34	47.9 n=79
	males	55.5 (1.7) n=52	52.2 (2) n=12	50.8 n=3	52.3 (1.7) n=7	50.7 (1.5) n=109	53.6 (1.8) n=59	n.a.	49.5 (1.4) n=40
	females	52.8 (1.8) n=60	48.7 (1.8) n=17	47.9 n=2	49.2 (1.3) n=11	46.9 (1.6) n=109	50.6 (1.6) n=55	n.a.	46.2 (1.2) n=39
BILL DEPTH mm	males	n.a.	14.7 (1) n=19	13.3 n=3	12.9 (.9) n=7	13.8 (.6) n=109	13.7 (.7) n=58	n.a.	12.9 (.7) n=65
	females	n.a.	12.1 (.6) n=17	11.4 n=2	11.7 (.6) n=11	12.1 (.5) n=109	12.0 (.5) n=51	n.a.	11.6 (.4) n=58

Tab. 1: Biometrics of Cory's Shearwater from Mediterranean and Atlantic Isles (Selvagen).

In brackets: s.d.

n.a. = figures not available

Selvagen: Zino, 1971; Chafarinas: Witt et al., 1984; Cabrera: Araujo et al., 1977; Tyrrhenian Sea (skins): original; Zembra: Gaultier, 1981; Linosa: Iapichino et al., 1983 and original; Malta: Sultana, pers.comm.; Paximada: Ristow & Wink, 1980.

possible, but they could not search in the islets at night. The only moroccan known colony to day is that of I. Chafarinas, quoted by de Juana et al. (1980). In 1984 de Juana et al. estimate it in the order of thousands of pairs. They observed 3,600 individuals at dusk on 6 June 1981. Witt observed in April about 9,000 individuals (de Juana, pers.comm.).

Some considerations about the Mediterranean population

In the Mediterranean basin there are 50-60 colonies generally localized on islets. The population numbers of only 27 colonies have been estimated. In these 27 colonies at least 60,000 pairs are known to breed, whereof 40,000 pairs in the islets of Zembra and Linosa. Since the colonies not censused are small, we think that less than 100,000 pairs would breed in the Mediterranean. We also have to consider the immatures which occur in the colonies during the breeding cycle. According to Mougin & Stahl (1982) in the I. Selvagen the immatures are slightly more numerous than the adults, whereas according to Araujo et al. (1976) in I. Cabrera they may be three times as many immatures as the number of adults. We were not able to estimate the ratio immatures/adults in the colony of Linosa, but we consider a ratio of 0.5/1 reliable (see Appendix 2). In this case the total mediterranean population (including immatures) could be over 250-300,000 individuals. For the time being it is not possible to estimate them more accurately.

It is useful to remember that between 22nd October and 15th November 1977 Telleria (1980) observed 33,355 Cory's Shearwaters to leave the Mediterranean through the Strait of Gibraltar, and estimated a passage of over 150,000 individuals by the means of sample counts. It is noteworthy that: first Cory's Shearwater also migrate during the night, secondly Telleria observed only individuals along the Spanish coast and thirdly when he left the observatory place, migration was still going on. On the ground of that we believe that many more than 150,000 individuals migrated through the Strait in that period.

Telleria (1980) observed two different peaks, one between 23 and 30 October and another between 5 and 11 November, probably corresponding respectively to adults and juveniles. If we consider that the breeding pairs lay every year one egg, with a breeding success of 0.8 (0.64-0.93: Araujo et al., 1977; Gaultier, 1981; Thibault, 1985; Wink et al., 1982), the juveniles of the second peak should be at least 50,000.

In conclusion by assessing the above data and considering also that some individuals winter in Sicilian waters (Brichetti, 1979; Lo Valvo & Massa, unpubl.) and in the Balearic sea (Muntaner et al., 1984), it seems that the mediterranean population may be over 300,000 individuals.

● Biometrics of the population

Tab. 1 and fig. 2 show the values of the Mediterranean and Atlantic populations. Tab. 2 gives the level of significance of statistical difference between the pairs of populations.

Wing. The largest individuals live in the I. Selvagen. The individuals of the I. Chafarinas have the longest wing of the Mediterranean, whereas those of Aegean (Dionisiades) have the shortest one. Other populations have intermediate measurements, statistically different from each other. Only Zembra and Linosa have populations statistically not distinguishable by the wing length.

	WING		TARZUS		BILL LENGTH		BILL DEPTH		WEIGHT	
	males	females	males	females	males	females	males	females	males	females
SELVAGEN	-	P<.012	S.S.	S.S.	P<.001	P<.001	-	-	P<.001	P<.001
CHAFARINAS	-	P<.001	P<.001	P<.001	P<.001	P<.001	-	-	-	-
SELVAGEN TYRRHENIAN	-	P<.001	-	-	P<.001	P<.001	-	-	-	-
SELVAGEN ZEMBRA	-	P<.001	P<.001	P<.001	P<.001	P<.001	-	-	P<.001	P<.001
SELVAGEN LINOSA	-	P<.001	P<.001	P<.001	P<.001	P<.001	-	-	P<.001	P<.001
SELVAGEN PAKHMADA	-	P<.001	P<.001	P<.001	P<.001	P<.001	-	-	P<.001	P<.001
CHAFARINAS TYRRHENIAN	-	P<.001	P<.001	P<.001	S.S.	S.S.	P<.001	S.S.	-	-
CHAFARINAS ZEMBRA	P<.008	P<.001	-	-	P<.002	P<.001	P<.001	S.S.	-	-
CHAFARINAS LINOSA	S.S.	P<.018	P<.011	P<.027	P<.02	P<.001	P<.001	S.S.	S.S.	P<.001
CHAFARINAS PAKHMADA	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001
TYRRHENIAN ZEMBRA	S.S.	S.S.	-	-	P<.001	P<.001	P<.001	P<.014	-	-
TYRRHENIAN LINOSA	S.S.	S.S.	P<.001	P<.005	S.S.	P<.008	P<.007	P<.008	-	-
TYRRHENIAN PAKHMADA	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	S.S.	S.S.	-	-
ZEMBRA LINOSA	S.S.	S.S.	-	-	P<.001	P<.001	S.S.	S.S.	-	-
ZEMBRA PAKHMADA	P<.001	P<.001	-	-	P<.02	P<.008	P<.001	P<.001	-	-
LINOSA PAKHMADA	P<.001	P<.001	S.S.	P<.034	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001

Tab. 2: Levels of statistically significant probability among different populations of Cory's Shearwaters (test t of Student).

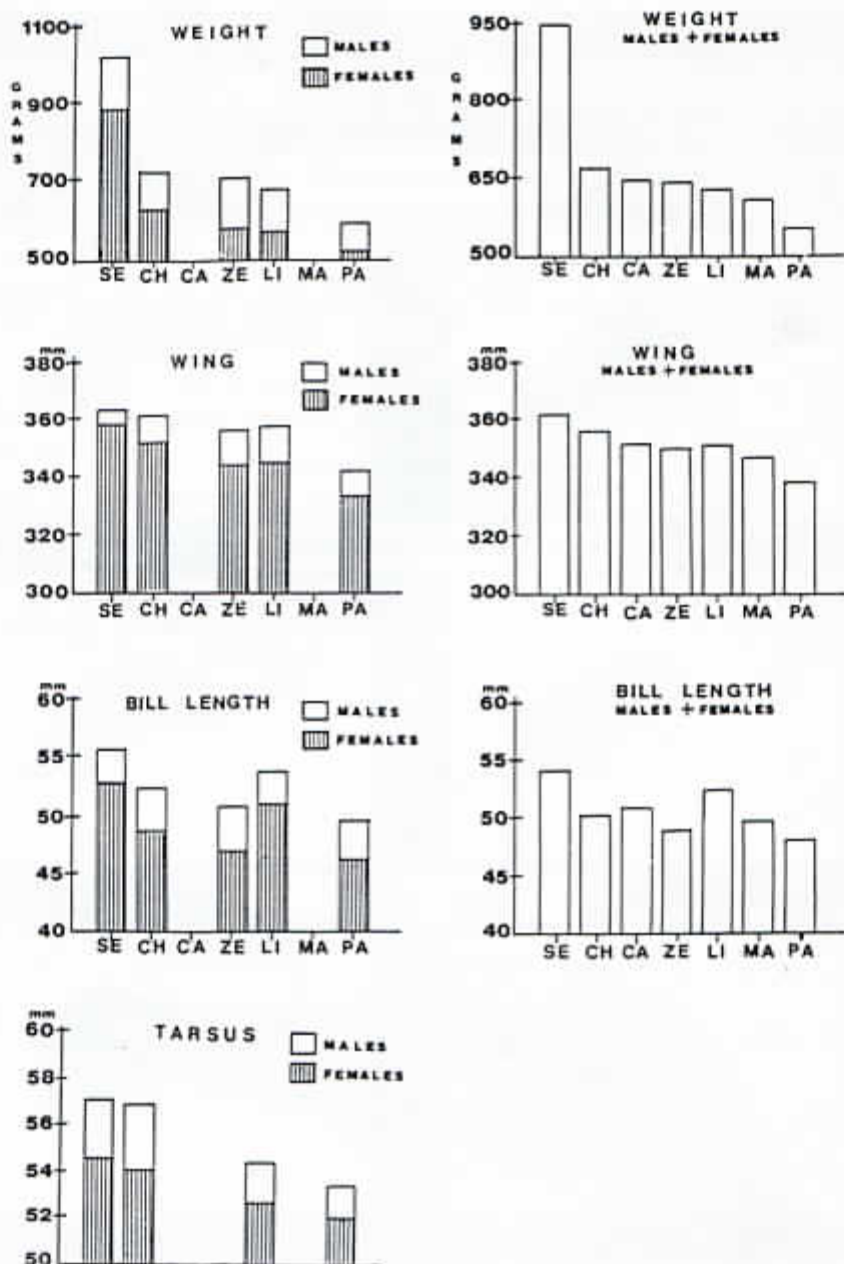


Fig. 2: Geographical trend of some biometrical parameters of the Cory's Shearwater.  
 SE = Selvagen; CH = Chafarinas; CA = Cabrera; ZE = Zembra; LI = Linosa; MA = Malta; PA = Paximada.



**Tarsus.** The individuals of the I. Selvagen and Chafarinas have no statistically different tarsi, but they are longer than those of other populations. The specimens of the Tyrrhenian sea, probably coming from colonies of Corsica or Sardinia, have the shortest tarsi. Their measurements were taken from skins and the results may be due to this reason. Similarly the individuals measured coming from Cabrera have also quite short tarsi.

**Bill.** The total bill length (b.l.1 of fig. 3) proved to be statistically different in all populations, excluding the comparison between those of Chafarinas and the skins of Tyrrhenian origin and also between the individuals of Linosa and the same skins (males only).

It is interesting to observe that this was the only statistically different parameter between Zembra and Linosa. The bill of individuals of Linosa resulted to be rather long and one could think that there were some errors while taking the measurements. However we compared two samples of measurements taken independently by each of us at Linosa, and we did not find any appreciable difference (0.6 mm). According to Busse (1983) a possible error in measuring is in the order of 1 mm. We can therefore conclude, unless both of us made a mistake, that the bill of individuals of Linosa is longer than the one of Shearwaters of Zembra.

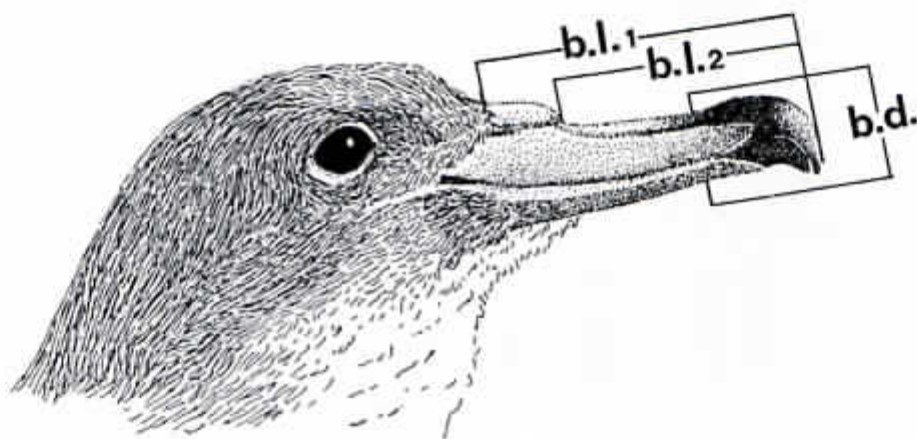


Fig. 3: Bill measurements of the Cory's Shearwater.  
 b.l.1 = total bill length; b.l.2 = bill length from the nostril to the tip; b.d. = bill depth.



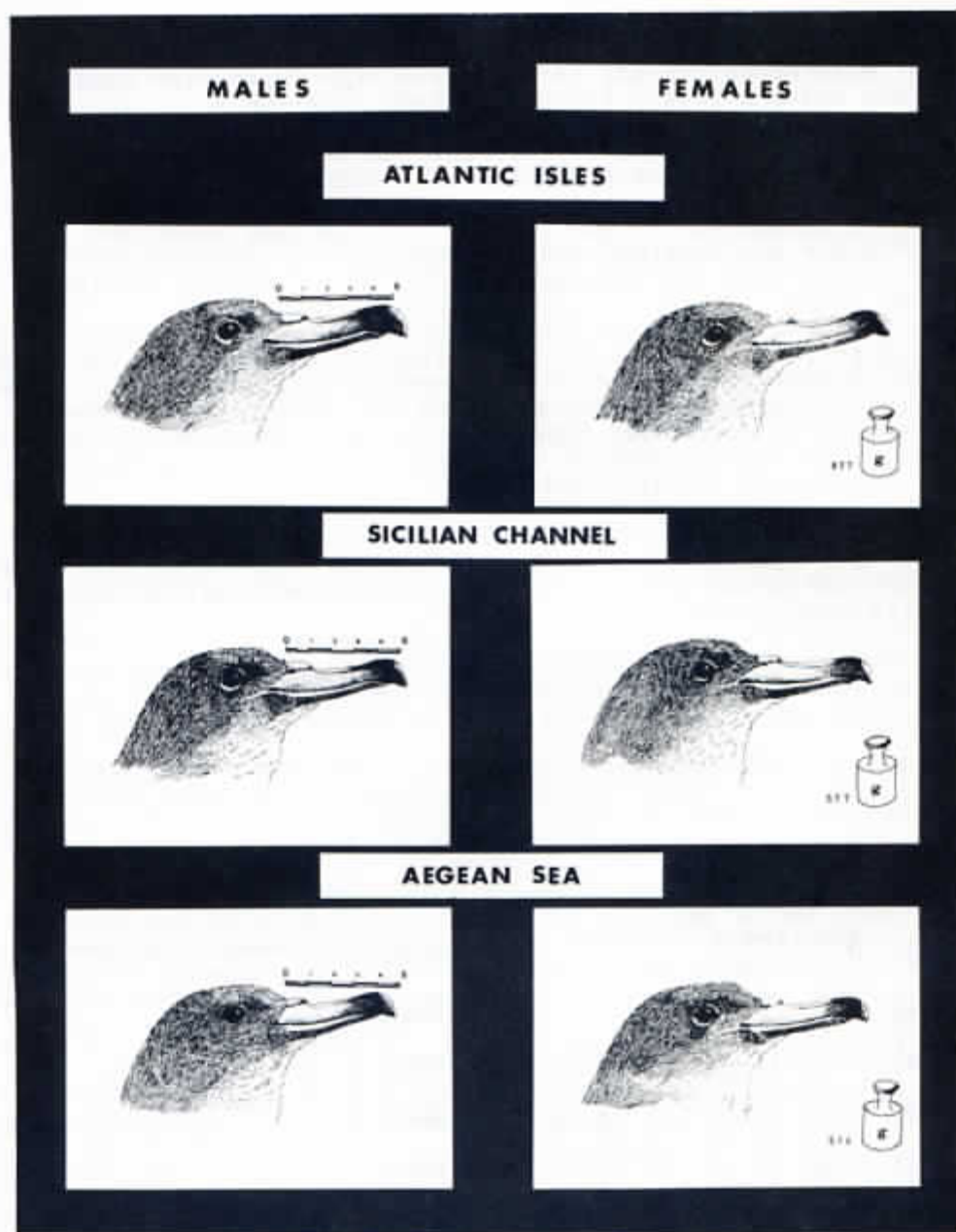


Fig. 4: Bill proportions of the Atlantic (Selvagen) and Mediterranean (Linosa and Dragonada) Cory's Shearwaters. See also tab. 1.

The second bill length (b.l.2 of fig. 3) was measured of only the individuals at Linosa and Paximada (Iapichino et al., 1983; Wink et al., 1982) as well as of the Tyrrhenian skins ( $40.8 \pm 1.3$  and  $38.4 \pm 1.2$  respectively for the males and the females of Linosa;  $38.6 \pm 1.2$  and  $36.5 \pm 0.9$  for those of Paximada;  $39.6 \pm 0.6$  and  $37.8 \pm 0.7$  for the skins of the Tyrrhenian). We found a statistically significant difference between the values of Linosa and Paximada ( $P < 0.001$  for both sexes), between those of Linosa and Tyrrhenia ( $P < 0.05$  for the males and  $P < 0.1$  for the females) and between those of Paximada and Tyrrhenia ( $P < 0.05$  for the males and  $P < 0.001$  for the females).

The bill depth (b.d. of fig. 3) of only some populations was taken and it proved to be statistically different. The skins of the Tyrrhenian sea resulted to have a bill less thick. A statistical difference between these and the individuals of Paximada was not found. Sexual dimorphism in bill depth is not evident. Thus statistical difference was only tested for males from Zembra, Linosa and the Tyrrhenian sea.

In fig. 4 the heads of males and females of the Atlantic isles (Selvagen), Sicilian Channel (Linosa) and Aegean Sea (Dragonada) are drawn in order to show the proportional differences of bill measurements.

The product bill length x depth is thought to be a good index to separate the sexes (Ristow & Wink, 1980; Wink et al., 1982; Witt et al., 1984). In fact, as shown in fig. 5 and tab. 3,

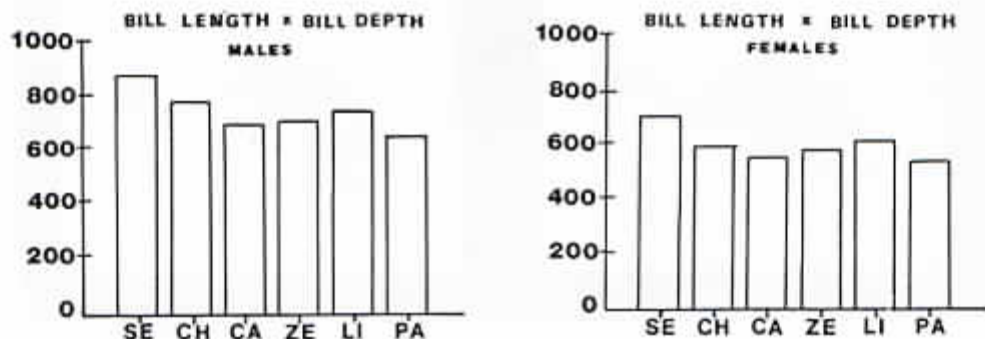


Fig. 5: Bill length x depth of some Cory's Shearwater populations. SE = Selvagen; CH = Chafarinas; CA = Cabrera; ZE = Zembra; LI = Linosa; MA = Malta; PA = Paximada.

this product allows both to separate the sexes and the populations. Data from Cabrera are very similar to those of Paximada, but the sample of Cabrera is too small for any statistical analysis. It is interesting to observe that also the skins of the Tyrrhenian males score low values. The trend is different for the females, excluding the specimens of Cabrera and Paximada, which show the smallest values.

	SELVAGEN	CHAFARINAS	CABRERA	TYRRHENIAN SEA	ZEMBRA	LINOSA	PAXIMADA
Males	866 (791- 949)	767 (688- 851)	676 (633- 718)	675 (608- 745)	701 (652- 751)	734 (673- 798)	638 (587- 692)
Females	700 (672- 721)	589 (539- 655)	548 (515- 581)	576 (532- 621)	570 (529- 613)	607 (563- 652)	536 (504- 569)

Tab. 3: Values of bill length x bill depth of different populations of Cory's Shearwaters (mean, minimum and maximum).

Weight. Data of tab. 1 are statistically different for all the pairs taken into account, except for those concerning the males of the Chafarinas and Linosa (tab. 2). Yet the weight values fluctuate from year to year and throughout the year.

At Zembra Gaultier (1981) observed the following trend during 1978 and 1979: in May he found the maximum weight dimorphism of the sexes (185.6 g), probably due to the weight decrease of the female for egg laying; the female weight increased in July and the sexual dimorphism diminished to 111.6 g. At last, in October, both sexes lost weight and sexual dimorphism lowered to 86.7 g.

In I. Linosa we observed three different trends in three different years (see also tab. 4 and fig. 6).

1982. In April we found a weight dimorphism of the sexes of 118 g, which increased in May to 139 g, because of the weight decrease of the females. In August the dimorphism was only 65 g: the females had put on weight, while the males got lighter.

1983. The weight dimorphism was 94 g in April, and 102 g in the first days of September. In comparison to the same period of 1982, in April the males were 6% heavier and the females 10%, while in September males and females were respectively 9% and 5% heavier than in August 1982.

1984. In April the weight dimorphism was still of 94 g, as the previous year, but the weight of both sexes was very low as com-

		1982	1983	1984
APRIL	males	705	747	636
	females	587	653	542
MAY-JUNE	males	694	-	666
	females	555	-	559
AUGUST-SEPTEMBER	males	678	747	701
	females	613	645	579

Tab. 4: Trend of weight of the Cory's Shearwater at Linosa (Sicilian Channel) in 1982, 1983 and 1984.  
 1982: 25-30 April; 21-29 May; 20-30 August.  
 1983: 10-15 April; 10-14 September.  
 1984: 20-30 April; 4-6 June; 20-30 August.

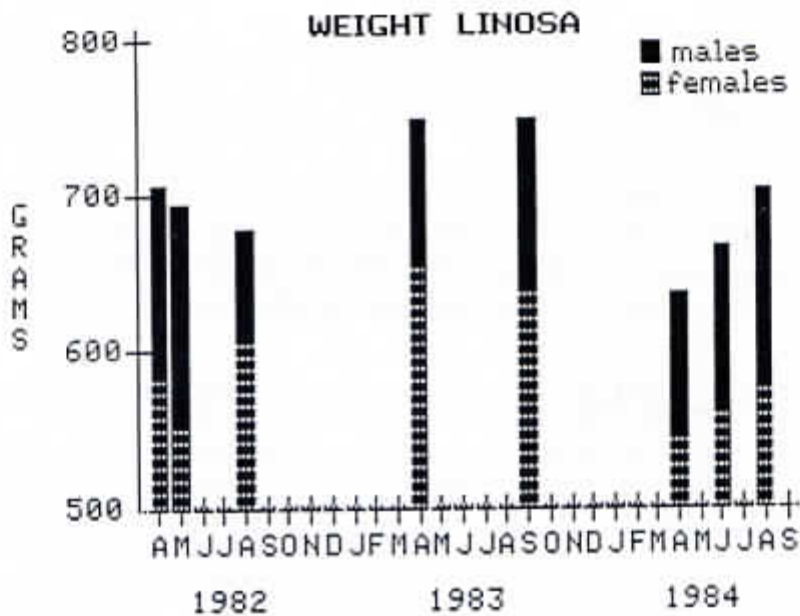


Fig. 6: Trend of weight (males and females) in different years, taken on the population of Linosa.



pared to 1983 (10% less than in 1983 for the males and 8% for the females). In the first days of June weight increased and the dimorphism was 107 g. In August, weight still increased especially among males and the dimorphism was found to be 122 g, the highest observed in this period at Linosa.

We can conclude that, since weight depends on the availability of food in the wintering and breeding areas, this statistical comparison may be pointless. It is probable that, especially in some difficult years, the long period of courtships preceding laying effects the increase of fat needed for the metabolic activity that Cory's Shearwaters are undergoing during the following months.

#### Ratio egg weight/female weight

Jouanin (1976) thought that there was no difference about this ratio between the population of the Selvagen and that of Zembra. On the contrary the data today available seem to confirm the difference on the ratio between the populations of the Selvagen and the Mediterranean (tab. 5). Jouventin & Mougín (1981) give the following linear regression between the logarithm of the egg weight and that of the adult for the Procellariiformes:  $y = 0.774 x^{0.722}$ . The values for the Cory's Shearwaters give us the following regression:  $y = 0.415 x^{0.55}$  ( $r = 0.87$ ;  $P < 0.05$ ). Generally the ratio egg weight/incubating female weight of mediterranean populations is more similar to that of some Procellariiformes as *Puffinus* and *Fulmarus* than the ratio of Atlantic Cory's Shearwaters (see the Appendix of Jouventin & Mougín, 1981). This characterizes even more the smaller body size of Mediterranean individuals in respect to Atlantic ones.

SELVAGEN	11.8	(Zino, 1971)
ZEMBRA	14.6	(Gaultier, 1981)
LINOSA	14.5	(Lo Valvo & Massa, unpubl.)
PAXIMADA	14.9	(Ristow & Wink, 1981)

Tab. 5: Ratio egg weight - female weight  $\times 100$

#### Concluding considerations about biometrics

Iapichino et al. (1983) hypothesized a clinal variation from Atlantic isles towards the Eastern Mediterranean. Some data here discussed seem to confirm this hypothesis. However there are some populations that do not follow this rule, e.g. those of the Balearic Islands and perhaps of Corsica or Sardinia (Tyrrhenian skins of tab. 1) which seem to be smaller than the other Western Mediterranean.

Statistical differences in biometrics should show that every population is genetically closed, probably without any relationship or exchange with other populations. Moreover, the breeding site fidelity of juveniles and adults, observed in the I. Selvagen (Jouanin et al., 1977) and the breeding site fidelity of adults in I. Linosa (Lo Valvo & Massa unpubl.) seem to be good reasons for considering at least the largest colonies closed or isolated, probably as isolated as Puffinus p. yelkouan compared to P. p. mauretanicus.

● Fishing areas of the Mediterranean

Probably the size of colonies and the biometrics of populations are correlated to food availability during the breeding cycle. From FAO (1983) we come to know the annual catches of fishing in mediterranean areas for a period of ten years. Tab. 6 gives the average values. There are no differences between the data of the Western and Central Mediterranean, whereas there are remarkable differences with the Eastern Mediterranean. If these annual fishing values can explain the relatively low number of the Cory's Shearwater in the Aegean Sea, they do not explain

		MEDITERRANEAN			
		Western	Central	Eastern	Black Sea
All the species	$\bar{x}$	108,675	157,238	45,087	496,510
	s.d.	54,501	25,283	18,970	115,173
Clupeidae	$\bar{x}$	34,450	30,847	9,329	99,869
	s.d.	25,360	12,475	3,744	38,279
Engraulis encrasicolus	$\bar{x}$	16,212	22,369	7,898	299,040
	s.d.	10,406	13,301	2,013	85,559
Cephalopoda	$\bar{x}$	6,339	12,832	1,274	-
	s.d.	3,043	1,297	642	-
All coastal pelagics	$\bar{x}$	64,508	62,595	19,867	447,446
	s.d.	40,162	24,288	10,752	107,783

Tab. 6: Annual catches by major groups and by fishing areas in metric tons for a period of ten years (from FAO, 1983).  
 Western Mediterranean = from the Strait of Gibraltar to Cape Bon, Northern Sicily and Italy.  
 Central Mediterranean = Sicilian Channel, Ionian Sea and Adriatic Sea to Greece, excluding Aegean Sea.  
 Eastern Mediterranean = Aegean Sea and Levant Sea.

the particular concentration of colonies in the Sicilian Channel. Besides it seems that a great percentage of caught fish is thrown back to the sea. In the Sicilian Channel at least 50,000 tons of fish are thrown back from the boats of Mazara del Vallo (F. Andaloro, pers. comm.). These figures are not included in the official statistical data.

In the Sicilian Channel the populations of Zembra (Gaultier, 1981) and Linosa (Sarà, 1983) are feeding especially on superficial pelagic fishes with slender forms, weighing no more than 80 g (Sarà, 1983). In September-October 1982 Sarà (1983) found the largest concentrations of Cory's Shearwaters in the Sicilian Channel at about 60km (Sarà, 1983, was able to establish that they came from Linosa, finding among them an individual ringed in that isle) and even 250 km southwards Linosa. According to Gaultier (1981) one adult ringed while incubating on 30 May 1974 in the I. Zembra, was captured in the month of September of the same year (while it had to attend the chick) off the Capo Murro di Porco (Siracusa), 250 km from Zembra.

These distances from the breeding sites are rather below those that can be covered by a Cory's Shearwater. It has been observed that Mediterranean Shearwaters feed their chicks on the average once every two days (Thibault, 1985; Lo Valvo & Massa, unpubl.). Since a chick is being fed in turns by male and female, each adult has four days to go to the feeding areas and back with the food concentrated on its oil. Mougín et al. (1984), by Pennycuick's (1969) formulas, estimate 30.7 km/h the minimum-power speed (=  $V_{mp}$ ) (that is the speed at which energy is used most slowly) of the Selvagen Cory's Shearwaters. Mediterranean Cory's Shearwaters are smaller both in weight and wing surface, and their  $V_{mp}$ , according to Pennycuick's (1969) formulas, results in only 26.9 km/h. If a Shearwater flies for 12 hours per day, it may cover 650 km every two days. As we observed earlier, the real covered distance is smaller, probably because of the great availability of food in the Sicilian Channel.

Tab. 6 also shows some fishing data in the Black Sea. This area is particularly fertile, as it results from the catches of Clupeidae and Engraulis encrasicolus. Many Manx Shearwaters coming from the Aegean Sea have been observed in the Black Sea during the spring-summer months (15-20,000, but also up to 30,000: Van Impe, 1975), whereas the Cory's Shearwater was rarely observed there (see Kumerloeve, 1972, note 2). This could show the proportion of the two Shearwater populations in the Aegean Sea.

#### • Notes about the breeding cycle

The Cory's Shearwater is among the species of Procellariiformes with a highly synchronous breeding cycle. In the Mediterranean basin laying begins on 19-20 May and ends in the first days of June. In the I. Selvagen, and probably in the Azores and Canaries, laying is a week later. In tab. 7 we report the available data about the laying and hatching periods and the



	Laying period	Incubation days	Hatching period	References
SELVAGEN	27 May - 6 June	53.8	17 - 19 July	(Zino, 1971)
CABRERA	25 May - 6 June ?	55 ?	18 - 29 July ?	(Araujo et al., 1977)
CORSICA	<u>20</u> May - 2 June x = 26 May	51.3	14 - 26 July	(Thibault, 1985)
ZEMBRA	<u>19</u> May - 2 June x = 27 May	50.8	10 - 24 July	(Gaultier, 1981)
LINOSA	<u>20</u> May - 3 June x = 27 May	51	10 - 25 July	(Lo Valvo & Massa, unpubl.)
CRETA	20 May ? - 1 June	51 ?	13 - 22 July	(Wink et al., 1982) (Round & Swann, 1977)

Tab. 7: Dates of laying and hatching and days of incubation for six different populations of Cory's Shearwater.  
? = figures not certain.

time required for incubation. Only figures of Cabrera are not within the Mediterranean range, but since Araujo et al. (1977) controlled the laying of the colony of Cabrera only from 22 to 27 May 1974, their data do not have to be considered definitive.

In literature we found only one date disagreeing with those reported in tab. 7: Giglioli (1907) wrote to have found on the 10th August 1882 some adults incubating on the islet of Lampione. Is this a mistaken date?

In the Mediterranean Sea the number of incubation days is lower than in the I. Selvagen ( $51.3 \pm 1.12$  and  $53.8 \pm 0.83$ ). This difference proves to be statistically significant ( $t$  of Student;  $P < 0.001$ ).

We remember that generally there is a significant correlation between the weight of the adult and the number of incubation days; for the Procellariiformes  $r = 0.83$ ,  $P < 0.001$ : Jouventin & Mougín (1981). We also found a good correlation for the Atlantic and Mediterranean Cory's Shearwaters ( $r = 0.98$ ,  $P < 0.001$ ).



Appendix 1 - Census of the Cory's Shearwaters in I. Linosa (Sicilian Channel) by capture-recapture method per sample-area

• Method

Census was performed in 1982 in I. Linosa. 855 adults of Cory's Shearwater have been ringed near their nests in an area estimated at least 1/10 of the total area of the colony (excluding some smaller colonies located in different areas of the isle). During ringing, along a pre-arranged route, all the ringed and recovered individuals were recorded (200 in total). Afterwards the elaboration method of Petersen-Lincoln (Begon, 1979) was applied. It consists of taking from a population, whose total amount  $N$  is unknown, a sample of  $M$  individuals. These are ringed and released. Subsequently in the same population  $n$  individuals are recaptured, but only  $m$  of them ringed and  $n-m$  unringed. If all the individuals have the same probability to be randomly captured, the proportion of the ringed individuals of the second sample is an estimate of the proportion of the ringed individuals in the total population (Meunier & Solari, 1979). Then  $n/m = N/M$ , from which  $N = Mn/m$  (index of Petersen-Lincoln).

If we used the capture-recapture method in different nights, it is possible to obtain a mean of different estimates. In this case the sample  $i$  ( $i = 1, \dots, K$ ), constituted by  $n_i$  individuals, contains  $m_i$  ringed individuals. Every night the unringed  $n_i - m_i$  are ringed and released. Before the  $i$ -th sample, population contains  $N$  individuals (total number), whose  $M_i$  are ringed. Calculation may be performed by the mean of estimates of the population for each capture-recapture sample. Formulas have been obtained by Chapman (1951 in Meunier & Solari, 1979) and Seber (1973 in Begon, 1979) from Petersen-Lincoln method.

• Results

The two formulas of the tab. 8 give respectively the values of 1,622 and 1,466 individuals, that is 700-800 pairs in the sample-area. If we consider that sample-area is at least one tenth of the total area of the colony, the total number of pairs may be estimated of at least 7-8,000 pairs. Since the Cory's Shearwater breeds in other areas of Linosa, an estimate of 10,000 pairs for the whole islet is not excessive.

As it is custom of Linosa inhabitants to take the eggs of the Cory's Shearwater, we can calculate figures for some areas of the islet. So, at least 400 eggs have been collected in the sample-area (the accessible part) and 500 in another colony outside the study area. Thus our estimate of 10,000 pairs for the whole islet should result reliable.

Appendix 2 - Estimate of the immatures within a colony

It is  $P = Eka/1-b$ , where  $P$  is the total number of the population,  $k$  is the rate of survival of immatures in the first life year,  $E$  is the number of laid eggs by the considered popu-

day (i)	1	2	3	4	5	6	7	8	9	10
n(i)	230	122	42	71	37	81	35	163	82	22
m(i)	-	15	15	13	6	22	15	27	74	13
M(i)	-	230	337	364	422	453	512	532	688	676
M(i) n(i)	-	28060	14154	25844	15614	36693	17920	86716	54776	14872

n(i) : individuals taken on the i-th day;

m(i) : ringed individuals, among the n(i) ones, recaptured on the i-th day;

M(i) : total ringed individuals up to the i-th day.

$$\bar{N} = \frac{\sum M(i)n(i)}{(\sum m(i)) + 1} \quad \text{or} \quad \bar{N} = \sum \left[ \frac{(M+1)(n+1)}{(m+1)} \right] \frac{1}{k-1}$$

Tab. 8: Results of censuses performed in the sample-area of Linosa.

$\bar{N}$  = mean of estimates of the population for every capture-recapture sample.

lation in the year,  $\underline{a}$  is the rate of survival of eggs and chicks in the nest,  $\underline{b}$  is the rate of annual survival of adults. We can estimate  $\underline{k}$  by the formula  $k = 2(1-b)/ab\bar{n}^{-1}$ , where  $\bar{n}$  is the average age of the first brood. We can estimate from literature and our own data the following parameters as shown:  $\underline{a} = 0.65$ ;  $\underline{b} = 0.95$ ;  $\underline{n} = 9$ .

So, a population which lays 3,000 eggs is constituted by 15,360 individuals and another one which lays 10,000 eggs is constituted by 30,720 individuals. If we consider that 3,000, 5,000 and 10,000 eggs correspond respectively to 3,000, 5,000 and 10,000 pairs of adults, we can estimate that at least another 3,216, 5,360 and 10,720 immatures constitute respectively the three populations, that is 50% of the adults.

### References

- Araujo, J.; Munoz Cobo, J. & Purroy, F.J. (1976). Populations of seabirds in the Cabrera archipelago (Balearic Islands). *Ardea*, 64: 83-84.

- Araujo, J.; Munoz Cobo, J. & Purroy, F.J. (1977). Los rapaces y aves marinas del archipelago de Cabrera. *Naturalia Hispanica*, 12: 1-94.
- Begon, M. (1979). Investigating animal abundance. Arnold, London.
- Berthon, D. & Berthon, S. (1984). Compte rendu de l'expédition Balbuzard sur les côtes méditerranéennes du Maroc. *Oiseau et Rev. fr. Orn.*, 54: 201-213.
- Brichetti, P.A. (1979). Distribuzione geografica degli Uccelli nidificanti in Italia, Corsica ed Isole Maltesi. *Natura Bresciana*, 16: 82-158.
- Busse, P. (1983). Biometrical standards in the operation Baltic work. *The Ring*, 10: 125-138.
- De Juana, E. (1984). The status and conservation of seabirds in the Spanish Mediterranean. Pp. 347-361 in: Croxall, J.T., Evans, P.G.H. & Schreiber, R.W., Status and conservation of the World's Seabirds. ICBP Technical Publ. n°2.
- De Juana, E.; Varela, J. & Witt, H.H. (1980). Le Puffin cendré Calonectris diomedea nicheur aux îles Chafarines. *Alauda*, 48: 27-31.
- De Juana, E.; Varela, J. & Witt, H.H. (1984). The conservation of seabirds at the Chafarinas Islands. Pp. 364-370 in: Croxall, J.T.; Evans, P.G.H. & Schreiber, R.W., Status and conservation of the World's Seabirds. ICBP Technical Publ., n°2.
- Di Carlo, E.A. (1963). Gli Uccelli estivi delle Isole Tremiti. *Riv. Ital. Orn.*, 33: 57-78.
- F.A.O. (1983). General Fisheries Council for the Mediterranean Nominal catches 1970-80. *Statistical Bull.*, n°4.
- Gaultier, T. (1981). Contribution à l'étude de la population de Puffins cendrés (Calonectris diomedea) de l'île de Zembra (Tunisie). Ministère Enseign. Sup. et Rech. Sc., Inst. Rech. Sc. et Techn., 169 pp.
- Giglioli, E.H. (1907). Avifauna Italica. Secondo resoconto. S. Giuseppe, Florence.
- Guyot, I.; Launay, G. & Vidal, P. (1985). Oiseaux de mer nicheurs du Midi de la France et de Corse: évolution et importance des effectifs. Pp. 31-47 in: Oiseaux marins nicheurs du Midi et de la Corse. *Annales du C.R.O.P.*, n°2.
- Iapichino, C.; Lo Valvo, F. & Massa, B. (1983). Biometria della Berta maggiore (Calonectris diomedea) dell'isola di Linnosa (Pelagie). *Riv. Ital. Orn.*, 53: 145-152.



- Jacob, J.P. & Courbet, B. (1980). Oiseaux de mer nicheurs sur la côte algérienne. *Gerfaut*, 70: 385-401.
- James, P.C. (1984). The status and conservation of Seabirds in Mediterranean Sea. Pp. 371-375 in: Croxall, J.T.; Evans, P.G.H. & Schreiber, R.W., Status and conservation of the World's Seabirds. ICBP Technical Publ. n°2.
- Jouanin, C. (1976). Note sur la biométrie des Puffins cendrés de Tunisie. *Oiseau et Rev. fr. Orn.*, 46: 97-102.
- Jouanin, C.; Roux, F. & Zino, A. (1977). Sur les premiers résultats du baguage des Puffins cendrés aux îles Selvagen. *Oiseau et Rev. fr. Orn.*, 47: 351-358.
- Jouventin, P. & Mougin, J.L. (1981). Les stratégies adaptatives des oiseaux de mer. *Rev. Ecol.*, 35: 217-272.
- Kumerloeve, H. (1972). Le statut du Puffin cendré Procellaria diomedea Scopoli dans le golfe saronique (Grèce). *Alauda*, 40: 102-104.
- Massa, B. (1973). L'avifauna estiva degli arcipelaghi delle Egadi e dello Stagnone (Trapani, Sicilia). *Atti Accad. Gioenia sc. nat. Catania*, 5: 63-95.
- Matveiev, S.D. & Vasic, V.F. (1973). *Catalogus Faunae Jugoslaviae. Aves. Acad. Sc. Art. Slovenica, Ljubljana.*
- Meunier, M. & Solari, A. (1979). Estimation de la densité de population à partir des captures-recaptures: application au campagnol des champs. *Mammalia*, 43: 1-24.
- Mougin, J.L.; Roux, F.; Stahl, J.C. & Jouanin, C. (1984). L'évolution des effectifs des Puffins cendrés Calonectris diomedea borealis de l'île Selvagen Grande (30°09' N, 15°52' W) de 1980 à 1983. *Bocagiana*, 75: 1-8.
- Mougin, J.L. & Stahl, J.C. (1982). Essai de dénombrement des Puffins cendrés Calonectris diomedea borealis de l'île Selvagen Grande. *Bocagiana*, 63: 1-17.
- Muntaner, J.; Escandell, A.; Ramos, E. & Orfila, G. (1984). Adición y revisión faunística de las especies de la publicación "Avifauna de Menorca". Pp. 177-205 in: Muntaner, J. & Congost, J., *Avifauna de Menorca*, 2nd ed. *Treb. Mus. Zool.*, 1: 1-205.
- Pennyquick, C.J. (1969). The mechanics of bird migration. *Ibis*, 111: 525-556.
- Ristow, D. & Wink, M. (1980). Sexual dimorphism of Cory's Shearwater. *Il Merill*, 21: 9-12.
- Round, P.D. & Swann, R.L. (1977). Aspects of the breeding of Cory's Shearwater Calonectris diomedea in Crete. *Ibis*, 119: 350-353.



- Sarà, M. (1983). Osservazioni sulla consistenza numerica e sull'alimentazione della Berta maggiore (Calonectris diomedea) nel Canale di Sicilia. Riv. ital. Orn., 53: 183-193.
- Schenk, H. & Torre, A. (1986). Breeding distribution, numbers and conservation of Seabirds in Sardinia, 1978-85. in Medmaravis, Proceedings of 1st Mediterranean Seabird Symposium, Springer Verlag, Heidelberg (this volume).
- Spina, F. (1982). Note ornitologiche dalle isole Tremiti (Mare Adriatico). Riv. ital. Orn. 52: 110-118.
- Sultana, J. & Gauci, C. (1982). A new guide to the birds of Malta. MOS, Malta.
- Telleria, J.L. (1980). Autumn migration of Cory's Shearwater through the Straits of Gibraltar. Bird Study, 27: 21-26.
- Thibault, J.C. (1985). La reproduction du Puffin cendré Calonectris diomedea en Corse. Pp. 49-55 in: Oiseaux marins nicheurs du Midi et de la Corse. Annales du C.R.O.P., n°2.
- Van Impe, J. (1975). Sur les mouvements du Puffinus p. yelkouan en Mer Noire. Alauda, 43: 185-187.
- Vaughan, R. (1980). Notes on Cory's Shearwater (Calonectris diomedea) and some other birds on Linosa, Pelagic Isles. Riv. ital. Orn., 50: 143-154.
- Vaurie, C. (1965). The Birds of the Palearctic Fauna. Vol. 2 (Non Passeriformes). Whiterby, London.
- Wink, M.; Wink, C. & Ristow, D. (1982). Brutbiologie mediterraner Gelbschnabelsturmtaucher (Calonectris d. diomedea). Seevogel, 127-135.
- Witt, H.H.; De Juana, E. & Varela, J.M. (1984). Geschlechtsspezifische Größenunterschiede in einer westmediterranen Population des Gelbschnabelsturmtauchers (Calonectris diomedea). Die Vogelwarte, 32: 234-236.