Wader count of the Banc d'Arguin, Mauritania, in January/February 1997

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A new count of the waders and waterbirds on the Banc d‹Arguin (Mauritania) in 1997 confirms the decline in numbers suggested by recent winter counts (Gowthorpe *et al.* 1996), although not on the same scale and not in all species. We counted a total of two million of waders, similar to the total numbers counted in 1979 and 1980. However, we counted more Dunlin *Calidris alpina* and Curlew Sandpipers *Calidris ferruginea*, and fewer Knot *Calidris canutus* and Bar-tailed Godwits *Limosa lapponica* than nearly two decades ago. The same trend was found in coastal waders in Guinea-Bissau, but Redshank *Tringa totanus* and Greenshank *Tringa nebularia* showed an increase on the Banc d‹Arguin, possibly because there are more shrimp and young fish now due to the over-exploitation of fish further offshore, and a decrease in Bissau. In Oystercatchers *Haematopus ostralegus* the reverse was true: they decreased on the Banc d'Arguin, due to the disappearance of their main prey: the Bloody Giant Cockle, and increased in Bissau. The most notable declines were in Kentish Plover *Charadrius alexandrinus*, Turnstone *Arenaria interpres*, Little Stint *Calidris minuta* and Knot on the Banc d'Arguin as well in Bissau. On the Banc d'Arguin, the birds were counted in the same sections as in 1980 allowing direct comparison of the 1997 and 1980 counts, as well as the feeding densities on different parts of the Banc d'Arguin. It is recommended (1) to monitor the wader numbers on the Banc d'Arguin on a more regular basis, (2) to subdivide the count into the sections as used in 1980 and 1997 and (3) to accept, at least for the moment, that the only way to monitor waders numbers on the Banc d'Arguin is by performing a complete count of the entire area.

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INTRODUCTION

Around two million waders, over a quarter of all waders found wintering along the entire European and West-African coast, are concentrated in one single wetland, the Banc d'Arguin in Mauritania. This natural wetland of shallow seas, low islands and vast tidal flats is host to upwards of two million waders and many other waterbirds. This impressive total amounts to twice the total number of all wintering coastal waders found in the Danish-German-Dutch Wadden Sea or in all combined British estuaries. Despite its huge importance, few attempts have been made to completely count the waders on the Banc d'Arguin. Knight & Dick (1975) were the first to try in autumn 1973, but their count did not cover the entire area. Fortunately, the counts carried out during the winters of 1978-79 (Trotignon *et al.* 1980) and 1979-80 (Altenburg *et al.* 1982, Engelmoer *et al.* 1984) were (nearly) complete. Apart from a count in the summer of 1988 (Van Dijk *et al.* 1990), it took more than ten years before a new winter count occurred (Gowthorpe *et al.* 1996). In retrospect, one may ask why none of the ornithologists working in the area felt the need to organise a new count. There are several reasons. The two counts in 1979 and 1980 respectively arrived at about the same number of over two million waders and there was no reason to doubt that the wintering number would have changed since then. The Banc d'Arguin is one of the most remote and unspoilt coastal wetlands in the world and seems to have remained unchanged over recent decades. Moreover, it takes four experienced counters at least a month to visit all tidal roosts on the Banc d'Arguin and count the waders. So in summary, why do so much work again, if two million of waders are the expected outcome?

Fortunately, this reasoning did not restrain Gowthorpe *et al.* (1996) from attempting a new count. Instead of confirming the status quo, their results were alarming. They pointed to the fact that, during the intervening years, there must have been a significant decline in the number of wintering waders and other waterfowl, as well as in the breeding population of Long-tailed Cormorant *Phalacrocorax africanus* and six different tern species. They also suggested a possible common explanation for these negative trends: over-exploitation of fish causing a disturbance of the entire ecosystem. The Banc d'Arguin is the shallowest part of an extensive upwelling zone that appears along the Mauritanian coast (e.g. Wolff *et al.*

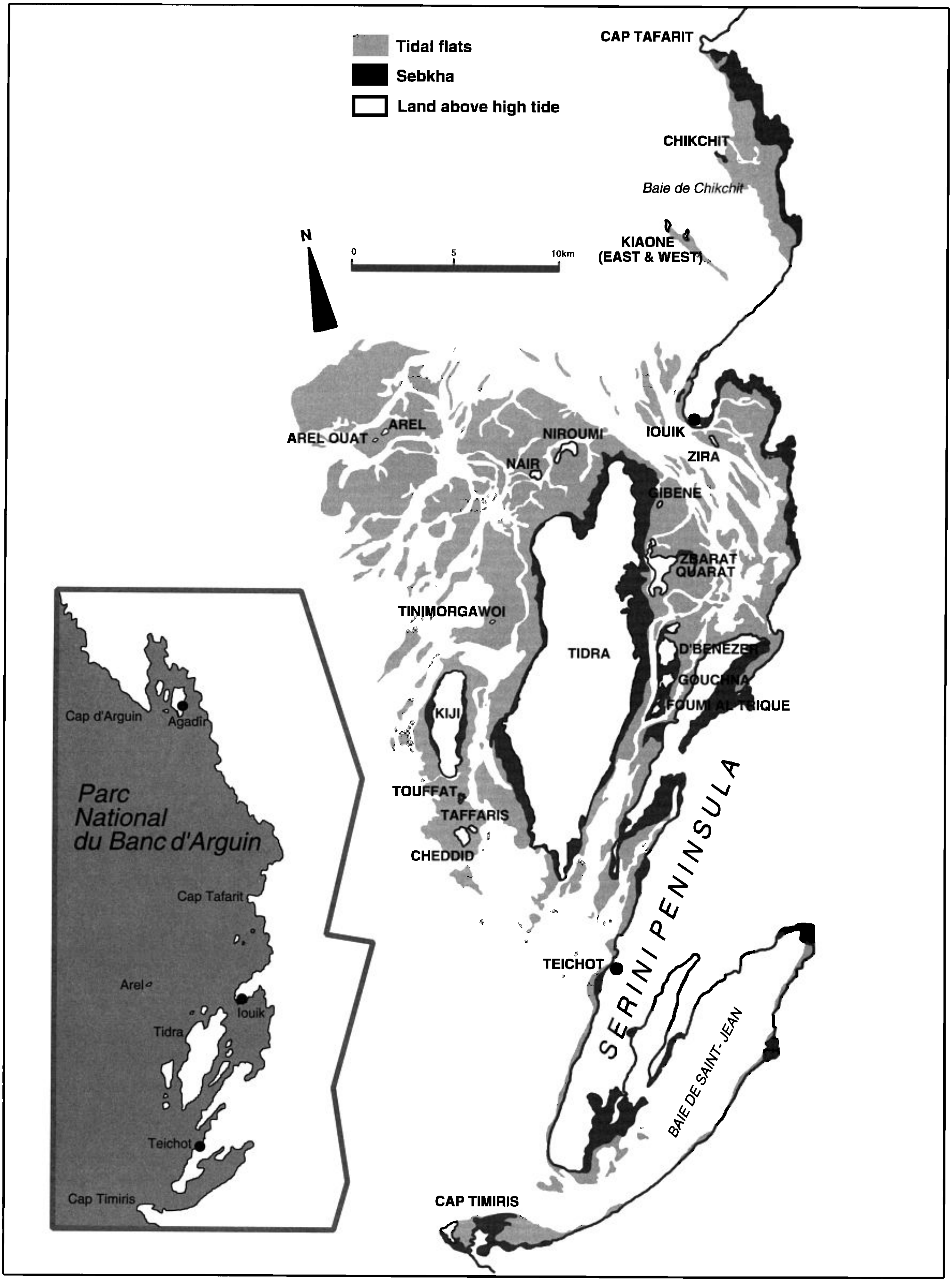

Figure 1. The Banc d'Arguin, redrawn from Wolff & Smit (1990). Inset figure shows the entire National Park of the Banc d'Arguin.

1993b). This attracts, further offshore, an international fleet of many fishing boats, using huge fine-mesh nets. Local fishermen on the Banc d'Arguin who use small sailing boats and standing nets to catch fish, mainly mullet, complain that their catch has decreased dramatically over recent years. Indeed, it is conceivable that the decline in fish numbers on the Banc d'Arguin is a direct consequence of the increase in the industrial fisheries further offshore. Although it remains difficult to see how this could effect the feeding situation for the many waders, as these birds are dependent on the benthic fauna on the intertidal flats, the staff of the 'Parc National du Banc d'Arguin' and the board of the 'Fondation Internationale du Banc d'Arguin' felt an urgent need to know the present status of wintering waders and other waterbirds.

COUNTING ERRORS

Any new winter count on the Banc d'Arguin will meet the same mix of problems as any preceding count. There are at least three factors that could affect count accuracy. First, to prevent double counts or missing birds, adjoining tidal roosts have to be counted during the same high water period, but this is impossible to achieve as long as the counts are performed by only a small group of counters. Therefore, because of the enormous size of the area involved, the counts have to be completed during many different high water periods, with the attendant risk of missing birds and/or counting them twice. Secondly, the majority of the waders roost on beaches and sand banks which are usually extremely flat, so any small fluctuations in the high tide water level greatly influences the distribution of these roosts. The counters during the winter of 1980 faced this dilemma. For them it was not fully clear whether the nearly half million waders counted on the small isle of Tinimorgawoi, but then absent at a second count, when the tide was at a higher water level, had to be included in the total count (Altenburg *et al.* 1982). This problem might be prevented by counting waders on the Banc d'Arguin only at certain water levels, for example during spring tides, but the disadvantage of such a restriction is an extension of the total counting period.

The third reason that might confound count accuracy, has to do with the fact that waders on the Banc d'Arguin often form huge flocks at high tide. Rappoldt *et al.* (1985) compared estimated numbers with real flock size and concluded that the estimates are correct, at least on average. Apparently, flying birds are easier to count than sitting birds. The average counting error was 17% in flying birds and 37% in birds gathered on the roost. Rappoldt *et al.* (1985) also found that this error is independent of flock size, although their data is from flocks of not more than a few thousands birds. Assuming that this error is the same for each flock, it is possible to calculate the error of estimate when the birds are counted in different flocks. Theoretically, the error of estimate for the summed total number will decrease with the square root of the number of flocks being counted. This is the reason why the estimate of one million of waders along the British coast is

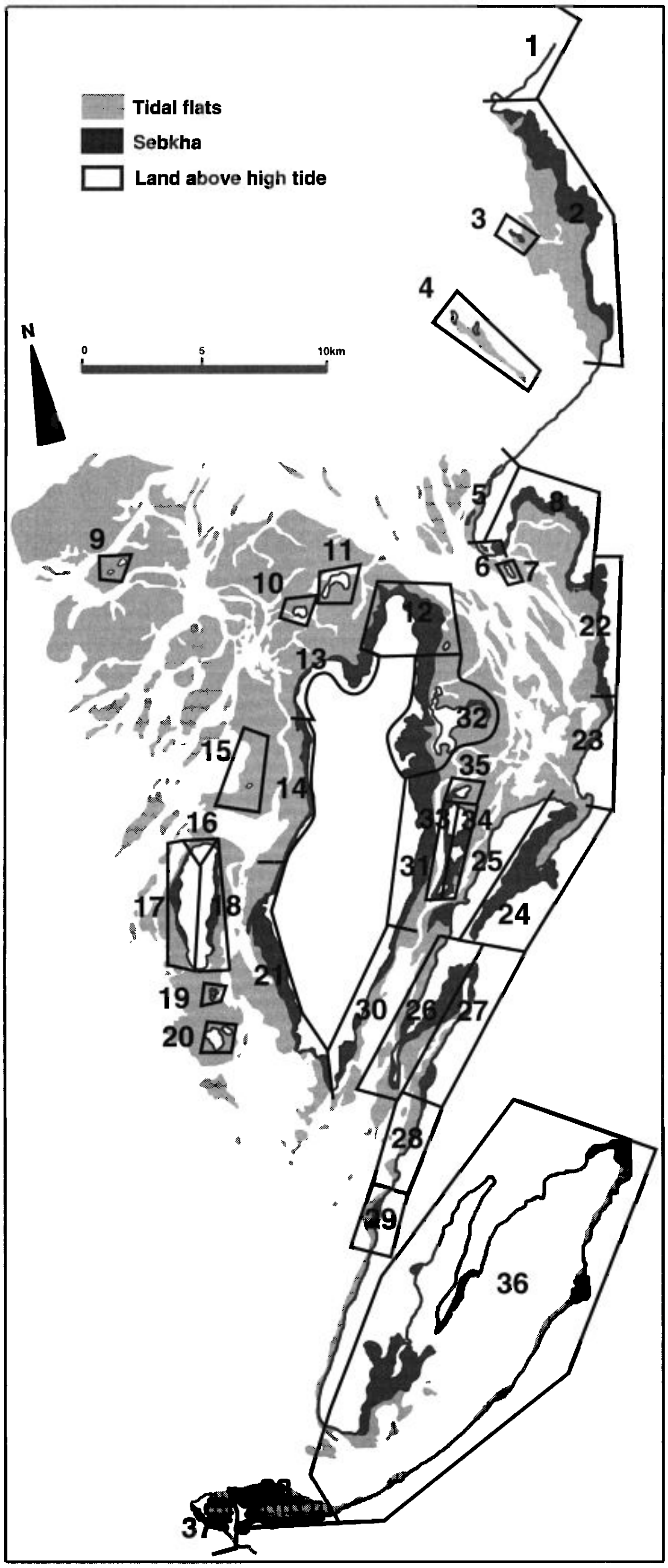

Figure 2. The high water counting areas on the Banc d'Arguin subdivided into 38 sections, numbered from 1 to 38; sections 3 and 4 were not counted in 1997.

much more accurate than an estimate of two million of waders on the Banc d'Arguin; the waders in Britain are counted on thousands of roosts so the thousands of random counting errors will almost completely cancel each other out. On the Banc d'Arguin, however, half of the birds are counted on a few huge roosts, and for some species the situation is even worse. In 1980, for example, 55% of all Kentish Plovers *Charadrius* *alexandrinus*, 44% of all Sanderling *Calidris alba* and 40% of all Little Stint *Calidris minuta* on the Banc d'Arguin, were counted on a single roost, the isle Tinimorgawoi. Consequently, in these species the error of estimate for the Banc d'Arguin as a whole largely depends on the errors made during this single count. Depending on the distribution pattern of the species on the Banc d'Arguin, the error of estimate for the total numbers may vary between 5% and 30%, assuming that the average counting error in flocks is 37%. However, we do not know whether the random error is larger if birds occur in mixed-species flocks or if they are assembled in enormous roosts of hundred of thousands of birds. Moreover, we do not know whether huge flocks are systematically under or over-estimated.

Fortunately, not all waders on the Banc d'Arguin have to be counted while present in huge flocks. Altenburg *et al.* (1982) had divided the Banc d'Arguin into 38 compartments of which, in most, the number of counted waders varied between 10,000 and 100,000. With some exceptions, most waders in these sections have to be counted on several roosts. Therefore, the theoretical error of estimate might be fairly small for most sections and this gives an extra opportunity to compare the numbers counted in 1980 with the numbers counted in winter 1997. When these 38 sections are again assembled into 15 larger compartments, the 1997 count can then also be compared with the counts of autumn 1973 and winter 1978/1979, at least for most of the larger sections.

METHODS

Sections

Wolff & Smit (1990) made a map of the Banc d'Arguin based on a LANDSAT-4 MSS image, here reproduced as Figure 1. They were able to distinguish sebkha (salt-crusted areas above high water level at average spring tide), mangroves, *Spartina* marshes, sandy tidal flats, muddy tidal flats, intertidal seagrass beds and, finally, intertidal flats for which substrate or vegetation was unknown. Most tidal flats of the latter category are situated west of Tidra. It concerns low-lying flats already being covered by the incoming tide when the satellite passed over the Banc d'Arguin.

The boundaries of the 36 sections indicated in Figure 2 are based on Altenburg *et al.* (1982), but there are three differences. (1) The shore along the mainland coast of the peninsula of Serini between sections 25 and 27 was not counted in 1980. We did not count many waders there, but added these numbers to the birds already counted in section 25. (2) The same holds for the north-west coast of Tidra between section 13 and 14; the birds counted here in 1997 were added to section 14. (3) Section 32 was incompletely counted in 1980, since the isle of Zbarat quarat and apparently also the adjacent coastline of Tidra were overlooked (see Altenburg *et al.* 1982, where Gibene is indicated 6 km south of its real position). We counted 141,000 waders on Zbarat quarat, among which were 82,000 Dunlin *Calidris alpina*,

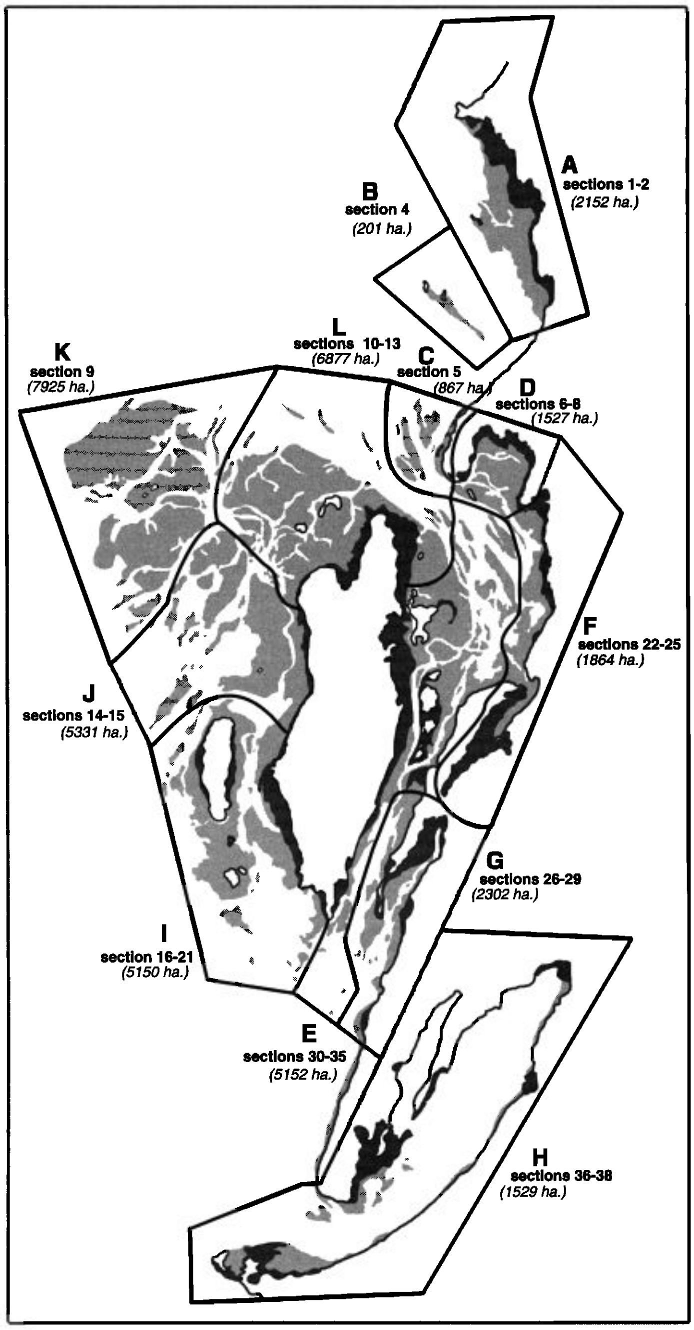

Figure 3. The tidal flats used by the waders as feeding areas subdivided into 11 sections, indicated by the letters A to K; section B was not counted in 1997. The surface area of the tidal flats (ha) per section is indicated, as well as the counting sections (Figure 2) of the corresponding high water roosts.

24,000 Knot *Calidris canutus* and 15,000 Bar-tailed Godwits *Limosa lapponica*. The numbers were added to the numbers counted along the coast of Tidra within this section.

For the 1997 survey, Wolff & Smit's (1990) map was digitised again in order to calculate the surface areas of the tidal flats separately for the sections indicated with the letters A to K in Figure 3. In total, we calculated an area of 385 km², which is 10% less than the surface area of the tidal flats (427 km²) given by Wolff & Smit (1990). Our estimates of wader densities are based on our figures of the surface areas, as shown in Figure 3. In order to calculate the feeding density of the waders on various areas of the Banc d'Arguin, we had to decide which tidal flats are used by the waders roosting in the larger sections. In most cases it was easy to draw the demarcation lines in Figure 3. For example, all birds feeding in the Baie de Chikchit (section A) or the Baie d'Aouatif (section D) flew to the adjoining shore. Moreover, since we spent many dozens of hours on the sailing boat during incoming and receding tides, we were able to observe the directions of the tidal flights and hence knew which low-tide feeding areas and which high-tide roosts belong to each other. For instance, we counted from the boat 96,000 waders being driven by the rising tide from mudflats half way between Arel and Tidra. They all flew in the direction of Tidra and therefore we were able to indicate the demarcation line between section J and K. In the same way, we discovered that the waders on tidal flats between the mainland coast and the north-east side of Tidra, also flew in the direction of Tidra. On the other hand, we still do not know where the birds roost who feed on the tidal flats some kilometres west of Cape Iouik. We assume that they roost north of Iouik (section C), but possibly these birds roost on Tidra (section L). Nair and Niroumi had to be added to north side of Tidra, because the flights to and from the roosts within this section indicate that it is all one complex. The same can be said for the isles of Taffaris and Cheddid, and the south-west side of Tidra. Hence we assembled the 15 larger sub-areas of Altenburg *et al.* (1982) into 12 compartments given in Figure 3 (of which section B was not counted in 1997). However, we did not add section 24 to the sections 26 - 29 (which are situated on the other side of the water shed between Serini and Tidra), but to the adjoining sections 22 and 23 further north. The surface area of the tidal flats in the 12 sections A to L are shown in Figure 3.

Counting methods

The counting methods used in earlier counts have been described in detail by Altenburg *et al.* (1982). Their detailed descriptions became very helpful in the planning of our daily counts. The counts themselves were made in the same way as in 1980: each count section was covered by one or two people, sometimes observing from different strategic points, but usually while walking along the high water line. In the latter case, counters walked towards each other to minimise the risk of missing or double-counting waders. Each day, we completed three to seven count units; hence we were able to count some of the largest parts of the Banc d'Arguin in one day, for instance: the entire Baie de Chikchit (section A), the Baie d'Aouatif including the isle of Zira (section D) and peninsula of Ajoueïr (section G).

During the count we used zoom-telescopes on sturdy tripods and binoculars. Weather conditions were extremely good. The wind, usually rather strong on the Banc d'Arguin (Wolff & Smit 1990), was relatively mild in our period of counting. There were some sand and dust storms, but fortunately never during the counts. It was also helpful that the sky was covered by clouds for some weeks (which is extremely rare for the Banc d'Arguin, certainly in winter). Consequently, the sky was never hazy and the waders could even be counted at large distances. The counters ranked the accuracy of their counts subjectively on a five-point scale from 1 = 'not accurate' to 5 = 'very accurate'. The average 'accuracy', calculated for each compartment, is given in the heading of Table 1.

Land transport consisted of two 4x4 pickups and for travel between the islands, we used a local 'lanche‹, a large sailing boat which was hired complete with a three-man crew in Iouik. We also had two two-man kajaks with us and these were invaluable at gaining us access to very shallow shores. In the field we used the maps produced by Altenburg *et al.* (1982) and Wolff & Smit (1990). In practice, the skill of our driver and skipper appeared to be very important too, while in some cases a GPS was essential to ascertain our exact co-ordinates.

Water level

The predicted water level at Dakar, published in the Admiralty Tide Table, was used to estimate the high and low water level at Iouik. From continuous water measurements in Iouik in 1985 and 1986 (Smit *et al.* 1989) and 1988 (Zwarts unpublished) we knew that the time of high water in Iouik was 4.55 hours later than in Dakar, on average, varying between 5.07 hours on spring tides and 4.43 hours on neap tides. The high water level in Iouik, expressed as cm relative to the mean sea level in Iouik, was equal to high water level (dm) in Dakar x 15.4 - 150. The predicted time of high water in Iouik could be used on the majority of the Banc d'Arguin, but high water was delayed by more than one hour near the water shed between Tidra and Serini. According to our observations in the field, the local differences in the time of high tide were certainly not as large as indicated by Altenburg *et al.* (1982).

Itinerary

Except for two travel days, birds were counted every day, from the day of arrival (24 January 1997) to the day of departure (18 February 1997). During this period, it was spring tide on 25 January (+151 cm relative to mean sea level at night and +129 cm by day) and 8/9 February (+150 cm at night and +130 cm by day) and neap tide on 2 February (+ 103 cm by day) and 17 February (+ 101 cm by day). The days at which the different sections were counted are given in the heading of Table 1.

Approaching from the south we therefore counted the most southerly sections on 24-25 January (south side of section H), then carried on further north to the Biological Station at Iouik. From here, we counted the roosts along the mainland coast in the north-east part of the Banc d'Arguin on 26 - 28 January (section A, C, D & F). On 29 January we sailed to Arel and returned to Iouik on 1 February after counting Arel during two high water periods (section K). On 2 February we left by lanche and, on successive days between 2 and 7 February, counted the east, south and south-west side of Tidra, including a part of the mainland coast east of Tidra and the islands of

Table 1. Number of waders, other waterbirds and birds of prey counted in the 36 of the 38 sections (see Figure 2) in January/February 1997; the date of counting is indicated, but for section 38 this is only the day when the southern part was counted; the northern part was counted at 18 February. The accuracy was subjectively scored from 1 (not accurate) to 5 (very accurate). The two-letter abbreviations refer to the names of the wader species plotted in Figs. 4, 13 & 14.

Section	**1**	**2**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Date	**27/1**	**28/1**	**28/1**	**26/1**	**26/1**	**26/1**	**31/1**	**12/2**	**12/2**	**3/2**	**11/2**	**10/2**	**10/2**	**7/2**	**7/2**	**7/2**	**7/2**	**7/2**
Accuracy	**5**	**4**	**5**	**5**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**2**	**5**	**5**	**5**	**5**	**5**
Oystercatcher (Oy)	6	558	220	8	40	849	55	300	99	584	1	0	0	0	12	0	0	6
Avocet	0	12	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Ringed Plover (RP)	16	7234	241	10	330	1555	4600	900	3700	1679	6391	3100	10000	0	445	2850	310	1080
Kentish Plover (KP)	7	664	15	0	20	254	10	0	28	93	206	200	1500	0	2	0	0	60
Grey Plover (GP)	2	1156	366	14	284	1633	2000	430	900	533	624	602	1000	0	232	72	27	203
Knot (Kn)	0	51535	6000	0	1600	13212	9000	0	3200	4670	1520	26050	31000	0	1700	9200	1825	3700
Sanderling (Sa)	72	1489	493	315	140	818	4500	710	1673	589	141	640	3000	0	70	120	60	159
Little Stint (LS)	0	4517	0	0	50	155	10	0	173	475	811	1275	2000	0	5	15	50	400
Curlew Sandpiper (CS)	3	1917	278	0	1000	4402	90000	11350	36000	1130	17519	10400	19000	0	300	620	950	9380
Dunlin (Du)	21	72265	2552	2	2710	38030	90000	6450	130000	26117	78987	76500	53000	0	15700	28000	2900	15250
Bar-tailed Godwit (BG)	0	15309	1557	13	2500	16597	26000	11600	26125	9727	20370	7790	101000	0	8750	14100	1040	2950
Whimbrel (Wh)	0	402	160	1	10	524	1000	150	2867	641	611	187	2500	0	396	905	162	310
Curlew (Cu)	0	122	101	3	265	397	700	90	196	139	624	1105	300	0	38	185	3	150
Redshank (Re)	0	8181	524	0	500	2611	14000	6500	10000	789	4220	7270	8500	0	695	9100	460	9000
Greenshank (Gr)	1	313	85	0	5	545	400	436	240	93	27	97	0	0	23	36	0	24
Turnstone (Tu)	12	318	117	760	50	342	1500	180	215	321	217	57	0	0	162	214	34	543
Cormorant	0	145	14	0	1500	276	17000	60	5	3537	4	0	0	30	127	18	0	240
Long-tailed Cormorant	0	30	130	0	980	18	2500	1900	30	500	10	0	0	0	0	0	0	0
White Pelican	0	2	11	0	25	0	600	13	0	0	0	0	0	5	3	17	37	52
Western Reef Heron	0	16	12	0	13	17	680	64	75	38	40	66	0	120	117	5	65	220
W.R.Heron/Little Egret	0	51	6	0	15	85	2170	215	320	48	170	400	0	50	97	20	118	188
Grey Heron	0	58	21	1	65	51	810	126	134	44	131	182	0	300	235	111	14	25
Spoonbill	0	104	54	0	112	114	1900	670	151	147	672	103	0	376	497	6	255	395
Greater Flamingo	0	400	17	0	72	378	10000	0	110	240	1370	900	5200	6000	1700	900	782	1754
Black-headed Gull	0	1	4	16	2	0	2	1	0	1	0	0	0	0	1	0	1	4
Grey-headed Gull	0	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Slender-billed Gull	0	102	48	121	30	131	1300	610	48	21	0	0	0	13	106	0	27	542
Lesser Black-backed Gull	25	229	94	111	1	98	2000	26	410	123	30	901	0	300	150	110	165	808
Gull-billed Tern	0	1	5	0	0	3	5	5	2	11	0	10	0	0	1	0	7	2
Caspian Tern	3	142	6	1	60	4	3500	5	78	30	11	2	0	20	290	15	4	111
Sandwich Tern	4	95	16	0	0	47	20	15	2	33	4	0	0	0	15	0	0	32
Little Tern	0	1	1	0	9	0	100	0	2	1	0	0	0	0	16	2	0	2
Royal Tern	3	284	29	0	0	0	2400	130	20	37	12	0	0	0	310	9	0	6
Lesser Crested Tern	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Osprey	1	22	2	1	1	13	0	0	0	2	0	0	0	0	0	0	0	1
Peregrine Falcon	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Barbary Falcon	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lanner Falcon	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saker Falcon	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Marsh Harrier	0	8	1	0	0	3	2	1	2	3	5	0	0	0	4	1	2	0
WADERS-total	**140**	**165997**	**12709**	**1126**	**9504**	**81931**	**243775**	**39096**	**215416**	**47580**	**132269**	**135273**	**232800**	**0**	**28530**	**65417**	**7821**	**43215**
ALL BIRDS-total	**176**	**167695**	**13187**	**1380**	**12394**	**83170**	**288764**	**42940**	**216805**	**52397**	**134728**	**137837**	**238000**	**7214**	**32199**	**66631**	**9298**	**47597**

Table 1. continued

Section	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**Sum**
Date	**6+8/2**	**2/2**	**2/2**	**16/2**	**5/2**	**17/2**	**17/2**	**17/2**	**17/2**	**5+6/2**	**4+5/2**	**4/2**	**5+6/2**	**5+6/2**	**5/2**	**25/1**	**24/1**	**25/1**	**all**
Accuracy	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**sections**
Oystercatcher (Oy)	2	151	49	7	0	2	23	0	0	0	221	1497	2	50	100	41	26	7	**4916**
Avocet	6	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	**28**
Ringed Plover (RP)	2505	576	1290	924	0	2685	84	11	15	80	642	2933	122	280	574	115	232	505	**58014**
Kentish Plover (KP)	296	115	93	28	39	834	8	10	0	130	8	941	18	18	35	19	0	54	**5705**
Grey Plover (GP)	653	374	435	129	165	491	0	15	5	95	331	1473	15	102	602	49	199	143	**15354**
Knot (Kn)	13605	3328	4700	911	0	4237	445	180	32	1128	4422	24291	25	2720	2850	2081	5	254	**229426**
Sanderling (Sa)	34	438	500	38	38	615	28	50	58	73	314	1437	167	202	72	679	326	98	**20156**
Little Stint (LS)	1860	512	0	22	45	5	0	0	0	11	104	8	0	0	0	0	1	52	**12556**
Curlew Sandpiper (CS)	6520	1025	510	691	438	5245	300	100	0	347	210	3575	180	830	1150	229	500	153	**226252**
Dunlin (Du)	50040	12413	10550	13129	0	34150	2600	900	543	15100	15726	99360	714	980	21390	479	1521	728	**918807**
Bar-tailed Godwit (BG)	26677	2457	2670	3430	209	8487	2300	210	195	1145	1951	19532	47	2890	4000	289	231	286	**342434**
Whimbrel (Wh)	445	326	517	135	1088	80	22	4	11	125	332	1259	3	90	214	9	4	6	**15496**
Curlew (Cu)	139	44	33	7	91	72	26	3	0	21	24	1031	37	208	402	1	0	2	**6559**
Redshank (Re)	3056	707	260	970	257	897	0	28	0	321	753	9748	4	350	2750	0	60	7	**102523**
Greenshank (Gr)	233	71	28	108	0	306	122	13	0	61	57	205	2	23	183	106	79	98	**4020**
Turnstone (Tu)	193	189	155	46	0	174	22	6	1	34	216	254	31	65	77	228	183	149	**7065**
Cormorant	98	7	44	11	104	1326	9	5	19	56	120	192	286	101	18	78	31	0	**5362**
Long-tailed Cormorant	1	0	0	21	0	0	0	0	0	1	57	260	11	1	0	0	0	0	**6616**
White Pelican	36	0	0	2	3	570	42	0	0	2	42	4	17	0	55	36	33	0	**1624**
Western Reef Heron	23	0	4	7	61	22	6	1	0	4	0	40	5	0	19	3	3	1	**1688**
W.R. Heron/Little Egret	15	42	3	7	0	158	3	2	0	32	30	54	8	6	83	9	15	1	**4418**
Grey Heron	140	64	27	18	3	171	29	0	6	67	38	136	53	76	116	49	11	20	**3369**
Spoonbill	268	53	46	0	5	336	35	0	21	14	79	220	140	0	280	57	27	0	**7254**
Greater Flamingo	1869	83	139	174	48	608	150	0	90	327	518	923	0	200	219	123	3	1	**35387**
Black-headed Gull	1	0	1	0	137	0	0	2	3	0	0	0	0	1	0	3	0	0	**44**
Grey-headed Gull	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	**14**
Slender-billed Gull	73	109	5	24	0	4	28	26	114	4	15	94	0	20	14	247	522	4	**4305**
Lesser Black-backed Gull	647	18	108	62	0	130	70	47	171	49	48	262	47	1	14	274	5235	110	**12882**
Gull-billed Tern	0	20	8	4	4	4	0	0	0	3	4	43	5	22	12	2	0	1	**180**
Caspian Tern	128	1	2	9	0	69	0	0	10	39	20	80	0	8	7	76	306	29	**5069**
Sandwich Tern	24	12	0	0	0	27	0	0	0	3	0	2	0	0	0	10	301	2	**664**
Little Tern	27	2	2	2	3	0	0	0	0	2	1	1	4	0	1	4	1	4	**186**
Royal Tern	31	3	0	0	0	8	0	1	1	6	7	22	0	4	2	13	0	2	**3340**
Lesser Crested Tern	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Osprey	6	2	2	2	0	1	0	0	0	1	1	4	1	1	1	6	0	0	**72**
Peregrine Falcon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**5**
Barbary Falcon	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Lanner Falcon	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Saker Falcon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Marsh Harrier	0	0	1	0	0	1	0	0	0	0	2	5	0	1	1	1	3	0	**48**
WADERS-total	**106264**	**22726**	**21790**	**20575**	**2370**	**58283**	**5980**	**1530**	**860**	**18671**	**25311**	**167544**	**1367**	**8808**	**34399**	**4325**	**3367**	**2542**	**1969311**
ALL BIRDS-total	**109651**	**23143**	**22182**	**20919**	**2740**	**61718**	**6352**	**1615**	**1295**	**19281**	**26293**	**169887**	**1944**	**9251**	**35241**	**5316**	**9859**	**2717**	**2081852**

Table 2. Total number of waders counted on the Banc d'Arguin in 1997, compared to the three previous counts. Gowthorpe *et al.* (1996) give wide ranges for some species (e.g. 100 000 - 140 000 Curlew Sandpipers); the average value has been given here. As noted in the text, possibly about 170000 waders have been missed in the 1979 count and 140000 waders in 1980. Since the waders in the northern part of the Banc d'Arguin (Presque'ile de Cap Blanc (Baie de l'Etoile) and the Baie d'Arguin) were only counted in 1979, these numbers are not included in the total given here.

Wader species	1979	1980	1990/94	1997
Oystercatcher	6232	9121	5000	4916
Avocet	0	0	0	28
Ringed Plover	128915	97990	40000	58014
Kentish Plover	6340	17380	10000	5705
Grey Plover	13210	18386	10000	15354
Knot	305620	364101	120000	229426
Sanderling	3860	33850	32000	20156
Little Stint	983	43889	41000	12556
Curlew Sandpiper	116000	173228	120000	26252
Dunlin	664500	816483	550000	918807
Bar-tailed Godwit	532925	542889	175000	342434
Whimbrel	17445	15546	10000	15496
Curlew	1800	14168	6500	6559
Redshank	30235	67570	35000	102523
Greenshank	770	1591	500	4020
Turnstone	5795	16931	6500	7065
TOTAL	**1834630**	**2233123**	**1161500**	**1969339**

Cheddid, Touffat and Kiji south-west and west of Tidra (sections E & I). On 8-12 February, the north-west side of Tidra was counted, including the islands of Nair and Niroumi (sections J & L). After a fortnight's boat trip, we returned to Iouik to leave by car to count the Baie d'Arguin (13-15 February; these results are not given here, but in the companion paper: Zwarts *et al.* 1998). The remaining sections of the mainland coast in the south-east of the Banc d'Arguin (section G and north side of H) were counted during the return trip (16-18 February).

RESULTS

Numbers

Waders and other waterbirds were counted in 78 areas. These detailed counts were carried out using the same sections as Altenburg *et al.* (1982). Two of their 38 sections were not visited: sections 3 and 4 (isle of Chikchit and isle of Kiaone). Only a few waders appeared to roost there in 1980 and thus it seemed not to be worthwhile to spend so much time to reach these isolated isles. The numbers in the other 36 sections are given in Table 1. The number of other waterbirds and birds of prey are also listed.

All areas were counted once, with four exceptions: (1) The bay north-west of Iouik (section C) was counted on 27 and 28 January. The numbers were about the same, but we took the second count as it included a more northerly section of beach. (2) The Baie de Chikchit (section A) was also counted on 27 and 28 January. The first count was incomplete, so we returned the next day to count again, this time successfully; the second count was selected. (3) Arel (section K) was counted during an incoming tide as well as during high tide on 30 and 31 January. On the first day, we were not able to perform an accurate count of the waders which flew to, and roosted on, Arel Ouát (an extremely small isle south-west of Arel). Hence we selected the count of 31 January. (4) The north-west side of Tidra (section J) was counted on 9 and 10 February, after the southern part had already been counted on 8 February. The water level was so high on 9 February that the extensive sebkha was completely flooded and the hundreds of thousands of waders were counted scattered over an area 2 km wide and 4 km long (so we know now for sure that the sebkha on west Tidra is correctly indicated as very wide on Altenburg *et al.*‹s (1982) map, and certainly not as small as depicted on Wolff & Smit‹s (1990) map, here reproduced as Figures 1-3. Most of

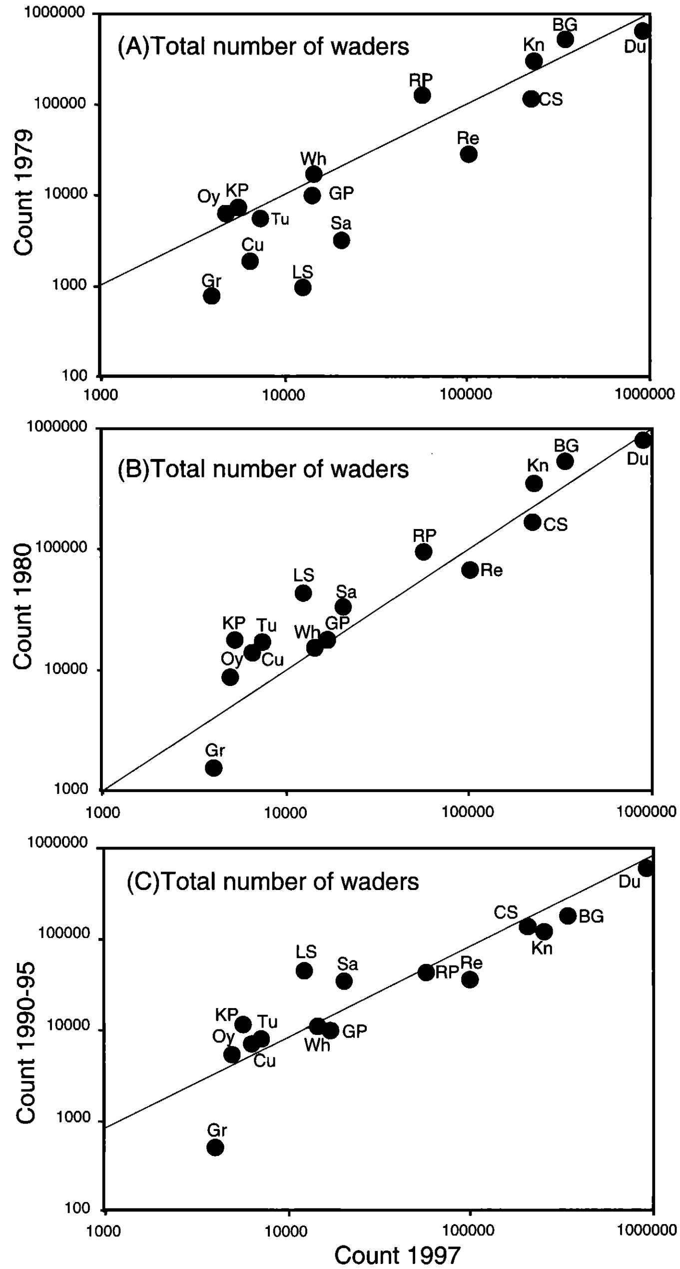

Figure 4. The total number of 15 wader species counted in (A) 1979, (B) 1980 or (C) 1990-1994 plotted against the number counted in 1997. The wader species are indicated with a two-letter code; see Table 1. The diagonal shows the y=x-relation.

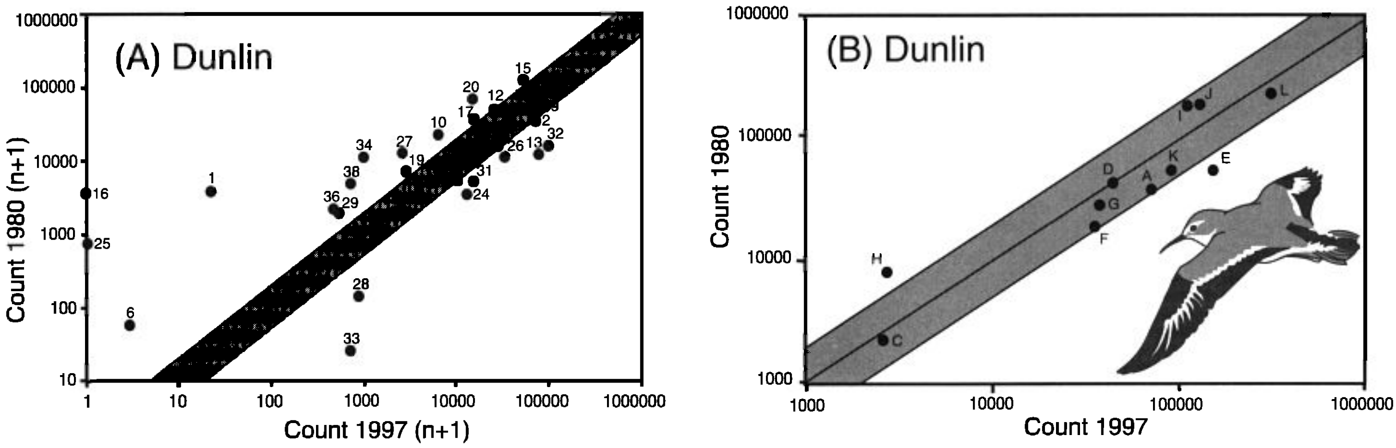

Figure 5. The number of Dunlin counted per (A) small or (B) large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The grey bar indicates the area between y=2x and y=0.5x.

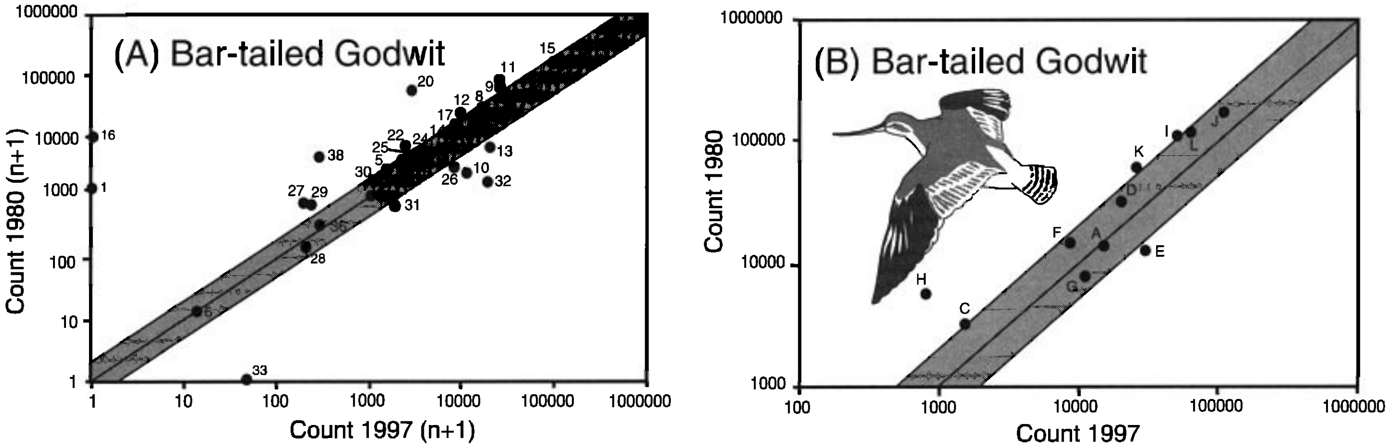

Figure 6. The number of Bar-tailed Godwits counted per (A) small or (B) large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The grey bar indicates the area between y=2x and y=0.5x.

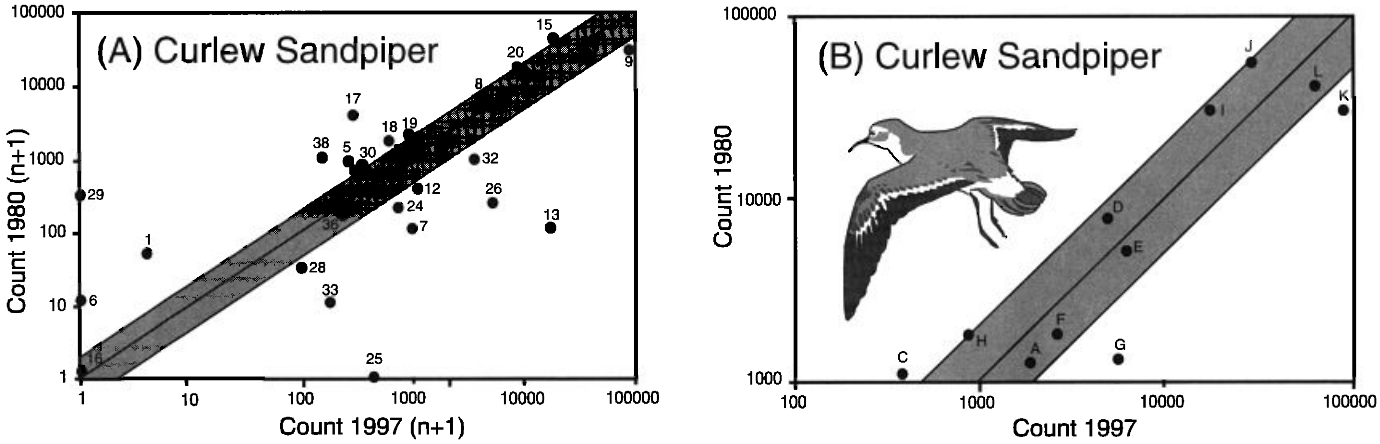

Figure 7. The number of Curlew Sandpipers counted per (A) small or (B) large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The grey bar indicates the area between y=2x and y=0.5x.

these birds came in the hour before high tide when the small isle of Tinimorgawoi, just a few kilometres off the coast, was flooded. The next day we repeated the count. This time, the sebkha was not flooded and the majority of waders were found roosting along the waterline, and were therefore far easier to count. Only a fraction of the birds counted the day before were present, the majority remained to roost on Tinimorgawoi, above which we regularly saw huge cloudlike flocks of birds. Since no waders appeared to roost on Tinimorgawoi on 9 February, we took the difference between the two counts as the numbers present on Tinimorgawoi during the high tide of 10 February. Hence this number is given in Table 1, although the waders on the island itself have not been counted.

Altogether, we were satisfied with the results obtained. The count was complete. There had been no problems in possible double-counting or missing birds. The two areas for which we obtained inaccurate data (Baie de Chikchit and Arel with Arel Ouât) had been successfully counted the next day. All small roosts had been counted accurately. The only area for which we had an incomplete count was the Baie de St. Jean (section 36). In this area we walked along the shore near the village

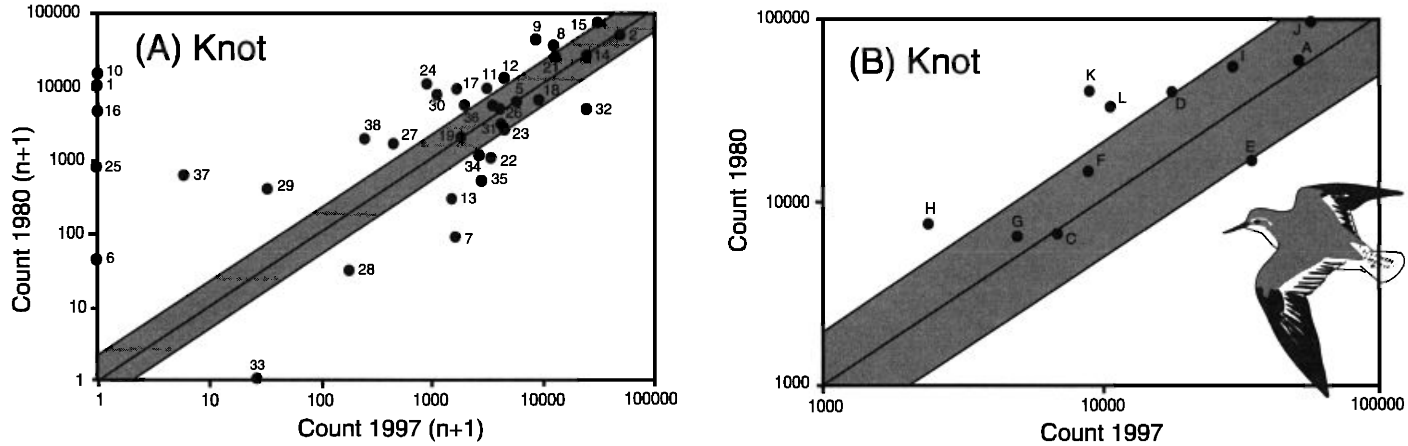

Figure 8. The number of Knot counted per (A) small or (B) large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The grey bar indicates the area between y=2x and y=0.5x.

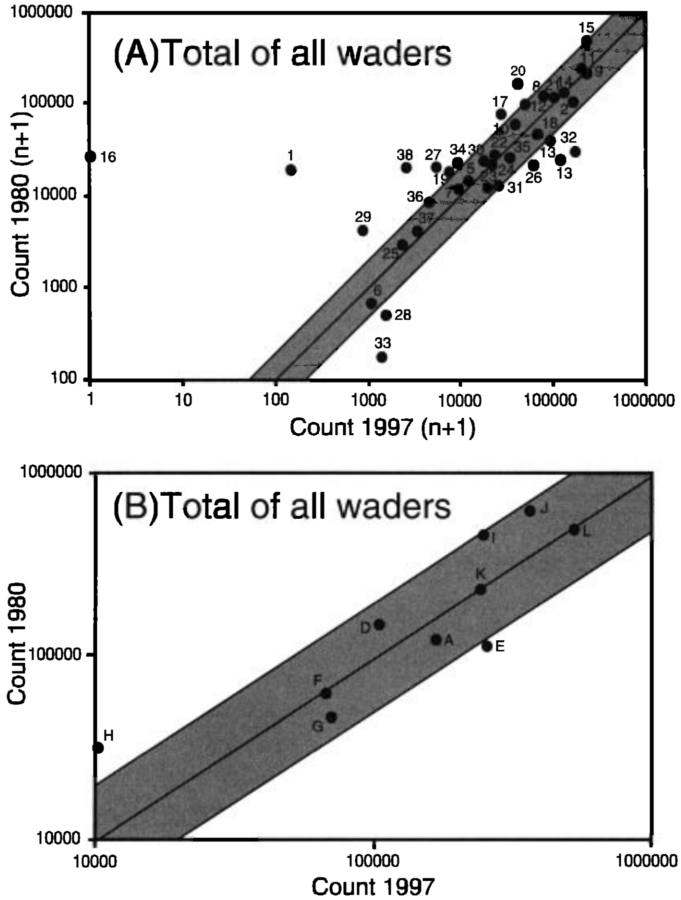

Figure 9. The total number of waders counted per (A) small or (B) large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The grey bar indicates the area between y=2x and y=0.5x.

Rgueiba Thila and from there on drove by car around the bay to the village Nouamghar, but since the track is only near the coast in the south-west part of the bay, the waders were not counted in the eastern half of the bay. The most difficult count was on 9 February when an estimated 370,000 waders were scattered over the flooded sebkha on the north-west side of Tidra (section 14).

In conclusion, we found we were able to spend more time in the field than the winter team of 1980. Our counting team was larger and we spent more days counting. Moreover, our planning was made easier by being able to use the detailed descriptions of the earlier teams. All day-time high water periods were used to accomplish counts, since we could always travel between count sections at low tide or even by night. The exception was the trip from and to Arel which took place during high tide.

Table 2 compares the total numbers of waders in 1997 with the three previous counts. The total number of waders in 1997 was somewhere between the totals for 1979 and 1980. However, when comparisons are made for individual species, some differences are evident. Firstly, there were four species (Curlew Sandpiper *Calidris ferruginea*, Dunlin, Redshank *Tringa totanus* and Greenshank *Tringa nebularia*) for which we counted the highest totals yet recorded. Secondly, there were three species (Ringed Plover *Charadrius hiaticula*, Knot, Bar-tailed Godwit) for which the 1997 numbers were lower than the 1979 and 1980 count, although not as low as in 1990/94. And thirdly, there were another four species (Oystercatcher *Haematopus ostralegus*, Kentish Plover, Sanderling and Little Stint) of which we counted lower numbers in 1997 than in 1990/94; for Kentish Plover in particular, we recorded fewer birds than in any of the three previous counts.

The 1997 count was more thorough than the three previously. Zbarat Quarat (section 32), where we counted 140,000 waders, was not visited in 1980. The same area was included in the 1979 count (called Île Iwili by Trotignon *et al.* (1980)), but the coastline of north-east Tidra within section 32 was not counted. Also section 22 and 23 and the west side of Niroumi (section 11) were not counted in 1979. We observed 28,000 waders along the coastline of section 32, 44,000 waders in section 22 and 23 and 215,000 waders on Niroumi (section 11). Trotignon *et al.* found only 110,000 waders on Niroumi; assuming that they counted half of the roosting birds on Niroumi, an estimated 170,000 waders might be added to their totals given in Table 2.

It remains difficult to decide to what degree the differences between the winter counts are due to counting errors. Since the same count sections were used in both 1980 and 1997, the

Table 3. The number of waders counted on the Banc d'Arguin in 1997 given as % relative to the number counted in 1980. The % in the first column is calculated from the totals given in Table 2. The two other columns give the average difference based upon the ratio calculated of either the 11 large or 36 small sections; further explanation in text.

Count 1997/1980, %	Total	10 sect.	36 sect.
Oystercatcher	53.90	84.71	90.49
Ringed Plover	59.20	73.75	57.16
Kentish Plover	32.83	38.08	70.75
Grey Plover	83.51	98.97	100.76
Knot	63.01	54.81	83.11
Sanderling	59.55	95.57	108.13
Little Stint	28.61	13.16	27.69
Curlew Sandpiper	130.61	121.12	117.73
Dunlin	112.53	114.26	88.29
Bar-tailed Godwit	63.08	65.76	75.13
Whimbrel	99.68	101.02	195.24
Curlew	46.29	100.23	62.38
Redshank	151.73	166.7	5 228.02
Greenshank	252.67	317.58	169.06
Turnstone	41.73	43.05	85.83
TOTAL	**88.19**	**91.11**	**81.09**

possibility of counting error can be investigated. A comparison of the numbers of Dunlin in 1980 and 1997 for the different sections (Figure 5A) reveals that, in both winters, the same sections contained many Dunlin and other sections only a few. The scatter is wide, however, even on the double-log-scale used; the correlation coefficient is only +0.68. In 15 sections, more than twice as many waders were counted in 1980 than in 1997, and in seven the numbers counted were less than half those recorded in 1980. Thus, in only 14 of the 36 sections did the numbers in both winters differ by a factor of less than 2. The variation is much smaller when plotted for the 11 larger sections (Figure 5B): only two of these 11 sections deviate by more than a factor of 2. The correlation coefficient increases to +0.87.

The scatter is about the same in the other common species: Bar-tailed Godwit (Figure 6), Curlew Sandpiper (Figure 7) and Knot (Figure 8), or if all waders are taken together (Figure 9). When the 36 sections are amalgamated into 11 larger ones, the correlation increases from r = +0.60 to r = +0.84 in the Bar-tailed Godwit, from +0.70 to +0.88 in Curlew Sandpiper, from +0.42 to +0.82 in Knot and from +0.56 to +0.87 for all waders together.

In 1997, we counted 229,000 Knot compared with 364,000 in 1980, a decrease of 37%. Figure 8 shows that in most sections there were fewer Knot in 1997 than in 1980, but the variation is large. We calculated the relative change in numbers between the two winters per section and found that the average decrease, calculated for the 11 large sections was 44% and for the 36 small sections was 17%. Since we are dealing here with ratios, we took the ratio of the log-transformed numbers, after which we took the anti-log of the average ratio. The same calculations were repeated for all wader species (Table 3). The overall decrease in the Bar-tailed Godwit was, like in Knot, 37%, but the average decrease in the large and small sections was nearly the same, 35% and 25%, respectively.

These results give some confidence that, indeed, there were less Knot and Bar-tailed Godwits on the Banc d'Arguin in 1997 than in 1980. Which column in Table 3 gives the most likely change in number between 1980 and 1997? If each section is regarded as a random sample of the birds wintering on the Banc d'Arguin, the average change calculated over the different sections would be better than a comparison of the summed totals. This is only true, however, if the distribution of birds does not change between counts and that seems to be unlikely. For instance, Oystercatchers are always easy to count, so the counts must be very accurate compared to the other species. In 1980, most Oystercatchers were concentrated in the Baie d'Aouatif (section D) and the adjoining tidal flats along the mainland coast more to the south (section F), whereas only a few birds were found elsewhere. In 1997, the previously large numbers in sections D and F had diminished, but the decline elsewhere on the Banc d'Arguin was much less, or even absent. As a consequence, the average decline calculated for all 36 sections, was only 10%, while the total number for the entire Banc d'Arguin has decreased by 46% (Table 3). These examples show that by counting only some sections of the Banc d'Arguin, the derived prediction of the total number on the Banc d'Arguin may be accurate in some cases (as shown for Bar-tailed Godwit), but not in others (as shown for Oystercatcher).

When birds roost in separate, single-species flocks, they are easier to count than when they are mixed up with other species. This is especially true if the species are difficult to distinguish. In single-species flocks, counting errors are made, such as discussed in the introduction, but when, for instance, different sandpiper species in winter plumage, have joined the same, huge roost, the real problem is often not to estimate the total number of sandpipers, but how many of them are Dunlin or Curlew Sandpipers. One way to check the estimated numbers of each species, is to count them also on the low water feeding areas. This was done on Arel, for instance, and these random low water counts confirmed that in this part of the Banc d'Arguin Curlew Sandpipers were as common as Dunlin. Another way to analyse this problem is to calculate the proportion of Dunlin relative to the summed number of Dunlin and Curlew Sandpiper per section and compare this for 1980 and 1997 (Figure 10). To our surprise, the percentage of Dunlin was rather similar in both counts. In 1980, as well as in 1997, Dunlin were relatively more common in the eastern and northern part of the Banc d'Arguin.

Density

When the sections are compared, the tidal flats on the Banc d'Arguin are generally very similar. For instance, in nearly all

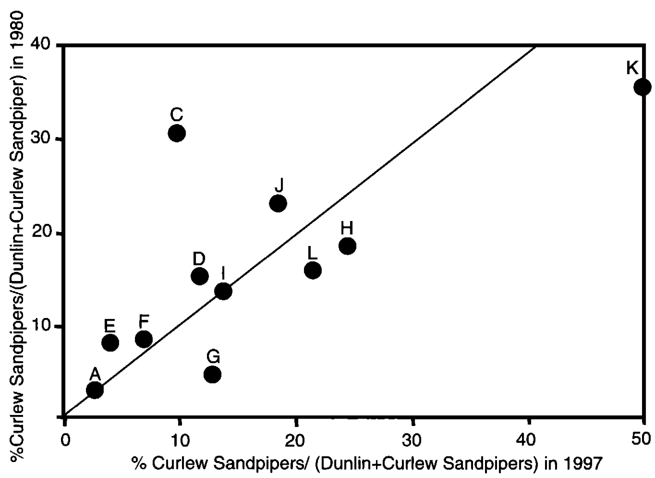

Figure 10. The proportion of Curlew Sandpipers relative to the numbers of Dunlin + Curlew Sandpipers counted per large section in 1980 and 1997 plotted against each other (see Figures 2 & 3). The diagonal shows the y=x-relation.

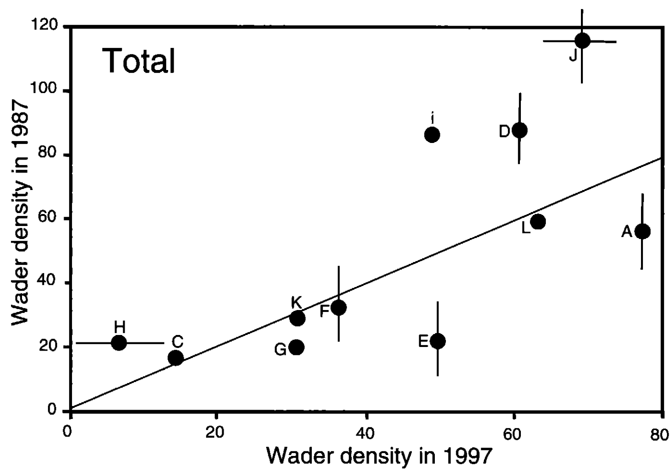

Figure 11. The density (total number of waders ha-1 tidal flat) in the 11 large sections (Figure 3) in 1980 and 1997 plotted against each other. Horizontal and/or vertical lines indicate sections for which the wader counts were less accurate in 1997 and/or 1980, respectively. The diagonal shows the y=x-relation.

sections, about half of the flats are covered by dense seagrass vegetation. Hence there is no reason to expect that there would be wide discrepancies in the feeding wader densities between these sections. The wader totals for the 11 large sections were converted into densities using the surface estimates given in Figure 3. Figure 11 plots the densities of all waders combined for 1980 and 1997. Contrary to expectation, the densities appear to vary between the sections. The variation in wader density was larger in 1980 than in 1997, but the average trend was rather similar. Before the same results are shown, and discussed, for the separate wader species, some remarks have to be made about the accuracy of the counts made in some sections.

In two sections, the 1997 counts were less accurate: (1) in section J (Tidra NW) the many waders scattered over the flooded sebkha had to be counted in too short a time, (2) the eastern half of section H (Baie de St. Jean) was not counted; although we expected very few waders to be there, the result remains unsatisfactory. The density estimates for both sections are indicated by small horizontal lines in Figure 11. According to Altenburg *et al.* (1982), their counts were less accurate in four sections; these sections are indicated by vertical lines in Figure 11. Five sections remain, which in both years were claimed to be accurately counted. The feeding density in four of these five sections did not differ much between the two winters. In the four sections for which the counts were less accurate in 1980, two of the four density estimates were very similar. The deviations between the years were large for the section which in 1997 or in both years were counted less accurately.

By plotting these density estimates for both winters, besides the counting errors inherent in both winter figures, a possible third error is introduced: the delineation of the low water feeding areas may be incorrect. For example, as already indicated, when the birds from the feeding areas west of Cape Iouik roost on Tidra, instead of NW of Iouik. Thus, the density estimate for section C would be systematically too high and for section L too high. This type of error might be detected if the density estimates for a section were high and those for adjoining sections low, or vice versa. However, an analysis of the data did not indicate this. Figure 12 plots the density estimates for 12 wader species in both winters. Most wader species do not reach high feeding densities on the four adjoining section E, F, G and H, along the mainland coast, east and SE of Tidra. On the other hand, several species feed in high densities on the tidal flats along the mainland coast more to the north (section A and D). Most wader species reach their highest feeding densities on the west, and especially the north-west, side of Tidra (section J and L), whereas the feeding densities on Arel (section K) are usually lower. It might be, however, that the density estimate for section J is too high, because the surface area of the tidal flats is underestimated. It was in this section that low-lying tidal flats were already covered by the flooding tide when the satellite photo was made, so it may have been difficult to determine the low water line.

Comparison of all panels in Figure 12 reveals some systematic differences between the sections. In section A, for instance, Knot, and to a lesser degree Dunlin, reached high densities in 1980 and 1997. In contrast, Bar-tailed Godwit and especially Curlew Sandpiper were relatively rare in this area. How can this kind of difference be explained? We found no relationship between wader densities and the fraction of the tidal flats within the sections that was covered by seagrass. Such a relationship was not expected however, as the recorded wader densities are hardly different from those for bare tidal flats and seagrass fields (Zwarts *et al.* 1990). There also seems to be only a weak correlation with the local variation in density of prey. Wolff *et al.* (1993a) measured the biomass of the benthic macrofauna on the tidal flats of the Banc d'Arguin. They found that the average biomass on the tidal flats was high around Iouik (section D, E & F: 10.6 g ash-free dry weight per m^2) and further south along the mainland coast (section G: 8.4 g m^{-2}). The biomass was rather low north of Tidra (section L:

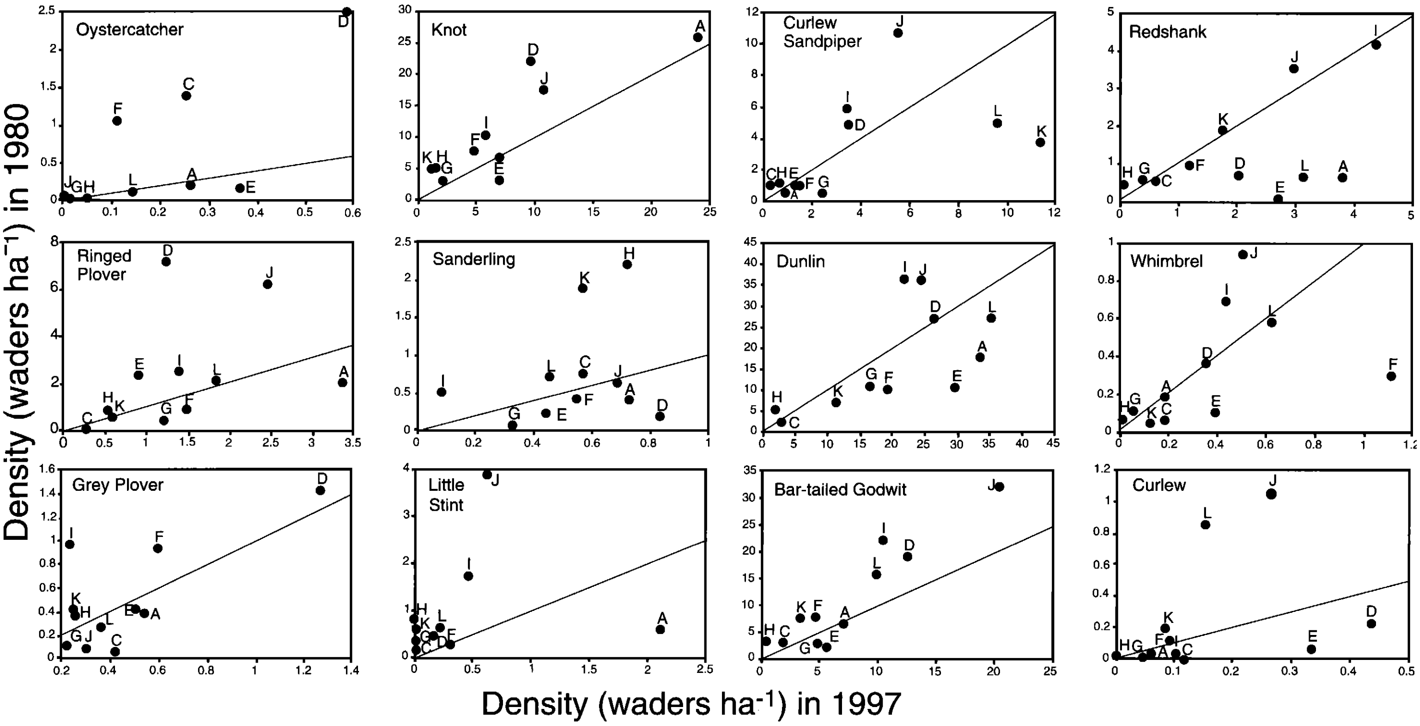

Figure 12. The density of 12 species (birds ha^{-1} tidal flat) in the 11 large sections (Figure 3) in 1980 plotted against 1997. The diagonals show the y=x-relation.

6.9 g m^{-2}) and around Arel (section K: 7.2 g m^{-2}). In agreement with these biomass data, wader densities are high around Iouik and low around Arel, but it is not true that waders reach high densities in section G and low densities in section L. There is a huge amount of work still to be done before we will understand the variation in wader densities such as depicted in Figure 12.

As shown in Table 2, the total numbers in 1997, with some exceptions, were lower than 1980 for most species. What is the effect of a change in total numbers on the overall distribution throughout the Banc d'Arguin? Is the change in density equal for all sections? And if it is not equal, is the change greater in the low-density areas or in the high-density areas? A comparison of the panels in Figure 12 shows that the species differ in this regard. In Bar-tailed Godwits, the feeding densities were comparable in all sections. In absolute numbers, more birds disappeared from the sections where they reached high feeding densities in 1980. In contrast, the absolute decrease in the feeding densities of Knot was more or less the same in all sections, with only a few birds remaining to feed in 1997 in the poor sections. In Redshank, yet another pattern was observed. In 1980, Redshank reached high feeding densities (2 - 5 birds ha^{-1}) in the sections west of Tidra (section I, J and K) while they foraged at < 1 bird ha^{-1} in the remaining sections. In 1997, we counted a total of 50% more Redshank than in 1980. The density remained at the same high level west of Tidra and at the same low level in the sections in the south-east part of the Banc d'Arguin. But their density rose from 0.5 to 2 - 4 birds ha^{-1} in the north-west part of the Banc d‹Arguin (section A, D, E & L). More counts have to be done, before we know whether the distribution over the Banc d'Arguin is density-related.

Are some species more equally spread out over the Banc d‹Arguin then others? This can be investigated by calculating the standard deviation (SD) of the density estimates as given in Figure 12 and express this SD as percentage relative to the average density calculated over the same 11 sections. Figure 13 plots these relative standard deviations for the 12 wader species in 1980 against the same data for 1997. Clearly, Dunlin are more equally distributed over the tidal flats on Banc d‹Arguin in both winters than Oystercatchers, Curlews *Numenius arquata* and Little Stint. There is, however, one remarkably large difference between the two winters. In most species, the density estimates for the sections differ (much) less from each other in 1997 than in 1980. It is not easy to give an explanation for this. Generally speaking, larger standard deviations may be due to counting errors. Indeed, in 1980 fewer sections were counted accurately than in 1997 (Figure 11) and especially the density estimates in 1980 for section J (and to a lesser degree section D) may, at least for most species, be statistically characterised as outliers. For instance, the wader density of the Kentish Plover varied in 1997 between 0.05 and 0.4 birds ha^{-1} in the different sections and this was also true for most sections in 1980, but in section J the density was then nearly 2 birds ha^{-1}.

DISCUSSION

Annual variation in the numbers of wintering waders on the Banc d'Arguin

Year-to-year variation in the number of waders wintering on the Banc d'Arguin is to be expected, due to the large annual variation in the breeding success of bird species originating from the Arctic. For Arctic-breeding geese it has been shown that the proportion of first-year birds, varying between 0 and 50%, greatly affects the year-to-year change in the world population (e.g. Ebbinge 1992). The variation in the world

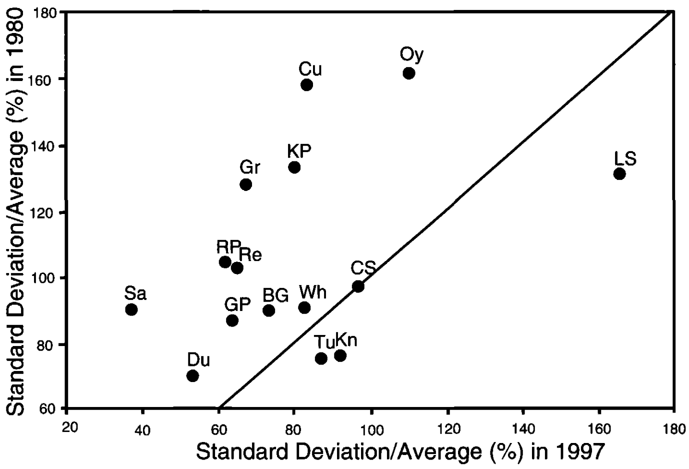

Figure 13. The standard deviation as a % of the average density in the 11 large sections (Figure 3) of the 15 wader species in 1980 and 1997 plotted against each other; same data as Figure 12. The wader species are indicated with a two-letter code; see Table 1. The diagonal shows the y=x-relation.

population of Arctic-breeding waders is unknown, but Roselaar (1979) was the first to show that the numbers of Curlew Sandpipers counted in staging areas in the temperate zone were dependent on the number of young produced the summer before (Roselaar 1979). The breeding success of waders in Russian tundras in summer 1996 was below average in the European part, but good or even very high, in the more eastern tundras (Tomkovich & Zharikov 1997). Hence we would expect that the numbers of Arctic wader on the Banc d'Arguin would be above average in winter 1997. Indeed, we counted relatively high numbers of Dunlin and Curlew Sandpipers, but low numbers of Knot and Bar-tailed Godwits.

The low numbers of waders on the Banc d'Arguin counted by Gowthorpe *et al.* (1996) cannot be explained by poor breeding success in the Arctic. Their numbers refer to counts made during five different winters, 1990 - 1994. Therefore, one would expect that the negative effect of the poor breeding season in 1989 and 1992 would be ruled out by the good breeding seasons in 1990, 1991 and 1993 (Kondratyev 1992, Yulov 1993, Ryabitsev 1993, Tomkovich 1994a & 1994b).

There is another possible explanation for the variation in wintering numbers, and that is the possible annual variation in their food resources. It has been shown for the Wadden Sea that there is a huge year-to-year variation in the density of the different prey species taken by the waders feeding on the tidal flats (Beukema *et al.* 1993). However, as discussed by Wolff (1991), the environmental conditions on the Banc d'Arguin are much less variable than in north-west Europe, from which it can be inferred that the food supply is more constant. On the other hand, because the food supply is less variable, the margin between the production of the benthic prey and the consumption by the waders could be far closer (Wolff 1991). This implies that small changes in the food supply might have a large impact on the wintering waders. Since nothing is known about the year-to-year variation in the food stock on the Banc d'Arguin, this remains merely speculation.

There is one prey species on the Banc d'Arguin, however, for which the change in density has been documented over the last 18 years: the Bloody Giant Cockle, *Anadara senilis*, the major prey for the Oystercatchers on the Banc d'Arguin. Wolff *et al.* (1987) showed that since 1980 the density of this bivalve had decreased from 56 m^{-2} in 1980 to 27 m-2 in 1986. In 1997, we determined the density in the permanent quadrat sampled in 1980, 1985 and 1986 and found a further reduction in the density to 7 m-2. The cockles had grown another 13 mm since 1986, from 72 to 85 mm, having reached in 1997 the respectable age of 29 years! Anadara reached its highest densities in the north-east part of the Banc d'Arguin in the eighties (Wolff *et al.* 1987) which is also when most Oystercatchers were concentrated here (Figure 12). The decline of Anadara caused, as already shown above, a large decline of the Oystercatchers in sections where their density was highest. This example shows that long-term changes in the food supply may affect bird numbers on the Banc d'Arguin as well as elsewhere, so we cannot exclude the possibility that the same is true for other wader species feeding on less spectacular prey species. However, we believe this is unlikely. Most wader species on the Banc d'Arguin take extremely small prey, predominantly worms (Zwarts *et al.* 1990). These species are short-lived, so long-term changes, such as those observed in an extremely long-living species such as *Anadara*, are not to be expected, unless there is a dramatic change in the environment. Further research is needed to show whether the apparent over-exploitation of fish further offshore (Gowthorpe *et al.* 1996) affects the biomass of the benthic prey of the tidal flats of the Banc d'Arguin. One of the effects of the suggested over-exploitation of fish, might be an increase of small fish and/or shrimps. If this is true, it might be the explanation for the increase of Redshank and Greenshank on the Banc d‹Arguin, since both species are known to feed mainly on these prey.

Trends in the numbers of wintering waders on the Banc d'Arguin and in Guinea-Bissau

Half of the 9,000 Oystercatchers on the Banc d‹Arguin have disappeared since 1980 (Table 2). Have they moved to an alternative wintering area? This can only be investigated for the coastal zone of Guinea-Bissau, 1,000 km south of the Banc d'Arguin, where waders have been counted in winter 1982/83 and 1986/87 (Zwarts 1988) and again in winter 1992/93, at least in the most important area: the Bijagos Archipelago (Salvig *et al.* 1994). The counts in the Bijagos revealed an increase of 5,500 Oystercatchers in Bissau, from 1,600 to 7,100 birds, so the Oystercatchers which disappeared from the Banc d'Arguin, probably did move to Guinea-Bissau. In the same way, we can check whether , for example, the increase of Redshank on the Banc d'Arguin caused a decrease of the same species in the Bijagos, and similarly whether the decrease of Knot on the Banc d'Arguin coincided with an increase of the numbers in Guinea-Bissau. Figure 14 plots the relative change in numbers for all wader species in Bissau between 1983+1987 and 1993 (from Table 1 in Salvig *et al.* 1994)

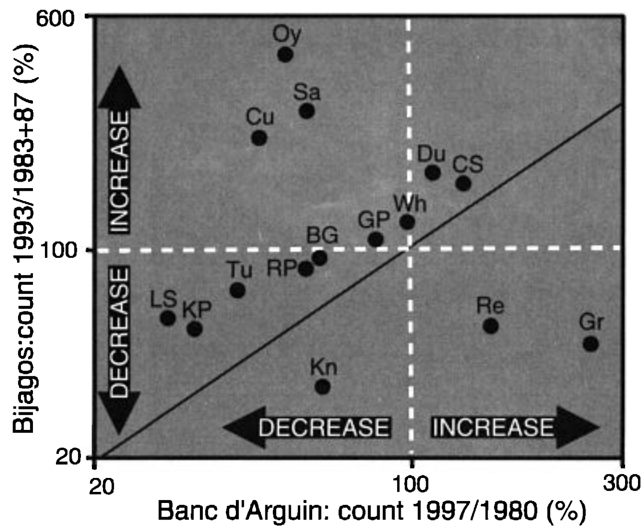

Figure 14. Relative change in number (%) in the estimated total numbers of 15 wader species in coastal Guinea-Bissau between 1983+1987 and 1993 as a function of the % change in the same wader species on the Banc d'Arguin between 1980 and 1997. Note that log-scales were used. The wader species are indicated with a two-letter code; see Table 1. The diagonal shows the y=x-relation.

against the relative change in numbers on the Banc d‹Arguin between 1980 and 1997 (from Table 2). Oystercatcher, Sanderling and Curlew increased in the Bijagos and decreased on the Banc d'Arguin. In contrast, Redshank and Greenshank decreased in the Bijagos and increased on the Banc d'Arguin. In all other species, the relative change in numbers was equal in both areas, although the change on the Banc d'Arguin was larger than in the Bijagos, with the exception of Knot, which showed a remarkably large decline in the Bijagos. The data summarised in Figure 14 suggests that over the last two decades there has been a decline in most of the wader species wintering in Bissau and on the Banc d'Arguin. The decrease in Little Stint and Kentish Plover is dramatic. The Curlew Sandpiper and Dunlin are the only species which showed an increase on the Banc d'Arguin as well as in the Bijagos.

It is a pity that a comparison between both sites could not be made for the same span of years. Possibly the trends shown in Figure 14 were more pronounced on the Banc d'Arguin than in the Bijagos, because the time span on the Banc d'Arguin was 17 years and only 6-10 years in the Bijagos. Another weak point might be that the estimated total numbers for the Bijagos are based on low water counts and since this method is very labour-intensive, not more than 25% of the surface area of the tidal flats were counted in the first count and 64% in the second one.

Unfortunately, the trends shown in Figure 14 could not be confirmed by the counts made on the Banc d'Arguin between 1990 and 1994: when the relative changes in numbers of the different wader species between 1980 and 1990/94 were plotted against the relative change between 1980 and 1997, the correlation appeared to be even negative, although non-significant. Clearly, more counts are needed on the Banc d'Arguin as well as in Guinea-Bissau to know (1) in which species fluctuations in the wintering numbers in both areas compensate for each other, (2) whether there are trends in the total numbers wintering in West Africa.

Figure 14 suggests a huge decline in the wintering numbers in West Africa for Little Stint, Kentish Plover and Turnstone *Arenaria interpres*. For Kentish Plover and Turnstone there are indeed indications that the population has decreased. Firstly, there is a decline in the European breeding population (Meininger & Székely and Hildén & Vuolanto for Kentish Plover and Turnstone, respectively, in Hagemeijer & Blair 1997). Secondly, among the wader species counted in late summer on the Frisian Island of Ameland (Dutch Wadden Sea) in the last 25 years, only Turnstone and Kentish Plover have decreased (Kersten *et al.* 1997). It would be a worthwhile effort to analyse other European staging areas for possible long-term trends in the numbers of waders counted during spring and autumn migration periods.

How to monitor the waders on the Banc d'Arguin in the future?

Thousands of people are involved each year in the international mid-winter counts of waders, geese, ducks and swans in Europe. These data are very useful because they can be used to monitor the fluctuations in bird populations. A total picture can only be ascertained for those species, like geese, that solely winter in Europe, but not for the majority of the coastal wader species, of which large proportions of the populations winter in tropical West Africa. So far, bird counts from the African wetlands are very scarce and certainly not available for a long series of years. That is why nothing is known about possible trends in the world population of many coastal wader species of which the majority of the population winter in Africa. The regular occurrence of a bad breeding season in the Arctic must cause large fluctuations in the winter populations of these Arctic-breeding species. It would be imprudent to assume that, in spite of these year-to-year fluctuations, the population would remain at the same level. In any case, the results summarised in Figure 14 suggest the contrary for several wader species in the last two decades.

About half of the waders wintering along the African west coast are concentrated on the Banc d'Arguin, so it would be a very worthwhile objective to monitor the wintering waders on the Banc d'Arguin on a more regular basis. Not only would this give useful information on the variation in number of waders on the Banc d'Arguin, but it would particularly help to interpret the annual variation in numbers counted in Europe. The message from Figure 14 is that it would not be sufficient to count only the Banc d'Arguin, but also, preferably during the same winters, the coastal zone in Guinea-Bissau and possibly even areas further south.

One possible approach to monitoring the waders on the Banc d'Arguin is not to attempt an exhaustive total count of all waders on the Banc d'Arguin each time, but to choose strategically-selected sections. These sections have to comply with one essential requirement: the sections must be

Table 4. Total number of waders counted along the mainland coast in the NW part of the Banc d'Arguin and on Arel (section A, C, D & K) during three winters, also given as % relative to the total number counted on the entire Banc d'Arguin in the same winter. The RSD is the standard deviation of the percentages calculated for the three counts, given as % relative to the mean percentage given in the last but one column.

	Numbers			Relative numbers				
WINTER	**1979**	**1980**	**1997**	**1979**	**1980**	**1997**	**average**	**RSD**
Oystercatcher	3390	5536	1736	54.4%	60.7%	35.3%	50.1%	21.5%
Ringed Plover	31200	20556	13986	24.2%	21.0%	24.1%	23.1%	6.5%
Kentish Plover	2200	3190	970	34.7%	18.4%	17.0%	23.4%	34.4%
Grey Plover	3950	6355	5455	29.9%	34.6%	35.5%	33.3%	7.4%
Knot	99200	137607	81347	32.5%	37.8%	35.5%	35.2%	6.2%
Sanderling	1500	16948	7827	38.9%	50.1%	38.8%	42.6%	12.4%
Little Stint	600	4280	4732	61.0%	9.8%	37.7%	36.2%	58.0%
Curlew Sandpiper	37400	39905	97600	32.2%	23.0%	43.1%	32.8%	25.0%
Dunlin	191000	138776	205580	28.7%	17.0%	22.4%	22.7%	21.1%
Bar-tailed Godwit	129500	107155	61976	24.3%	19.7%	18.1%	20.7%	12.7%
Redshank	12950	20056	25821	12.9%	29.7%	25.2%	22.6%	31.4%
Greenshank	97	580	1349	12.6%	36.5%	33.6%	27.5%	38.6%
Turnstone	1650	3999	3099	28.5%	23.6%	43.9%	32.0%	27.0%
TOTAL	**520387**	**508313**	**515163**	**28.4%**	**22.8%**	**26.2%**	**25.8%**	**8.9%**

representative for the entire Banc d'Arguin. This means that at each count a certain, invariable proportion of all the waders on the Banc d'Arguin must be counted in these sections. Hence, when waders switch from roosts inside the section to roosts outside, another section must be selected, or the section must be enlarged to such a degree that this switch problem is solved. Due to this problem it makes little sense to select the small islands around Tidra or sections on Tidra itself, so the only areas which are left are found on the periphery of the Banc d'Arguin: the isle of Arel (section K in the west, three sections in the north-west (section A, C, D) and the Baie de St. Jean in the south (section H). The last area is not of much interest since it is a large area, but attracts only a few waders. Would it be worthwhile to count in the future only the other four sections? In total 500,000 waders, a quarter of all waders on the Banc d'Arguin, are concentrated here (Table 4). As Table 4 shows, the absolute and relative numbers counted in these four sectors hardly differ between the winters of 1979, 1980 and 1997. This is only true, however, for the total number of waders and for some species, such as Ringed Plover *Charadrius hiaticula*, Grey Plover *Pluvialis squatarola* and Knot. For other species, such as Little Stint, Greenshank and Kentish Plover, the variation is much larger. The degree of variation is shown in the last column of Table 4. It gives the standard deviation as percentage of the average percentage of birds concentrated in the selected four sections. In most species the standard deviation is about 20% relative to the mean. This implies that it would be harder to use counts in the four selected sections as a tool to indicate changes in the number of waders wintering on the Banc d'Arguin as a whole.

We can conclude from all of this that at our present stage of knowledge about the Banc d'Arguin, it makes no sense to monitor the waders on the Banc d'Arguin in a selection of sections. Although the alternative is more intensive work , it is still recommended to count the entire Banc d'Arguin, but give the counted numbers per sections such as has been done in 1980 and in this count. By continuing this practice, it will make incomplete counts of the Banc d'Arguin in the future more valuable, because it gives the opportunity to estimate roughly the proportion of birds not being counted.

A completely new approach would be to monitor the wader populations on the Banc d'Arguin by counting them in selected low water feeding areas. This would be a good alternative to the high water counts if, but only if (1) good maps are available, (2) the surface area of the tidal flats is known and (3) the permanent counting areas can be delineated well enough. In Guinea-Bissau, waders disappeared at high tide into the mangroves, so counting at low tide was the only way to estimate the numbers present. Due to the presence of rocks, mangroves and other landmarks, the counting sites there could often be defined easily and usually be indicated on the excellent topographical maps. It will be much more difficult to determine the low water feeding density on the Banc d'Arguin in this way. Maybe the largest practical problem will be to mark the permanent counting sites, although GPS technology is now available. Even if the choice is made to start monitoring waders on the Banc d'Arguin by counting waders in selected low water plots, it would be worthwhile to combine it the first time(s) with a complete count of the roosting waders at high tide

The early counts of the Banc d'Arguin were carried out to assess just how many birds wintered there. Now five counts are available, the wintering numbers are more or less known. Future counts will have to target possible changes in the wintering numbers. It is therefore necessary to perform future counts more precisely than previously and on a more frequent basis than those accomplished over the past twenty years. The counters involved must have 'big flock' experience and the total count period must be sufficiently flexible to allow time enough to spend several days on difficult roosts (e.g. in section J and K).

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