The winter food and feeding habits of Shelduck in the Camargue, France

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Introduction

Feeding studies of the Shelduck *Tadorna tadorna* are well known from the British Isles (Olney 1965; Bryant & Leng 1975; Evans *et al*. 1979) where the species winters in estuaries and brackish marshes. In other parts of its range: in the Mediterranean, eastern Europe and central Asia, Shelduck frequent non-tidal saline lakes and lagoons. No intensive studies of Shelduck have been made in these habitats, apart from one in Lake Rezaiyeh in Iran (Savage 1964) and in Russia (Isakov in Dementiev *et al*. 1967) and these only during the summer months. This paper examines the diet, feeding methods and some of the factors determining the distribution and abundance of Shelduck during the winter months (Oct.–Feb. 1977–78 and 1978–79) in one such area, the salines of the Camargue.

The study area

In the Mediterranean region of France, Shelduck are confined chiefly to salt-water lagoons and salines. The latter form a series of hypersaline lagoons, artificially created for the exploitation of salt for industrial and commercial use. Of the 10 salines in operation, the two most important for wintering Shelduck are the salines of Salin-de-Giraud (12,000 ha) and the salines of Aigues-Mortes (7,000 ha) (Figure 1). These have winter maxima of approximately 500 and 1,000 Shelduck respectively. The overall wintering Shelduck population on the French Mediterranean coast numbers about 2,000 individuals, and the breeding population is estimated at 300–400 pairs.

The study area was the salines of Salin-de-Giraud, situated in the south-east of the Camargue. The salines are a series of

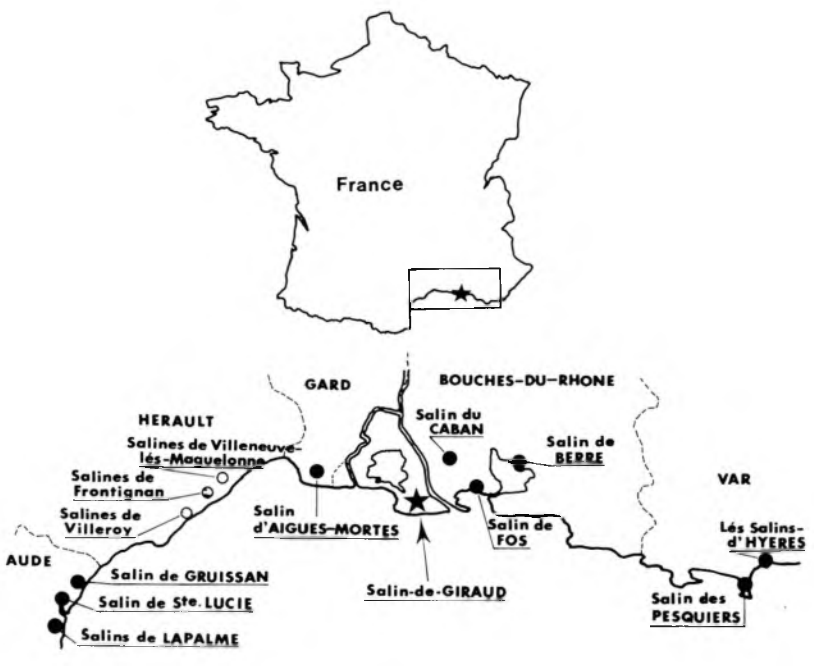

Figure 1. The study area (starred) and distribution of salines on the Mediterranean coast of France. Solid dots = salines in use; open circles = unexploited salines.

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shallow lagoons and canals in which salt is produced by evaporation of sea-water. Water is pumped from one lagoon to another in summer, and salinities vary from about 40‰ in the first lagoons up to saturation (300‰) in those where salt is harvested. There are numerous natural and artificial islands, many of which are covered with a dense halophytic vegetation in which Shelduck (c. 100 pairs) breed.

The high precipitation and low evaporation rates characteristic of the winter months are unsuited to salt production, therefore many of the 100 or so lagoons remain drained, but pools of low salinity form after rain. Other lagoons are used as storage reservoirs for high salinity water and remain full throughout the winter. Hence a wide range of conditions are represented.

Each lagoon is surrounded by banks and has clearly defined characteristics (area, depth, salinity, etc.). The very unstable physico-chemical conditions make this a truly extreme environment (Brock 1969) with a very low species richness, especially in winter. Birds other than Shelduck wintering in the salines are: Greater Flamingos *Phoenicopterus ruber roseus* (between 1,000 and 3,000 Flamingos regularly winter in the Camargue: Johnson 1979), Herring Gulls *Larus argentatus michahellis* and Black-headed Gull *L. ridibundus*, Dunlin *Calidris alpina*, Little Stint *C. minuta* and Redshank *Tringa totanus*. More detailed descriptions of these salines are given in Hoffmann (1958) and Anon. (1978).

The Shelduck study population

Methods

Fortnightly counts of the Shelduck present in the study area were made from September 1977 to February 1979. Counts were made in daylight hours from a vehicle by two observers along a fixed 125 km itinerary, covering all lagoons. The duration of each count varied from 6–9 hours according to the number of birds present. The number of Shelduck in each occupied lagoon was noted and marked on a map of the area, and the activity of the birds was recorded (feeding or roosting).

Results

The number of Shelduck wintering in the study area during the two winters is shown in Figure 2. Although the winter maxima in the two years are numerically similar (63[illegible] and 497) the numbers vary considerably both within and between winters. In both winters, the population dropped at times to less than 100 birds (e.g. in October 1977 and October–December 1978) following periods of low precipitation. Sightings of known colour-ringed individuals show that local movements between different salines in the region regularly occur. These may be an important response to changing conditions such as availability of food and feeding sites, as will be discussed later. Larger scale movements also occur and recent ringing recoveries show both emigration and immigration. One particularly interesting observation was of a colour-ringed bird from northern Europe seen in December 1978 (Spencer & Hudson 1979).

Food and feeding methods

Methods

The Shelduck is a fully protected species in Europe (in France since 1962). Removal of individuals from a small study population such as that of the Camargue would be unjustified. Shelducks do not regurgitate pellets of undigested food remains, therefore food studies, made only during the winter 1978–79, are based on faecal analysis and direct field observations. On the days immediately following each fortnightly count, visits were made to those lagoons where Shelduck had been feeding. Faecal samples were collected from each feeding site or its associated roost (to a maximum of 30 samples per site). Qualitative samples of zooplankton and benthos were taken (by hand-net) from exact feeding locations to compare the available food items with those found in the faeces.

In the laboratory, each faecal sample was examined individually under a microscope after washing in a 0·065 mm sieve to separate the items. All food items were identified and their relative abundance (% by volume) was estimated by eye. Items occurring only as accidentals (i.e. occupying <1% by volume) were scored with a '+'. The zoo-plankton and benthos samples were examined qualitatively to ensure that no items were being overlooked in the faeces. Because of the extreme poverty of food items available, most Shelduck were found to be feeding on only one food item at a time in any one lagoon. Four such food types were recognized:

1. Aquatic Coleoptera adults—*Potamonectes cerysii* and *Berosus spinosus*.
2. *Artemia*—adults, larvae and cysts. (Only cysts were present in the faeces after November.) According to recent studies (Barigozzi 1980; Bowen *et al.* 1980) *Artemia* is a polytypic genus. The Camargue populations have not yet been described.
3. Aquatic Diptera larvae—*Thinophilus achilleus* (Dolichopodidae).
4. Agal bioderm: Cyanophyceae—*Microcoleus chthonoplastes*.

Any faecal sample containing more than 90% by volume of one of these food types, was classified under that name. Samples containing two or more food types were classified as a fifth category: 'mixed', which comprised only 4% of the samples. Knowing the food type being taken by Shelduck at each feeding lagoon, and the number of birds using that lagoon, one can calculate the number of individuals feeding on each food type for the month in the study area.

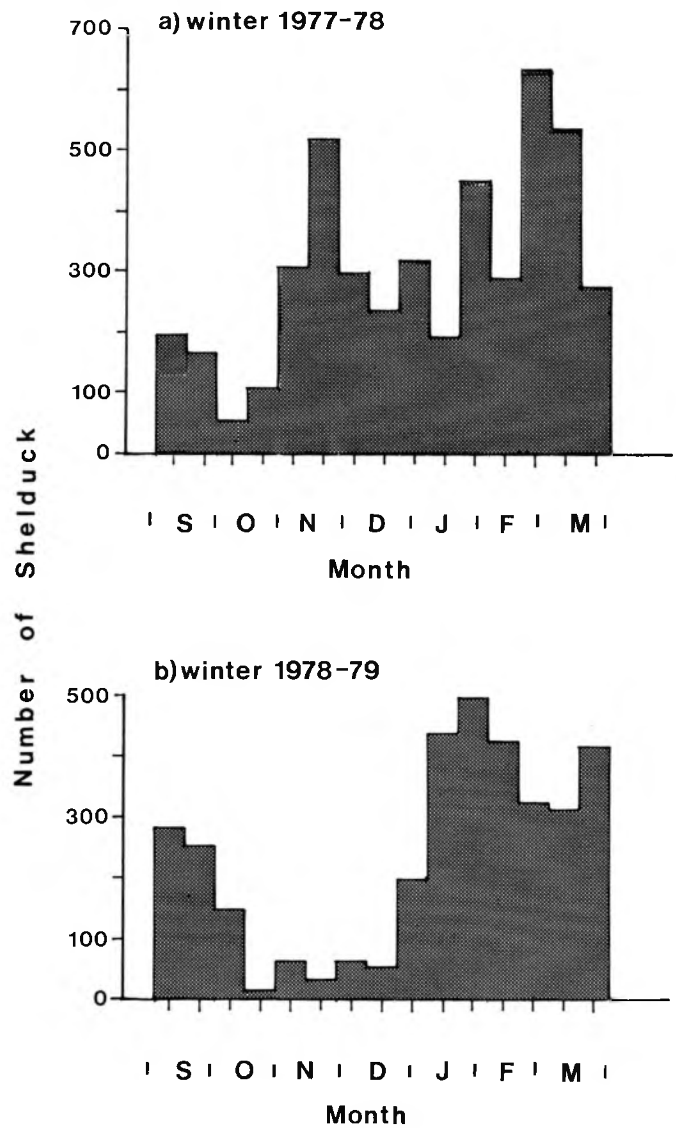

Figure 2. Fortnightly counts of Shelduck in the salines of the Camargue, winters 1977–78 and 1978–79.

For the rare occasions on which faeces of two food types were found at one site (e.g. Coleoptera adults and *Artemia* eggs), we assumed that the number of Shelduck feeding on each food type was equal to the ratio of faeces of each type collected. The diet of birds seen flying or in non-feeding groups was classified as 'unknown'.

Feeding methods were recorded by 'scan sampling' (Altmann 1974). Groups of birds of known diet were observed, and the feeding method being used by each individual was recorded every 10 minutes. Five feeding methods were recognized after Swennen & Van der Baan (1959) and Bryant & Leng (1975):

1. Dabbling on exposed mud (moist surface).
2. Scything at waters edge, and in deeper water.
3. Dabbling in shallow water (1–10 cm).
4. Head dipping in water (10–25 cm) by swimming birds.
5. Up-ending in deep water (25–40 cm).

Results

A total of 637 faecal samples were analysed. Fifteen food items were identified (Table 1) many of these occurring only as accidentals (e.g. angiosperm seeds although present in many faeces, were never an important food source).

The extreme physico-chemical severity of the Camargue salines in winter, resulted in a very poor diversity of food items. Ninety-six per cent of the faecal samples analysed were composed of one food type only, which corresponded with the available food found in the substrate and water samples. When an animal feeds on one food type only, the problem of differential digestion of food (see Hartley 1948; Owen 1975) is nullified. Faecal analysis is therefore a valid method for the study of Shelduck diet in this situation. Food items were very little digested in the faecal samples; exoskeletons of Coleoptera imagos, Diptera larvae and even *Artemia* all remaining intact and facilitating identification. The

Table 1. Food items of wintering Shelduck in the Camargue and faecal sample size collected per month. (% figures show the percentage of occurrence for each item).

	%				
Food item	Oct	Nov	Dec	Jan	Feb
COLEOPTERA					
Potamonectes cerysii (adults)	71·9	33·8	36·5	3·9	1·9
Berosus spinosus (adults)	23·3	3·0	2·2	0·6	—
Berosus spinosus (larvae)	5·8	—	—	—	—
HEMIPTERA					
Corixidae: *Sigara lateralis*	—	1·5	—	—	—
DIPTERA					
Dolichopodidae (larvae): *Thinophilus achilleus*	12·6	25·6	11·0	1·3	0·9
Chironomidae (larvae): *Halocladius varians*	—	—	—	1·3	0·9
Ephydridae (larvae): *Ephydra bivittata*	1·9	2·3	—	—	—
Ephydridae (pupae)	3·9	0·8	0·7	—	—
Unidentified imagos	—	2·3	0·7	—	—
CRUSTACEA					
BRANCHIOPODA					
Artemia spp. (adults and instars)	35·0	37·6	—	—	5·6
Artemia spp. (cysts)	20·4	67·7	97·8	40·4	45·4
OSTRACODA					
Cyprideis littoralis	—	0·8	1·5	0·6	—
ALGAE					
Microcoleus chthonoplastes (Cyanophyceae)	—	—	4·4	76·3	77·8
Enteromorpha sp. (Chlorophyceae)	—	—	—	0·6	—
ANGIOSPERMAE					
Seeds (mainly Graminae)	3·9	20·3	24·1	14·1	7·4
Faecal sample size per month (N)	103	133	137	156	108

most frequently taken food types were algal bioderm, *Artemia* and Coleoptera imagos. These accounted for 98% of birds of known diet. The number of birds feeding on each of these food types during each month of the study is given in Figure 3.

Each of these items could be exploited by Shelduck only under certain hydrological or climatological conditions. Feeding methods were characteristic for each food type (Table 2).

1. Coleoptera adults. *Potamonectes cerysii* and *Berosus spinosus*

Although present throughout the winter, these beetles were only an important food source in October. This coincides with the draining and drying out of many lagoons, which concentrates the beetles into shallow pools. Shelduck take the beetles as they rise for air, by picking them individually from the water surface, or by dabbling in shallow water.

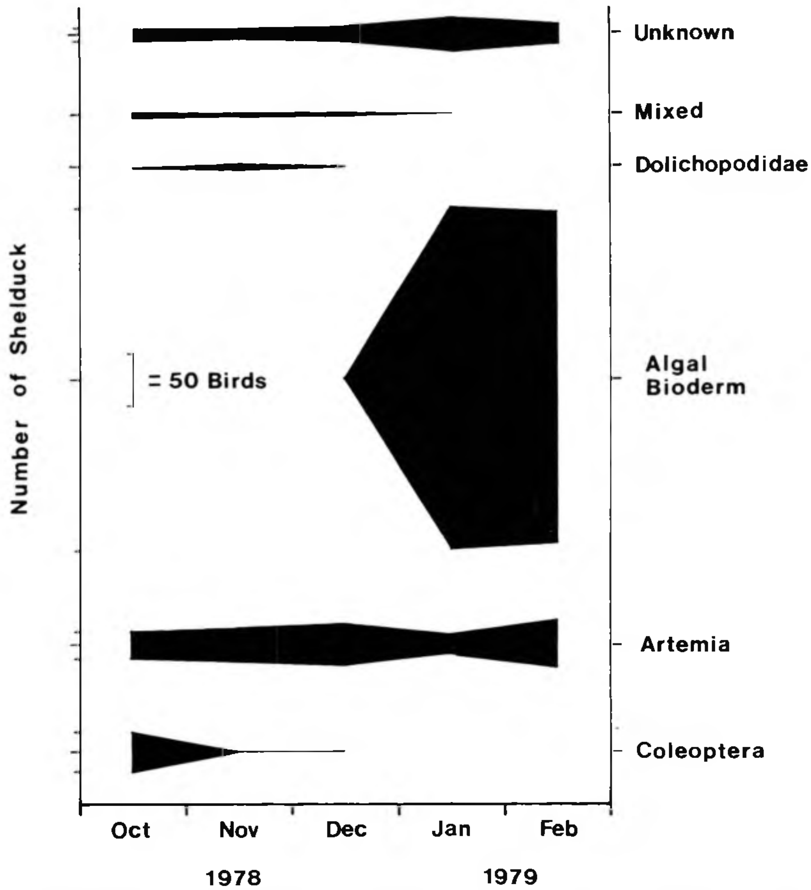

Figure 3. Calculated numbers of Shelduck feeding on the different food items, winter 1978–79.

Table 2. Shelduck feeding methods used for different food items (when known to be feeding on each food type). % use of each method: (1) Dabbling on mud, (2) Scything, (3) Dabbling in shallow water, (4) Head dipping, (5) Up-ending.

Food items	Feeding methods 1	2	3	4	5	Number of bird observations
Antemia (adults)	0·2	—	0·6	85·4	13·7	7,511
Artemia (cysts)	0·2	97·1	2·7	—	—	2,100
Algal bioderm	7·0	—	89·2	3·2	0·6	10,115

2. *Artemia*
This branchiopod crustacean occurs in summer, attaining densities of up to 30,000 and in wind blown concentrations numbers could be as high as several hundreds of thousands, per cubic metre (G. Macdonald, pers. com.). *Artemia* has been recorded as the most important food item of Shelduck in other hyper-saline habitats in summer (Dementiev & Gladkov 1967; Savage 1964) and this may also be true in the Camargue. In winter, adult and larval *Artemia* do not survive the low temperatures, and only resistant cysts remain until spring. Adults were recorded only until the end of November, the first cysts hatching at the end of February. These cysts were an important food for Shelduck throughout the winter in the higher salinity lagoons. Concentrations of cysts occur regularly under suitable wind conditions, which blow them into large scums which Shelduck exploit by a characteristic scything movement of the head, neck and bill. These scums form only on short stretches of shoreline and inlets, and the available feeding area may often limit the number of Shelduck taking this food type.

3. *Algal bioderm* (Cyanophycleae: *Microcoleus chthonoplastes*)
Blue-green algal mats are the most characteristic bottom substrate of the lower salinity lagoons. This was the most important single food item of Camargue Shelduck in late winter, and supported high densities of feeding birds. As a food source under favourable conditions, it is almost unlimited, occurring as a laminated carpet several centimetres thick, but in which only the surface millimetre or so consists of actively photosynthesizing plant cells, with a biomass of more than 500 g dry weight per m^2. The availability of bioderm to Shelduck depends on the substrate being moist. These low salinity lagoons are normally drained in winter and hence this requirement must be maintained by rainwater. During dry periods, the bioderm becomes hard and dry and therefore quite unsuitable for feeding Shelduck, which exploit this food source by dabbling in shallow water.

Discussion

Although this diet study is based on only one winter of observations, large differences are apparent between the winter food and feeding ecology of Shelduck in the Camargue and in Northern Europe. The small gastropod mollusc *Hydrobia ulvae* has been recorded as the most important food source from this latter region (Olney 1965; Bryant & Leng 1975), and may be an important factor determining the distribution and abundance of Shelduck in these areas. Although the mollusc *Hydrobia acuta* occurs in the Camargue salines in densities of up to 25,000 individuals/m^2 (R. Britton, pers. com.), it was never recorded as a food item of Shelduck. This may be due to lack of tidal cycles which may have an important influence on the behaviour of *Hydrobia*, and thus its availability to feeding Shelduck. Alternatively, *Hydrobia acuta* in the Camargue may be inaccessible to feeding Shelduck, as they generally inhabit deeper water only accessible to Flamingos.

In the Camargue, Shelduck are not feeding specialists. Olney (1965) suggested the possibility of Shelduck showing more flexible feeding behaviour in the light of their recent range expansion, and this hypothesis appears to be true for the Camargue. Here, Shelduck take a wide variety of items, as was found by Jenkins *et al.* (1975) and Evans *et al.* (1979) and are opportunistic feeders able to exploit the sudden abundances of food which may occur in this rather unpredictable environment. Several food types of varying form and size (*Artemia* cyst diameters: ca 0·25 mm, *Berosus* adult diameters: ca 5 mm) are taken and Shelduck have a variety of feeding methods suited to each food type.

The Camargue salines in winter have a very low species richness of different food types. In animal communities whose food webs have only a few pathways, instability of predator populations is predicted (MacArthur 1955). The Camargue Shelduck support this hypothesis, and numbers fluctuate considerably in response to the availability of their few food items.

A comparison of the mean monthly counts from the last two winters (Figure 2) shows very different trends, although the peak counts are numerically similar. In the 1977–78 winter the population reached its peak in November, whereas in 1978–79 it was not attained until January. Examination suggests that this is related to rainfall. When the mean monthly Shelduck count is plotted against the rainfall in the previous month, a strong correlation is seen ($r = 0{\cdot}91$, $P < 0{\cdot}001$) (Figure 4). This is related to the availability of the major winter food, algal bioderm.

Artemia cyst concentrations are a profitable food source for Shelduck, but are both temporally and spacially unpredictable, occurring in large quantities only under suitable wind conditions. Digestion of *Artemia* cysts by birds has been considered by several authors, as bird transport may be an important dispersal mechanism for this organism (Proctor 1964; Proctor & Malone 1965). MacDonald (1980) studied assimilation efficiency of *Artemia* cysts by Shelduck in captivity, and concluded that the cyst envelope is not a barrier to the digestive enzymes for the majority of cysts ingested. Shelduck were found to assimilate up to 33% of the available organic matter. Cysts have a 64% protein content by dry matter (Nixon 1970) and may therefore be an important protein source to Shelduck. The quantities available only support the few birds (20–40) which were regularly observed feeding on this food item. The only other food available in quantity during the critical winter months (Dec.–Feb.) was algal bioderm. This occurs mainly in lagoons which have been drained, and is only available to feeding Shelduck after rain, which maintains the feeding substrate moist. During the dry period (Oct.–Dec. 1978), although the number of Shelduck decreased in the Camargue, numbers remained high in other salines where water levels are maintained, thus providing sufficient food availability.

Observations of colour-ringed individuals show that these local movements do occur frequently. Following the rains in late December 1978, the Shelduck population rose dramatically (58 to 378), all new arrivals feeding on Algal Bioderm which had become available as a feeding substrate.

Our observations in the Camargue salines suggest that when certain hydrological conditions prevail, the carrying capacity for wintering Shelduck is limited. In dry periods this is determined by the availability of Algal Biodern, the most important food item in winter. Following periods of high precipitation, the available feeding area becomes almost unlimited. Other non-physical factors may also be important in determining the number of Shelduck using the area, for example, interspecific competition with Flamingos. These aspects as yet remain unstudied.

Acknowledgements

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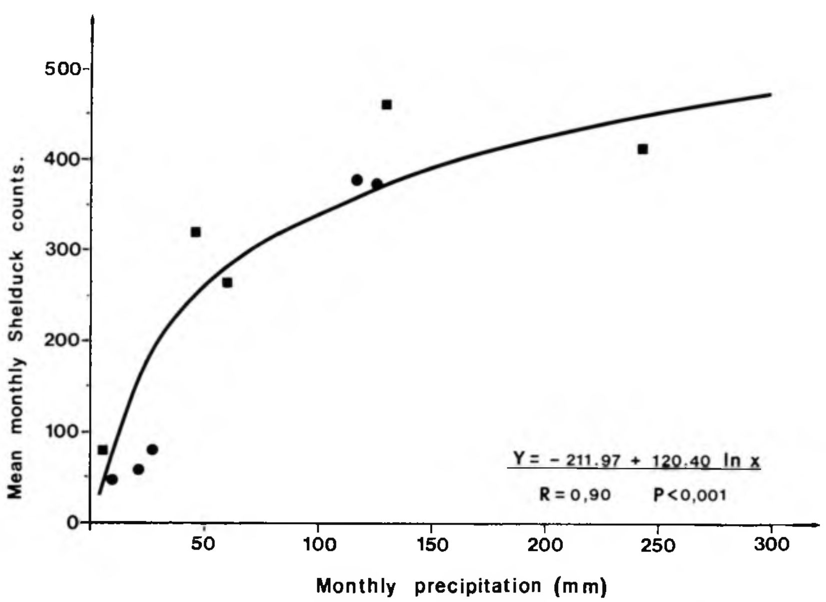

Figure 4. The relation between rainfall and the number of Shelduck wintering in the Camargue. Points are the mean monthly counts plotted against total precipitation in the previous month. Squares = winter 1977–78; dots = winter 1978–79. (Logarithmic curve fit.)

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Summary

The wintering Shelduck *Tadorna tadorna* population of the Mediterranean coast of France numbers 1,500–2,000 individuals. These inhabit a series of non-tidal hyper-saline lagoons, quite unlike those of northern Europe. The diet of Shelduck in the salines of the Camargue was restricted by the very low diversity of available food items. The study was based on faecal analysis and direct observations in the field. The most important food types were algal bioderm, *Artemia* and aquatic Coleoptera adults. Unique feeding methods characterized each food type. Each food type only became available under specific meteorological conditions (rain-fall, wind and evaporation). The availability of the most important food (algal bioderm) was determined by rainfall, which maintained the substrate moist for feeding. The numbers of Shelduck using the study area over two different winters 1977–78 and 1978–79 is correlated with the precipitation.

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