The W.A.G.B.I.—Wildfowl Trust Experimental Reserve — the first eleven years

Introduction

This reserve was originally established in 1956, when the Kent Sand and Ballast Company gave permission to the Wildfowlers' Association of Great Britain and Ireland (W.A.G.B.I.) to manage their flooded gravel workings in west Kent, as a wildfowl reserve; close co-operation was quickly established with the Wildfowl Trust, and in 1961 the reserve was nominated as a joint experimental unit of the two organisations.

Two preliminary outlines of the management plan and progress have appeared in 1962 and 1965, whilst shorter reports have appeared each year in the *W.A.G.B.I. Annual Reports*. The two lakes within the reserve have undergone dramatic changes during the past eleven years as a result of the close co-operation which exists between the Company's managing director, Mr. George Wallis, and the local wildfowl enthusiasts, in arranging gravel extractions and the planning of modifications calculated to promote the interests of the area as a reserve. The success of these efforts will be apparent to all who study this report.

In 1967 a whole new pit will be flooded. Unlike the other lakes, the new water will be shallow and is likely to have far reaching effects on the waterfowl population of the reserve as a whole. It is desirable, therefore, to assess in detail the achievements of the reserve to date, covering the first eleven years and involving one of the longest series of daily observations on wildfowl made in this country. The first part of this report deals with the analysis of these observations; the second part presents the results of an intensive study of wildfowl feeding biology within the vicinity of the reserve, and is based upon an analysis of the food taken by local duck, which in its turn enabled the planting programme to be devised. Planting has been carried out almost continuously since 1958.

During the summer and autumn of 1966, the productivity of the introduced plants was investigated with special reference to the production of wildfowl food. The results of this investigation are presented in the third part of this report, and it must again be stressed that these results could not have met with the success they have done without the invaluable co-operation of Mr. Wallis. It therefore seems most appropriate that the analysis of achievements should include some indication, in part four, of the cost involved in the course of effecting the improvements which have been made to the habitat.

The whole combined effort represents a most important contribution to conservation in all its many aspects. The vital role of the ecologists concerned with this project is obvious for it was their sphere to identify the plants and other forms of life which the various wildfowl species depend upon for their very existence, and to direct the planting programme accordingly. The advice of such scientists is in fact essential to the proper conduct of any such reserve. Peter Olney's original concept of an analysis of the food preferences of local wildfowl has now extended into a long term study and has demonstrated differing feeding habits according to varying weather conditions and land management.

Part I. Development of the wildfowl population

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Summary

Data are presented for a continuous series of daily or weekly counts from 1956 to 1967. Mallard constituted the bulk of the wildfowl population, and steady increases have been recorded since the reserve was established. Results suggest that the encouragement of natural breeding by Mallard plays a more important part in establishing a local population, especially during the summer, than does the release of hand-reared birds. However, the first breeding records for Tufted Duck were obtained following the release of hand-reared birds, although the latter could not be definitely established as a prime factor of this development. The numbers of diving duck species in general increased rapidly following the cessation of gravel extraction from one of the two pits.

The number of species recorded annually has increased markedly since 1956. A maximum of seventeen was recorded in the severe winter of 1962-63; a total of twenty-one species of wildfowl has been recorded within the reserve, not including introductions or escapes.

In order to present population data in a reasonably concise form it is necessary to adopt the American " duck-day " system. This provides a means for the comparison of usage by, for example, a large number of wildfowl for a short duration, and a small number over perhaps the whole season. Unfortunately, this is bound to obscure certain factors, such as peak population times. Nevertheless, it is suitable for the investigation of wildfowl usage in relation to controlling factors, food and cover.

Although the reserve has been visited daily during the past eleven years, full data are not available for Mallard: the yearly totals from 1956-1962 have been interpolated from weekly counts in this species. Matthews (1959) has found that such procedures do, in fact, provide a reasonable approximation of the actual value. Daily counts have been made since 1963.

Data for the period summer 1956 to winter 1967 are summarised in Table I. In addition to the 21 listed, four other species have been recorded. These include a Lesser Snow Goose, present from 3rd December, 1963, to 3rd November, 1965, and a Barnacle Goose seen on 6th June, 1966. It is probable that both were escapes from collections. Canada and Greylag Geese have been introduced to the reserve, and their numbers, which have in recent years been supplemented by " wild " birds, are presented in Table II.

The data in Table I are self-evident, but certain features deserve special attention. Mallard have invariably constituted the bulk of the wildfowl population, and have increased continuously from 1956. The annual totals may be differentiated into summer and winter populations. The increase in the summer population seen since 1962 is due to a large extent to an increase in breeding within the reserve. The number of broods observed each year (Figure 1) has increased markedly, to attain a total of 44 in 1966. Whether or not the perceptible increase in the growth rate of the winter population, seen since 1962-63, can be attributed to the increase in breeding stock is difficult to assess. What is apparent, however, is that the release of hand-reared Mallard has had little impact within the reserve. There was some development of a summer population following the release of birds in 1958, but there has been no obvious effect on the population since 1962, following a decline in hand-rearing. From a conservation point of view, however, it may be assumed that the reserve has functioned successfully as a point of release of hand-reared Mallard, before their subsequent absorption into the general population in that part of the country.

There has been a fairly steady increase among diving duck species. In 1961-62, there was a marked increase in Pochard and Tufted Duck populations, which has been maintained at or increased from these levels since then. It is of interest to note that, in the previous summer (1961) excavation ceased in the West Lake and submerged plants and animals rapidly became established. Clearly, Tufted Duck have benefited to a greater degree than Pochard. It is thought that this is partly a reflection of the nature of the submerged vegetation. The only species to become widely distributed within the West Lake is hornwort *Ceratophyllum demersum*. Whilst Olney (1963a, 1963b, 1964) has shown this species may have some value as a food plant, it is not exceptionally productive of seed at the reserve. It is believed that this species has suppressed the growth of more useful species

Table I. Annual wildfowl usage (in wildfowl days) of the W.A.G.B.I.—Wildfowl Trust Experimental Reserve, Sevenoaks, 1956-67.

Year includes summer and following winter, e.g., 1956/57 refers to summer 1956 and winter 1956/57. Figures in parenthesis refer to birds seen flying over the reserve, and are not included in totals.

	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	64/65	65/66	66/67
Dabbling/grazing ducks											
Mallard	6150	7900	9500	14700	17100	19900	22370	27945	33104	38201	41314
Teal	12	2	7	8	10	31	84	69	53	69	324
Garganey				1					1		3
Gadwall			1							497	491
Wigeon		3		20	2	25	77	6	101	41	11
Pintail							6	5	4	1	
Shoveler		1	2			11	17	8	33	27	10
Shelduck		1			2		3	2	2	7	7
Total	6162	7907	9510	14729	17114	19967	22557	28035	33298	38843	42160
Diving ducks											
Pochard	1	9	2	13	12	337	324	166	324	213	443
Tufted Duck		24	73	22	13	159	431	457	1722	1663	3134
Goldeneye						7	11		20	1	3
Eider							6				
Common Scoter		1						6			
Red-breasted Merganser							10	1			
Goosander					28	109	178	4		1	
Smew						14	248	5	8		1
Total	1	34	75	35	53	626	1208	589	2074	1878	3581
Geese and swans											
Whitefront							(295)	78		(100)	(45)
Russian Brent										1	
Mute	90	114			2	14	243	439	248	196	523
Whooper							73				
Bewick's							(7)				
Total	90	114			2	14	316	517	248	197	523
Grand Total	6253	8055	9585	14764	17169	20607	24081	29191	35620	40918	46264

Table II. Canada and Greylag population of the W.A.G.B.I.—Wildfowl Trust Experimental Reserve, Sevenoaks, 1956-67.

	Canada			*Greylag*		
Season	*Resident*	*Autumn Peak*	*Round-up*	*Resident*	*Autumn Peak*	*Round-up*
1956-57	27	27	—	—	—	—
1957-58	21	21	—	—	—	—
1958-59	45	45	—	—	—	—
1959-60	48	48	—	—	—	—
1960-61	48	48	—	—	—	—
1961-62	45	80	—	5	5	—
1962-63	70	60	50	9	12	—
1963-64	33	63	—	12	12	—
1964-65	66	160	24	26	26	—
1965-66	41	123	13	17	17	—
1966-67	51	155	—	19	27	—

occurring here, notably *Potamogeton* spp. (Olney, pers. com.). At present, therefore, the amount of suitable food available to Pochard is still rather limited. The situation is rather different with regard to the Tufted Duck, which has increased rapidly since 1961. This could be attributed to a rapidly increasing invertebrate population which, whilst no doubt affected to a greater or lesser degree by the nature of submerged vegetation, will have almost certainly increased since the cessation of extraction activity in 1961. It must be remembered, however, that disturbance has also been considerably reduced by this change.

Table II gives the seasonal numbers of Canada and Greylag Geese present. It will be noted that with three round-ups during the flightless period, in 1962, 1964 and 1965, Canada Geese have been kept well controlled. In the case of Canada Geese peak numbers have been recorded quite regularly for six weeks in autumn from early September. This is the only time when the residents are joined by others from elsewhere. The reserve is used almost solely as a roost throughout the year, except from the breeding season to the end of the flightless period in the second half of July. It is at this time that the geese graze on the submerged water plants by upending. The plant species most seriously affected appears to be *Potamogeton crispus*, which grows abundantly in part of the East Lake. Seeds are rarely formed and indeed very few flowers may be observed. It is thought that the latter are grazed off by geese and perhaps Mute Swans also, resulting in a serious depletion of food suitable for Pochard and other ducks. It seems probable also that the depth of water is often too great for heavy seed yields by this species; better results with this otherwise productive plant are expected in the new shallow pit to be completed in 1967.

There is some evidence to suggest that the smaller Greylags are unsuccessful competitors with Canada Geese, particularly in the choice of nesting sites. Fighting has been observed and for the past three years nesting Greylags have flown to a lake about six miles south, returning

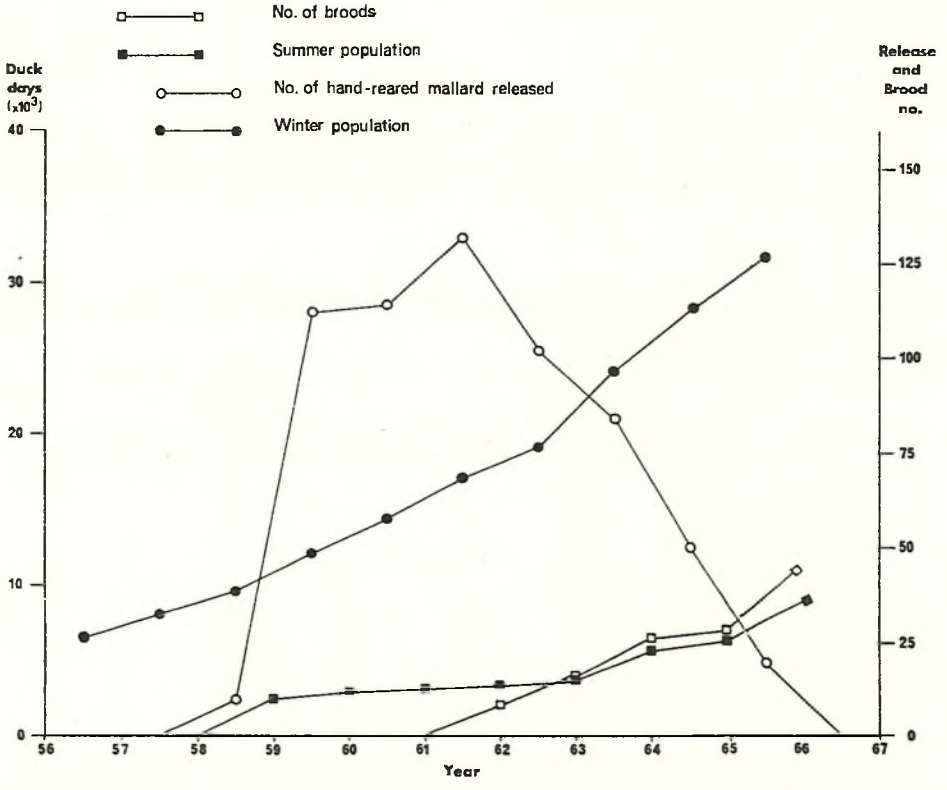

Figure 1. Mallard population at the W.A.G.B.I.—Wildfowl Trust experimental reserve.

to the reserve with their families in late autumn.

One of the benefits to be derived from a well-established Mallard population has been the attraction of other species of wildfowl to the reserve. Twenty-one different species have now been recorded, not including feral geese, introductions or escapes, and there has been a general increase in the number of different species seen each year. Data for the severe winter of 1962-63 shows how important such local reserves can be under extreme conditions; no less than seventeen species were recorded during this period.

As might be expected, the number of species visiting the reserve is considerably lower during the summer, but even here a definite increase has been observed since the reserve was established. The summer of 1966 was particularly successful, with a record number of seven summer visiting species; these included Tufted Duck which amounted to a total of 720 duck-days, affected in no small way by the notable presence of five breeding pairs. (It should be noted that young birds were not included in the calculation of "wildfowl-days" until fully grown.) It is interesting to note that this first breeding record occurred in the year following the initial release of seven hand-reared Tufted Duck. Five of the latter were colour-ringed, but no such rings were observed among breeding birds.

In 1965, fifteen Gadwall were released, followed by a further nineteen in 1966, with two Pochard in the same year. It remains to be seen what effect these introductions have on the status of the reserve as a natural breeding ground for these species.

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Part II. The feeding ecology of local Mallard and other wildfowl

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Summary

The feeding habits of Mallard *Anas p. platyrhynchos* in an area near Sevenoaks, Kent, were investigated by 226 stomach analyses and by observations between 1957 and 1965. The main feeding areas included the river and its banks, the wet meadows by the river, the gravel pits and their margins and beneath oak trees *Quercus robur* in the valley. The dominant plants in these areas are described. The food taken varied each year, depending on the production and availability of food items, which were correlated with changes in the habitat (e.g. river clearance, grazing) and with the effects of differing weather conditions (e.g. flooding, dry summers).

The most frequently taken foods were: in the river, the leaf and stem of water crowfoot *Ranunculus aquatilis,* together with the mollusc *Hydrobia jenkinsi* and the caddis fly *Hydropsyche angustipennis,* and to a lesser extent the seeds of flote-grass *Glyceria fluitans;* from the river banks, the seeds of bur-reed *Sparganium erectum* and water-pepper *Polygonum hydropiper;* from the wet meadows, the seeds of creeping buttercup *Ranunculus repens,* persicaria *Polygonum persicaria,* hammer sedge *Carex hirta* and sharp dock *Rumex conglomeratus;* in and around the gravel pits a wide variety, mainly the seeds of alder *Alnus glutinosa,* various *Polygonum* species, *S. erectum* and parts of horsetail *Equisetum,* as well as Chironomidae and *Hydropsyche* larvae.

Acorns were eaten in the years when oaks produced seed.

Forty other wildfowl were collected and their stomach contents were analysed. They included Teal *Anas c. crecca,* Wigeon *A. penelope,* Tufted Duck *Aythya fuligula,* Pochard *A. ferina,* Smew *Mergus albellus,* White-fronted Geese *Anser a. albifrons* and Canada Geese *Branta canadensis.*

Introduction

The food and feeding habits of Mallard *Anas p. platyrhynchos*, and other species of ducks and geese, were studied over an eight year period in an area along the River Darent between Sevenoaks and Otford, Kent. This area includes two gravel pits, the details of which have already been described (Harrison et al. 1962, Olney 1964) and in which extensive management has already taken place. It was quite obvious from observations that birds feeding in the area between Otford and the gravel pits were flighting to and from the pits where some feeding was also taking place, but whose prime value, at least in the beginning of the survey, was as a roosting area. It follows that any food study would have to consider the area as a whole, though most birds were collected away from the pits.

Methods and materials

From 1957 to 1965, mainly during the allowed shooting season of 1st September to 31st January, 266 birds of ten species were collected. Of these only eleven were found to be empty of food. Eight birds were collected within the protected season under a licence issued by the Nature Conservancy. The methods of analysis were the same as those described in detail elsewhere (Olney 1961, 1963a). The nomenclature of all seeding plants follows that of Clapham, Tutin and Warburg (1962).

The main feeding areas include: (1) the river and its banks, (2) the meadows by the river—especially when they are partially flooded, (3) the gravel pits and their margins, and in the case of Mallard (4) beneath the oak trees *Quercus robur* which are scattered along the river valley. It is not possible in this paper to go into much detail when considering the vegetation. Within the river the dominant plants are water crowfoot *Ranunculus aquatilis*, horn-wort *Ceratophyllum demersum*, flote-grass *Glyceria fluitans*, canadian pondweed *Elodea canadensis*, starwort *Callitriche* sp., and duckweed *Lemna* spp. The river is fringed mainly with common bur-reed *Sparganium erectum* and reed-grass *Glyceria maxima*, and in some years with extensive patches of water-pepper *Polygonum hydropiper*. Alder *Alnus glutinosa* and willows *Salix* spp. are found along the river and throughout the valley. The meadows adjacent to the river are typically alluvial grassland habitats often containing semi-aquatic communities where the drainage is impeded. The most frequently occurring species here are various grasses, creeping buttercup *Ranunculus repens*, persicaria *Polygonum persicaria*, hammer sedge *Carex hirta*, sharp dock *Rumex conglomeratus* and soft rush *Juncus effusus*.

Most of this report is concerned with the Mallard. Relatively little material was obtained from the seven other species (five ducks and two geese) studied. This is described and discussed at the end of the paper. Two general locality names are used: the *Otford area*, which includes the grazing meadows adjacent to the river between Otford and the gravel-pits and the river and its banks, and the *gravel pit area*, which includes the pits and their margins.

MALLARD

a. *Otford area.* Two hundred and ten Mallard were collected from this area between 1957 and 1965. The main food items found in the stomach contents of these birds are shown in Table I. Plant material, mainly seeds, occurred in 204 (97.1%) of the birds, and occupied 85.7% of the total volume. Animal material was found in 85 (40.5%) birds and occupied 14.3% of the total volume.

The seeds of creeping buttercup *Ranunculus repens* were found more frequently than any other species, occurring in 35.2% of all birds examined. This is a common species in the meadows alongside the River Darent, particularly in those areas which are liable to flood. It was not always possible to distinguish between the seeds of *R. repens* and meadow buttercup *R. acris*, and in such cases they have been included *R. repens*. In four years of survey this was the most frequently occurring plant (Table II).

Common bur-reed seeds were found in 28.1% of the birds, occurring in each year, though rarely were they found in large numbers. In three years of the survey they were the most frequently occurring species. *S. erectum* is the dominant species of the river edges, and with planting it is now common in parts of the gravel pits.

The seeds of persicaria were found in 50 birds and occurred in all years apart from the first year. This species is found in a wide range of habitats in this area and can be particularly common in the wetter parts of the grazing meadows and in the disturbed communities around the pits. The closely related species, pale persicaria *P. lapathifolium* and knotted persicaria *P. nodosum* ecologically resemble (at least in this area) *P. persicaria*. Distinguishable seeds occurred in seven and six birds respectively.

Water-pepper seeds were found in 27 birds in all years apart from the 1958-59 shooting season. This species is characteristically found in damp places, and on river banks and can produce large numbers of seeds. Occasionally birds are shot which are crammed full of these seeds, and for example in November 1964, two birds were collected which contained c.3,500 and 1,500 seeds respectively.

The hammer or hairy sedge is a common plant of the damp, grazing meadows alongside the river, and its seeds were an important part of the diet of those birds feeding in this area. The seeds occurred in 37 birds and were found in each year of the survey, though not in great quantity.

The seeds of clustered or sharp dock were found in 33 birds and occurred in each season, apart from 1960-61. This variable species is a characteristic species of the damp grasslands by the river, and is also found, though less frequently, around the gravel pits.

The most commonly eaten grass species was flote-grass, whose seeds were found in 26 birds. This was a particularly important species during the 1964-65 season, when it was found in nine of the 34 birds examined, and in three birds shot in December and January large numbers were found—one bird had eaten over 9,000 seeds. Other grass species which occurred included reed-grass, glaucous sweet grass *G. declinata*, marsh foxtail *Alopecurus geniculatus* and Italian rye-grass *Lolium multiflorum*. However, none of these occurred often or in quantity.

Alder seeds were found in 25 birds in seven of the eight seasons. It is a common tree of the wetter parts of the valley and has been extensively planted around the gravel pits. The amount and availability of seed produced appears to vary considerably from year to year.

The seeds of *Rosa* spp., and hawthorn *Crataegus monogyna* occurred in 20 and 17 birds. These plants have a limited distribution in the valley and around the pits.

Acorns, the seeds of *Quercus robur*, though they occurred in only 16 birds, formed a substantial part of the total volume (45.3%). They were found in four of the eight years. The production of acorns varies from year to year and from tree to tree, and very large numbers were produced in some years by the relatively few (17) trees in the valley and around the pits. Mallard could often be seen feeding under these trees.

Blackberry *Rubus fruiticosus* agg. is widespread and common around the pits and throughout the valley. The seeds

Table I. Main food items from the stomach contents of 210 Mallard from the Otford area, 1957-65.

Plant material	*volume in ml.*	*Frequency*	*% of total frequency*
Seeds:			
Ranunculus repens	15.3	74	35.2
Sparganium erectum	5.0	59	28.1
Polygonum persicaria	7.7	50	23.8
Carex hirta	6.95	37	17.6
Rumex conglomeratus	2.9	33	15.7
Polygonum hydropiper	16.15	27	12.9
Glyceria fluitans	20.8	26	12.4
Alnus glutinosa	4.8	25	11.9
Rosa spp.	2.4	20	9.5
Quercus robur	264.3	17	8.1
Crataegus monogyna	4.15	17	8.1
Rubus fruticosus agg.	0.8	16	7.6
Leaf and shoot:			
Ranunculus aquatilis	19.0	19	9.0
Equisetum spp.	8.9	13	6.2
Animal material			
Hydropsychidae	27.95	33	15.7
Hydrobia jenkinsi	11.8	30	14.3
Chironomidae	2.2	14	6.7

Total volume = 583.9 ml.
Plant material = 500.3 ml. = 85.7% of total volume
97.1% of total frequency
Animal material = 83.6 ml. = 14.3% of total volume
40.5% of total frequency

Table II. Numbers of occurrences of principal food plants and animals in Mallard viscera obtained in eight seasons near Sevenoaks, Kent, 1957-8 to 1964-5.

Food	*Site*	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64	1964/65	total
Ranunculus repens	wet meadows	—	27	7	7	14	3	6	10	74
Carex hirta	„ „	2	14	4	3	6	1	2	5	37
Rumex conglomeratus	„ „	2	13	5	—	7	1	3	2	33
Polygonum persicaria	wet meadows and gravel pits	—	14	6	11	5	6	4	4	50
Ranunculus aquatilis	river	—	—	9	3	1	2	2	2	19
Glyceria fluitans	„	—	6	—	2	4	—	5	9	26
Hydrobia jenkinsi	„	3	6	8	2	2	8	1	—	30
Hydropsyche sp.	river and gravel pits	—	3	8	1	11	5	2	3	33
Polygonum hydropiper	river banks	1	—	1	7	4	5	2	7	27
Sparganium erectum	river banks and gravel pits	5	13	10	12	9	3	3	4	59
Alnus glutinosa	gravel pits	—	5	2	4	1	1	2	10	25
Equisetum sp.	„ „	—	2	—	4	4	—	1	2	13
Chironomidae	„ „	—	2	2	1	2	—	5	2	14
	total	13	105	62	57	70	35	38	60	440

were found in 16 birds and in each year of the survey, though never in large quantities.

Cereal grains were not found frequently though the amounts eaten were large. Wheat *Triticum aetivum* grains were eaten by nine birds and formed 7.6% of the total volume, and barley *Hordeum distichon* grains were eaten by six birds and formed 9.5% of the total volume.

Seeds of other species taken did not occur in any appreciable quantity or frequency. All of them are species which occur in the area, and are typical members of wet situations, grassland and disturbed communities.

Plant material other than seeds occupied 6.4% of the total volume. The leaf and shoot of various submerged aquatics occurred the most frequently with those of water crowfoot being found most often (9.0%). Other species found included a number of filamentous algae, canadian pondweed, horned pondweed *Zannichellia palustris*, and starwort. Duckweed was found in only one bird. All these species are common within the river or in the gravel pits. The stem and particularly the tips of horsetail *Equisetum* spp. which can be very common in parts of the wetter areas of the gravel pits, were found in 13 birds. In November 1961, two Mallard were shot which had been feeding on turnips.

Animal material was found in 89 (40.5%) birds and comprised 14.3% of the total volume. The larvae, and to a lesser extent the pupae, of the caddis fly *Hydropsyche angustipennis* occurred the most often, being found in 33 birds. They were taken in all but one of the eight years, usually in association with water crowfoot. They have been a particularly common member of the river fauna in this area. Jenkin's spire shell *Hydrobia jenkinsi*, also a common inhabitant of the river, was found in 30 birds. Other molluscs taken included the freshwater mussels *Sphaerium*, *Pisidium*, and *Anodonta*, and the gastropod *Bithynia tentaculata*. Only *Sphaerium corneum* occurred at all frequently (eight birds) and in any quantity, and though *Anodonta* is common in parts of the gravel pits, it was only found in one bird.

A considerable number of insect larvae and adults were taken, the most common of which were the non-biting midge (Chironomidae) larvae which occurred in 14 birds. At least eight Diptera families were identified (Stratiomyidae, Psychodidae, Dolichopodidae, Empididae, Chironomidae, Rhagionidae, Ephydridae and Simuliidae), though only Chironomids and the larvae and pupae of the blackflies *Simulium ornatum* and *S. erythrocephalum* occurred in any quantity. The larvae and adults of a number of water beetles were also taken including *Helophorus aquaticus*, *H. flavipes*, *Ilybius fuliginosus*, *Haliplus* sp., *Elmis* sp., and surprisingly considering its comparatively large size (about 29 mm.), one adult *Dytiscus marginalis*.

Crustaceans taken included the waterlice *Asellus aquaticus* and *A. meridianus*, the shrimp *Gammarus pulex* and in two birds small crayfish *Astacus pallipes*. There is some evidence that the numbers of *G. pulex* increased in the river after 1961 but after two years decreased because of the sterilization of female *G. pulex* by the parasite *Polymorphus minutus* (Crompton and Harrison 1965). This parasite was found in 50% of 104 Mallard between 1961 and 1964, though the number of possible intermediate hosts, including *G. pulex*, found in the diet of Mallard was not high.

Table III. Stomach contents of 16 Mallard from Sevenoaks gravel pit area, 1959-65.

Plant material	*Frequency*	*Animal material*	*Frequency*
Equisetum spp. tips	4	Larvae:	
Algae	2	*Hydropsyche* sp.	4
Seeds:		Chironomidae	3
Sparganium	3	Psychodidae	3
Alnus glutinosa	3		
Polygonium persicaria	3		
Polygonum amphibium	2		
Rumex conglomeratus	2		
Rubus fruticosus agg.	2		

Seeds occurring only once: Wheat, Barley, *Polygonum hydropiper*, *P. lapathifolium*, *P. nodosum*, *Lolium multiflorum*, *L. perenne*, *Bromus sterilis*, *Holcus lanatus*, *Juncus inflexus*, *Phleum pratense*, *Poa trivialis*, *Plantago lanceolata*, *Crateaegus monogyna*, *Chenopodium album*, *Atriplex patula*.
Animal material occurring only once: *Gammarus pulex*, *Asellus* sp., *Limnaea pereger*, *Anodonta* sp., Rhagionidae larvae, Dolichopodidae larvae.

Earthworms were taken by seven birds and in three formed the major part of the stomach contents. Only two species could be definitely identified: *Allolobophora caliginosa* and *Eiseniella tetraedra.*

The leech *Helobdella stagnalis* which is common in the shallower parts of the gravel pits was found in a Mallard shot in November 1961.

The only time fish were found was in January 1963, when two birds were found to contain small trout *Salmo fario* remains.

b. *Gravel pit area.* Sixteen Mallard were collected from this area between 1959 and 1965, including eight collected outside the shooting season. The list of species found is shown in Table III.

Few conclusions can be drawn from such a small sample. It does indicate that relatively more animal material is taken in the summer month (in July and August when six birds were collected, five contained animal material and occupied 60% of the total volume) and that the majority of plant species taken are those associated with disturbed habitats such as would occur around the edges of the pits.

Discussion

Each shooting season the diet and feeding habits changed to some extent (Figure 1 and Table IV) and these changes can be correlated with changes in the habitat (e.g. river clearance, cattle grazing, etc.) and with the effects of differing weather conditions (e.g. flooding, dry summers, etc.). Field observations on feeding were often confirmed by subsequent stomach analyses, and could be linked to changes in environmental conditions.

In 1957 much of the feeding occurred in the river and along the banks of the river. Though only seven birds were collected during the 1957-58 season the food they contained, which was mainly *S. erectum*, confirmed the field observations.

The wet summer and September floods of 1958 caused the meadows adjacent to the river to be inundated throughout most of the shooting season, though not to any great depth. Most feeding appeared to take place in the meadows—this is confirmed by the stomach contents—and to a lesser extent by the river banks. Statistical analysis showed significantly higher frequencies of wet meadow species taken in 1958-59. In this year also

Table IV. Main feeding areas and foods of Mallard near Sevenoaks, Kent.

Main areas	*Main foods*
Wet meadows	*Ranunculus repens, Carex hirta, Polygonum persicaria, Rumex conglomeratus.*
River	*Ranunculus aquatilis, Hydropsyche* sp., *Hydrobia jenkinsi, Glyceria fluitans.*
River banks	*Sparganium erectum, Polygonum hydropiper.*
Gravel pits	*Alnus glutinosa, P. persicaria, Equisetum* spp., *S. erectum, Hydropsyche* sp., Chironomidae.
River valley and pits	*Quercus robur.*

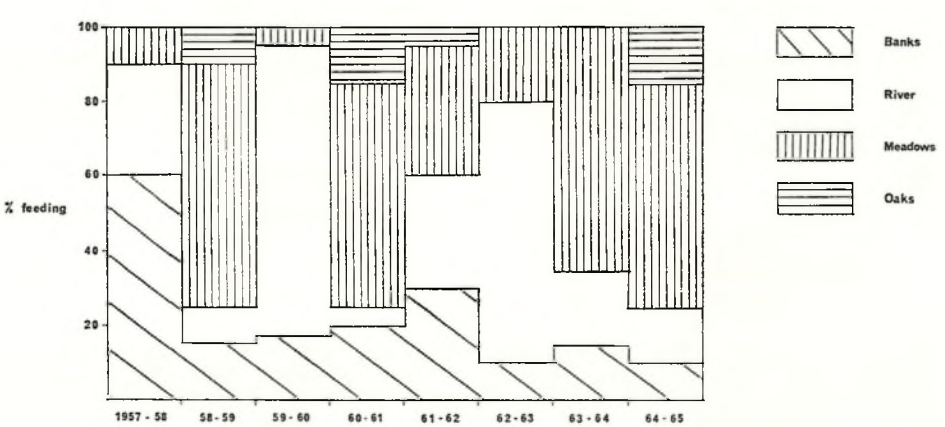

Figure 1. Feeding habits of Mallard in the Kent study area, 1957-58 to 1964-65.

most of the oak trees in the valley produced large quantities of acorns and many birds from November onwards were seen feeding under them.

The 1959 summer was very dry and hot and with extensive cattle grazing most meadow vegetation was eaten down and comparatively little seed was produced. In consequence the meadows were not favoured feeding grounds during the 1959-60 shooting season, and most of the food taken was obtained from the river with relatively frequent and large amounts of animal material being eaten, especially caddis-fly and black-fly.

The late summer, autumn and winter of 1960 were distinguished by prolonged and at times heavy rain. This resulted in widespread flooding of the water-meadows, where most of the feeding took place. Comparatively little feeding occurred in the river itself, though the seeds of bur-reed occurred in 46.2% of the birds examined from the 1960-61 season and appeared to be obtained mainly from the river banks. It was in this year, following the floods, that Mallard were first seen to be feeding on horsetail tips, particularly *Equisetum arvense*. The acorn crop was again large, after a year when virtually none were produced.

In 1961 a hot dry summer was followed by rain, and in the beginning of 1962 extensive flooding of the water-meadows occurred. Feeding during this season was spread over a large area, and food was taken from the meadows, from the river and from the river banks in about equal proportions. Again it was a year when some of the oaks produced large acorn crops.

During the 1962-63 shooting season, following a rather cool and wet summer, rain and snow occurred with a prolonged very cold spell into the spring of 1963. In the summer and autumn of 1962 the river was widened and a large proportion of the river bank flora was destroyed, particularly the beds of bur-reed. It was noted that most birds fed mainly in the river, or on the meadows before they were covered with snow and ice. Much of the food taken consisted of animal material (79.3% of the total volume; the most in any of the eight years under consideration) and most of this was obtained from the river, or later on when this was frozen over, from the open parts of the gravel pits. Again, statistical tests showed significantly higher frequencies of river species as compared with wet meadow and gravel pit species.

In 1963 the summer was cold and rather dull with a comparatively mild but wet autumn and winter, with the resultant widespread flooding of the low-lying meadows. There was also some weed clearance in the river during the summer and autumn. Most feeding occurred in the shallow flooded meadows and to a lesser extent in the river and on the banks, where the flora had re-established itself after the drastic clearance of the year before.

The summer of 1964 was dry followed by some rain and shallow flooding, and the conditions for meadow feeding were ideal with a good seed crop being produced and wet conditions prevailing. A large proportion of the food during the 1964-65 season was obtained from the wet meadows with comparatively little being taken from the river and its banks. This was again a year when acorns were produced in considerable quantities and Mallard were often seen feeding under the oak trees in the river valley. Plants characteristic of gravel pits featured significantly in the analysis of stomach contents.

It is obvious then that the general diet changes from year to year and this can be related to factors which effect the production and availability of food items. This does emphasise the need for food studies in one area to extend over a number of consecutive years.

The most striking change in the area in the last ten years has been the development of the gravel pits. More and more wildfowl feeding occurs within and immediately around the pits and this is likely to increase as the planting programme (Harrison, Harrison and Olney 1962, Olney 1964, Harrison and Harrison 1964) takes effect and more seed is produced, and more invertebrates become established, particularly amongst the submerged plants. The overall population of wildfowl is likely to increase, with extra feeding areas around and within the pits, and with the continued undisturbed river valley between Sevenoaks and Otford. This pattern of change (more feeding areas and more birds) is already becoming obvious.

OTHER SPECIES

Teal *Anas c.crecca*

Otford area. Sixteen Teal were collected from this area during the shooting season between 1959 and 1964. Seeds occurred in 15 of these birds and animal material in six. Then contents of the food tracts are shown in Table V.

The seeds of *Ranunculus repens, Rubus fruticosus* agg. and *Polygonum persicaria,* and Chironomidae larvae occurred the

most frequently and in the greatest quantity. This closely follows the rating of foods found in 96 Teal collected from inland waters around the country (Olney 1963a), and appears therefore to be a true indication of what the normal diet in this area is.

forming the largest proportion, is similar to that found in the larger samples described by Olney (1963b).

Otford area. Few Tufted Ducks fed in this area and only three were collected from off the river during 1962-63. Animal material predominated with the caddis-fly

Table V. Food in stomach contents of 16 Teal from Otford area, 1959-64.

Plant material	*Frequency*	*Animal material*	*Frequency*
Seeds:		Chironomidae larvae	6
Ranunculus repens	7	*Pisidium* sp.	2
Rubus fruticosus agg.	4		
Polygonum persicaria	4		
Rumex conglomeratus	3		

Seeds only occurring once: *Polygonum nodosum, P. amphibium, P. aviculare, Glyceria sp., Scirpus lacustris, Galium aparine, Rorippa officinale, Alnus glutinosa, Sambucus nigra, Juncus* sp., *Trifolium repens.*
Animal material occurring only once: *Asellus* sp., *Planorbis* sp., *Hydrobia jenkinsi,* Limnophilidae larvae, Polycentropidae larvae, Lumbricidae.

Wigeon *Anas penelope*

Two Wigeon feeding in the meadows of the river valley were collected in January 1963, and both contained grasses, including rough meadow-grass *Poa trivialis,* annual meadow-grass *P. annua,* and creeping fescue *Festuca rubra.*

Tufted Duck *Aythya fuligula*

Gravel pits. The number of Tufted Duck visiting the gravel pits has increased dramatically since 1960 (Harrison, Harrison and Meikle 1967), presumably mainly due to the increase in the invertebrate aquatic fauna. Five birds were collected in 1962 and one in 1964. The list of food items found is shown in Table VI. The type of food found, with molluscs

Table VI. Stomach contents of six Tufted Ducks from Sevenoaks gravel pits, 1962 and 1964.

Animal material	*Frequency*
Hydrobia jenkinsi	3
Pisidium sp.	3
Anodonta sp.	2
Limnaea pereger	2
Chironomidae	3
Helobdella stagnalis	2

Animal material occurring only once: *Planorbis complanatus, Gammarus pulex, Asellus aquaticus, Plantambus maculatus.*

Plant material occurring only once: *Ceratophyllum* sp., *Elodea canadensis,* and *Ranunculus aquatilis* leaf.

Hydropsyche angustipennis being found in each bird and forming the major part of the contents. Parts of a small crayfish *Astacus pallipes* were found in one bird and in another Tufted Duck picked up dead by the Bradbourne Lakes in January 1963, less than a mile away from the river, most of its last meal consisted of crayfish.

Pochard *Aythya ferina*

A Pochard collected on the gravel pits was found to contain food consisting mainly of a filamentous algae and a few Chironomidae larvae.

Smew *Mergus albellus*

Two female Smew were collected in January 1963 from off the river and were found to contain a number of small trout *Salmo fario,* the longest of which was 14 cm.

Canada Goose *Branta canadensis*

Eight Canada Geese were collected in the Otford area between 1960 and 1963, four of which were found to be empty of food. Three of the others had fed mainly on the leaf, stem and roots of white clover *Trifolium repens* and to a lesser extent on grasses. One bird had fed exclusively on barley grains.

White-fronted Goose *Anser a. albifrons*

A bird shot in January 1964 in the Otford area contained a number of grasses, including the creeping bent *Argostis stolonifera* var. *palustris,* and creeping fescue *Festuca rubra.*

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Part III. An appraisal of the planting programme, 1959-66

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Summary

The production of food (seed) and cover by plants, introduced in the course of management of the W.A.G.B.I.—Wildfowl Trust Experimental Reserve, was estimated in 1966. There were considerable differences between the yields of the sixteen species investigated, when food was assessed in terms of dry weight. In general, much higher yields could be obtained from agricultural crop species.

The amount of food produced was inadequate to support the winter population of wildfowl observed; the prime function of the reserve was to act as a roost in the vicinity of alternative feeding areas.

Considerable cover had been developed through planting, and appeared to be reflected in an increase in the breeding population. The moderate amount of food available may have been an important additional factor of the success of the reserve as a breeding station for wildfowl.

On the basis of results obtained, recommendations are made for short- and long-term planting programmes for similar areas.

Introduction

The establishment of wildfowl food and cover plants within the Kent Sand and Ballast Reserve was commenced in 1959. At that time, the reserve consisted of two gravel pits, both in active operation, with little or no marginal and submerged vegetation. The selection of plant species was based on results from the analysis of viscera of wildfowl shot in the immediate vicinity (Olney 1967). Planting has been carried out continuously since 1959, and has always reflected the results obtained from viscera analysis. In recent years, new species have been added which, although not necessarily of previous local importance to wildfowl, have been shown by Olney (1962, 1963a, 1963b, 1964) to be of general value to overwintering wildfowl in Great Britain. Wherever possible, planting to provide resting and loafing cover has incorporated species that are known to provide food also.

Perhaps the most difficult problem in

the development of gravel pits as wildfowl refuges lies in the steep banks and deep water which are generally encountered. Due largely to the co-operation of the owner, however, it has been possible to investigate various techniques for overcoming this problem. Since these techniques are often rather expensive to apply (Meikle 1967), it is important that they should be evaluated, so that the most efficient management programme can be immediately adopted following the instigation of new reserves of this nature. There can be little doubt that gravel pits will play an increasingly important role in the conservation of wildfowl, both in this country and abroad.

The effectiveness of many of the improvements has already been discussed by Harrison, Harrison and Olney (1962) and Harrison, Harrison and Meikle (1965). Some of the more recent modifications, such as the provision of small bays and low-lying areas for planting, have yet to become properly established. Since the area is a joint experimental reserve of the Wildfowl Trust and W.A.G.B.I., however, its progress will continue to be documented in the annual reports of these two organizations.

With vegetation now well established in and around the West Lake, and much of the East Lake also, it was considered that the summer of 1966 would be an opportune time for a critical analysis of the planting completed to date. Furthermore, during the second half of 1966, a new pit (the future North Lake) was excavated. This third sheet of water will be very different from the two existing lakes, mainly on account of its very shallow nature. It was important, therefore, that an assessment be completed in 1966, to permit a detailed analysis of the effectiveness of this additional feature in the future.

The vegetation within the reserve was investigated in two ways. First, the amount of wildfowl food produced by introduced plants (and by the naturally regenerated vegetation resulting from them) was estimated. Secondly, the banks and margins of each lake were examined with a view to evaluating the cover produced by different types of vegetation. The results of these studies have been presented in such a way as to provide some guidance to further planting elsewhere.

Methods

Food production by introduced plants

This investigation was simplified by the fact that successfully introduced plants only included those species whose prime food value has been shown by Olney (1962, 1963a, 1964b, 1965) to lie in their seed production. Production has been considered in terms of oven-dry (o.d.) weight, since this eliminates the highly variable water content of seeds, and may be readily reproduced for the purposes of comparative studies.

Seed production by species forming definite stands, such as reed-grass *Glyceria maxima* and amphibious bistort *Polygonum amphibium*, was calculated on the basis of stand area. Often, the various stages of seed formation overlapped, rendering direct measurement of total production impracticable. In such cases, the total number of inflorescences was estimated using quadrats, and by measurement of stand dimensions. The yield from ripe inflorescences was determined at a later date, to obtain an estimate of overall production. Allowances were made, where necessary, for losses during the intervening period. For example, several, or sometimes all, capitula within a single inflorescence of bur-reed *Sparganium erectum* died off before the seed had ripened.

Species not forming distinct beds or stands were dealt with as individual plants. The total number of flowering plants was counted, and a sample taken at the time of seed-ripening. Variation in ripening times of seeds within plants necessitated counting unripe seeds or capsules, with corrections made for subsequent changes in weight during ripening. In general, only large herbs and trees were measured in this manner, although the distribution of figwort *Scrophularia aquatica* was such that plants had to be considered individually. In the case of rush (*Juncus* spp.) clumps were counted according to diameter, and yields determined from samples of each size group.

The method of yield measurement may be inferred for each species from Table I. Owing to the very small quantities of material within the reserve, yields for bulrush *Schoenoplectus lacustris*, sea club-rush *Scirpus maritimus* and amphibious bistort were determined from stands in gravel and clay pits in the Slimbridge district. Birch (*Betula*) was not included in this investigation, although over a hundred seeding specimens were present; this was due to practical difficulties encountered in measuring seed production.

A number of seed collecting-boxes, similar to those described by Davidson *et al.* (1955), were placed beneath the canopy of a group of large alders, to provide an estimate of yield from trees older than those planted during the course of management.

Cover

The assessment of cover is, of necessity, somewhat subjective since its value cannot be readily determined. Existing vegetation, including that which had resulted from natural colonisation, was considered in terms of potential for nesting sites, and of value as feeding and resting areas for young birds. The former was taken as cover above water level, the latter as cover at water level, including that provided by overhanging branches.

The periphery of each lake was mapped in large scale (1:1,000); the amount of bank and water-margin cover was determined from this map with the aid of a mileage recorder.

Results

Food production

The mean plant or stand yields are listed for each species in Table I, together with overall yields for the reserve and an indication of seed size. The yields of a number of species not found or not seeding within the reserve, including certain agricultural crops, have been added to the table for comparative purposes.

The gross yield, 71 kgm., was perhaps lower than expected, but it should be remembered that only very narrow strips of land and water margin were suitable for planting. The yield is equivalent to rather less than two hundredweight of fresh cereal grain, which could be grown in about one twentieth of an acre, or recovered from about one acre of stubble.

The highest individual plant yields were obtained from rushes and great water dock *Rumex hydrolapathum*. Since these species occur towards opposite ends of a broad range of seed sizes, it is clear that size of seed itself is not necessarily an indicator of yield.

Among the species in which seed production was measured in relation to ground area occupied, persicaria or redleg *Polygonum persicaria* showed an outstandingly high yield, comparable with that of the related species, buckwheat *Polygonum fagopyrum*. The latter is commonly cultivated in North America as a wildfowl food plant. All other species listed have yields less than 50 gm./m². (about 4 cwt./acre).

It is interesting that rather low yields

Table I. Seed yields.

Species	*Mean wt. of single seed (gm)*	*Mean seed yield (gm) /plant*	*/m²*	*Wt. of seed produced (gm) West Lake*	*East Lake*	*Total*
Plants within the reserve						
Alnus glutinosa Ht: <4m.	0.00076	8.7	—	130	0	130
Ht: 4-8m.	0.00076	c.250	—	c.5,250	0	5,250
(Ht: >8m.)	0.00076	(730+)	—	0	(c.20,000)	(c.20,000)
Carex riparia	0.00145*	—	10.2	0	0	0
Glyceria maxima	0.00050	—	20.9	310	300	610
*Juncus effusus***	0.000017	29.2	—	1,450	15,780	17,230
*Juncus inflexus***	0.000016	39.0	—	2,040	11,630	13,670
*Luzula sylvatica***	0.00124	31.0	—	0	160	160
Polygonum amphibium	0.0033	—	6.0	6	15	21
Polygonum persicaria	0.0021	—	113.0	0	8,140	8,140
Potamogeton crispus	0.0035*	—	40.2*	0	0	0
Rubus fruticosus agg.	0.0022	—	38.7	4,060	2,400	6,460
Rumex hydrolapathum	0.0044	183.0	—	4,560	0	4,560
Rumex spp. (others)**	0.00081	8.7	—	3,270	3,380	6,650
Scirpus maritimus	0.0030*	—	11.0*	1	0	1
Schoenoplectus lacustris	0.00102*	—	16.7*	8	4	12
*Scrophularia aquatica***	0.000083	4.3	—	280	6,970	7,250
Sparganium erectum	0.0091	3.0	—	950	150	1,100
Total				22,315	48,929	71,244
Other species						
Alisma plantago-aquatica	0.00039	28.8	—			
Eleocharis palustris	0.00091	—	38.4			
Potamogeton natans	0.0028	—	24.5			
Agricultural crops						
Cereals (normal harvest)	0.042	—	c.500			
„ (stubble waste)	0.042	—	c.25			
Buckwheat	not known	—	c.150			

* Data obtained outside reserve. ** Self-introduced. ( ) Not included in totals.

were observed in alder *Alnus glutinosa* and bur-reed, species which featured prominently in the viscera analyses of locally-shot birds, described in Part II. It should be noted, however, that the 1966 seed crop in both of these species was exceptionally poor, compared with those observed in previous years. Alder is known to be somewhat periodic in mast yields, although actual periods of high production may not be the same in all plants. Analysis of the contents of seed collecting boxes, placed under three alder trees each about 10 m. in height, indicated a ground yield of 3.6 gm./m^2 over an area of approximately 450 m^2, i.e., a total yield of 1.62 kgm. or an average of 0.54 kgm. per tree. The boxes used in this investigation were recovered on 12th January, 1967; samples of "cones" collected on this date showed that about 26 per cent of the total yield had yet to be dispersed. Thus, the average tree yield was at least 0.73 kgm. (not including an unknown quantity of seed dispersed beyond the range covered by collecting boxes). This is almost treble the estimated yield of the oldest trees planted during the course of management.

It should be noted that no rushes had been deliberately planted in the reserve. The yields given in Table I resulted entirely from self-introduced and regenerated plants.

Some idea of the relative ease with which different species may be established in this type of habitat may be obtained from Table II, in which the numbers planted since 1959, and the numbers or area of stand established by 1966 are given. Through reference to Tables I and II together, it is possible to determine which species are most likely to be of immediate benefit to a new reserve; long term effects are less predictable, since even quite poor initial results could lead to extensive areas of established vegetation. It should be noted that, in certain cases, there is a discrepancy between the total yield quoted in Table I, and the product of plant yield (Table I) and number established (Table II). This is due to the inclusion of non-seeding plants in Table II.

Table II. Results of planting.

Species	*Number planted*	*Establishment* *Number*	*Area (m^2)*
Alnus glutinosa (Ht: >1m.)	2066	979	—
Atriplex patula	55	—	3.5
Betula spp. (Ht: >1m.)	1036	470	—
Carex riparia	30	—	116
Ceratophyllum demersum	16	—	>10,000
Chara sp.	23	Not found	
Eleocharis palustris	12	—	0
Glyceria maxima	526	—	29
Hippuris vulgaris	55	0	—
Juncus effusus	0	589	—
Juncus inflexus	0	351	—
Luzula sylvatica	0	—	5.2
Phragmites communis	55	—	0
Polygonum amphibium	41	—	3.5
Polygonum hydropiper	57	—	0
Polygonum persicaria	22	—	72
Potamogeton crispus	0	—	>1000
Potamogeton obtusifolius	0	—	>50
Rorippa nasturtium-aquatica	100	0	—
Rubus fruticosus agg.	192	—	167
Rumex hydrolapathum	54	25	—
Rumex spp. (others)	0	820	—
Scirpus maritimus	200	—	0.1
Schoenoplectus lacustris	46	—	0.7
Scrophularia aquatica	0	1680	—
Sparganium erectum	1425	3080	—
Zannichellia palustris	4	—	100

Numbers of other species planted: *Acer platanoides* (4), *A. pseudoplatanus* (10), *Crataegus monogyna* (101), *Fraxinus excelsior* (2), *Iris pseudacorus* (28), *Larix leptolepis* (184), *Lupinus arboreus* (6), *Pinus sylvestris* (406), *Populus* spp. (35), *Prunus avium* (6), *Pseudotsuga Douglasii* (19), *Quercus robur* (4), *Q. rubra* (4), *Salix atrocinerea* (6), *Salix* spp. (259), *Sorbus aucuparia* (5), *Thelycrania sanguinea* (23), *Ulex europaeus* (37).

Cover

The shoreline of the more mature West Lake was 1,395 m. long, of which 987 m. (71 per cent) were backed by bank cover suitable for nesting or affording a screen, and 735 m. (53 per cent) carried margin cover. The most extensive and dense bank cover usually comprised blackberry *Rubus fructicosis* agg., often with raspberry *R. idaeus* and elder *Sambucus nigra*, although stands of willow herb *Epilobium hirsutum* also provided excellent cover during summer. Alders and willows (*Salix* spp.) situated near the water's edge provided both bank and marginal cover. Other marginal cover consisted mainly of bur-reed, which had spread rapidly from planting centres, with some reed-grass, pond-sedge *Carex riparia* and occasional rushes.

The shoreline of the East Lake was 2,900 m. long, with 1,146 m. (39 per cent) bank cover and 800 m. (28 per cent) marginal cover. These low proportions of cover reflect the more juvenile nature of this pit, which is still being excavated. Blackberry and alder provided much of the bank cover. In contrast to the West Lake, rushes were the most abundant plants affording marginal cover, while bur-reed, reed-grass and pond-sedge assumed only local importance.

Discussion

The primary object of this investigation was to determine the extent to which planting had contributed to the establishment and maintenance of the wildfowl population in the reserve, described by Harrison, Harrison and Meikle (1967). It is, however, very difficult to obtain an accurate assessment of the value of vegetative components in establishing the population. Certainly, the development of cover was followed by an increase in the breeding population, as indicated by the steady rise in the number of Mallard broods over recent years.

The establishment of a large number of trees and shrubs, including species other than food plants, led to a reduction in general disturbance at the water's edge, and was possibly an important factor in the steady build-up of the winter population.

In order to determine the value of planting food species, it is first necessary to reassess calculated yields in terms of wildfowl maintenance potential. There is, as yet, no precise information relating to the daily food requirements of free-living wild-fowl. Jordan (1953) observed an average daily intake of 82 gm. (0.18 lb.), fresh weight, of small grains during winter in captive drake Mallard. Intake by females was rather less. It is difficult to extrapolate this figure for the requirement of a wild Mallard, which must be highly dependent on environmental factors such as temperature, disturbance and flight distances, and on season. For the purposes of assessing carrying capacity, insofar as it is affected by food, Jordan's figure (above) has been accepted as the minimum likely requirement of each duck. It seems almost certain that the natural requirement of Mallard is higher than this. However, any underestimation is offset by the fact that the Mallard, the heaviest duck under consideration, is not the only species present. Smaller species presumably have lower requirements (Jordan found that Blue-winged Teal consumed only 40% of the weight of small grain taken by Mallard). It is impossible to calculate precisely the oven dry weight equivalent for the mixed grains fed in Jordan's experiments. To compensate further for the higher requirements of wild birds, therefore, the same figure (82 gm.) has been adopted for expression as oven dry weight.

The calculated seed production by introduced plants for the two lakes in 1966 was 71 kgm. (157 lb.). From the above assumption, this may be regarded as equivalent to about 870 duck days. In addition to the calculated yield, however, a considerable amount of seed was produced by birch, several large oaks and many long established alders. Also, an unknown quantity of seed was brought into the West Lake by the River Darent. Yields from submerged plants were not measured; the extensive beds of curled pondweed *Potamogeton crispus* and hornwort *Ceratophyllum demersum* did not, in fact, contribute significant quantities of seed. The reasons for this appeared to be (i) excessive water depth, in the case of the former, and (ii) grazing of emergent flowers and seed heads of both species by resident geese during their flightless period.

All species of wildfowl frequenting the reserve exploit, to a greater or lesser extent, food sources not considered in this paper. Tufted Duck, for example, rely mainly on aquatic animal life (Olney 1963b, 1967), whilst Pochard often feed extensively on the seeds of submerged plants (Olney, pers. com.). No consideration has been made of the feeding habits of the relatively large population of Greylag and Canada Geese, which, besides grazing in surrounding fields, graze extensively on submerged plants during the summer.

It is important to consider the habitat and siting of plants when assessing their importance as a wildfowl food source. Blackberry scrub, for example, occupied considerable areas, yielding a relatively large quantity of seed. Much of this food probably remained unexploited by wildfowl, after falling into dry litter in sometimes impenetrable areas. In contrast, amphibious bistort, with only one seventh the yield of blackberry, is capable of extending into quite deep water (at least 2 m.). All seed falls into water or mud, where it may be utilised by wildfowl. It was not always possible to determine what proportion of food produced was actually available to wildfowl, since this depended on water level, the action of rainfall on banks, and the extent to which wildfowl feed on dry ground. It may be assumed that most of the seed of marginal species was available; however, the fate of seed produced by plants growing on the banks is open to question. Much of the alder seed ultimately fell into water, and accumulated with marginal debris. A sample of such debris, taken from a small pool near the East Lake in January, 1967, was found to include 15 per cent by weight (o.d.) alder seed.

Another characteristic that requires consideration is the buoyancy of seeds. Those of dock *Rumex* spp. sink immediately, whilst seed of birch and wych elm *Ulmus glabra* require several days of soaking before they sink (Pollard, unpublished). Praeger (1913) observed that seeds of bur-reed remain buoyant for at least a year. Clearly, the duration of buoyancy has an important bearing on the distribution of seed as food, and indeed, on the distribution of the plant species itself.

The availability of seed also depends on the period of dormancy before germination. Seeds of marsh yellowcress *Rorippa islandica*, submerged in August, were found to germinate almost immediately; seeds of sea club-rush, on the other hand, showed very low rates of germination even after a year (Pollard, unpublished).

Some seed species may be available or palatable to only a limited number of wildfowl species. Thus, the seed of curled pondweed may be dispersed into any depth of water up to about 2 m., but only in depths up to about 40 cm. would they be generally available to dabbling duck. Diving duck such as Pochard may take seed at any depth within the tolerance range of this plant. Size of seed may also be a critical factor in its utilisation. Seeds of bur-reed are sufficiently large to be selected and ingested as individual items. Seeds of soft rush *Juncus effusus*, weighing about 1/60,000 gm. each, are obviously too small to be considered individually by any duck. Nevertheless, two Teal, shot by the author in December, 1965, from a pack of about 150 birds on an estuary in Wales, contained about 4 gm. (o.d.) each of seeds of this species, i.e. about one quarter of a million items. Similarly, Olney (1963a) found an estimated 73,000 seeds of sharp-flowered rush *Juncus acutiflorus* in the gullet of a single Teal shot in Westmorland. It seems likely that these birds had been dibbling almost indiscriminately around the margins of a flash or ditch, where seeds had accumulated through wind and wave action. In view of the comparative rarity of rush seeds in wildfowl viscera, however, it is thought that these plants are only of importance in the absence of other species, i.e. in rather oligotrophic habitats.

Assessment of seed production in terms of dry weight alone does not take into account the nutritional values of the different foodstuffs. Even under controlled experimental conditions, these values are difficult to establish. With highly mobile subjects such as wildfowl, nutritional values may be almost impossible to determine under field conditions. It is believed, however, that the variability in dry weight yield, as observed among the species considered in this investigation, is likely to be a more important factor of their value as food sources than the variability in nutritional values of standard quantities.

It must be emphasised that the yields for each species given in this account are, in general, as determined within the reserve during 1966. Considerable deviation from these values may occur within the same species in different localities or in different seasons; environmental and climatic factors are known to affect yield. For example, Hunt and Lutz (1959) showed that water depth had a profound effect on the seed yield of curled pondweed. It is important, therefore, that the data presented in Table I are not extrapolated too rigidly to other localities.

The evaluation of the importance of food production within a small artificial reserve such as that studied is complicated by the movement of birds to other feeding grounds. There was a large discrepancy between calculated and observed carrying capacity (if, indeed, actual capacity had been attained). It was shown by Olney (1967) that a great deal of food was available to and was taken by wildfowl in the near vicinity of the reserve. Furthermore, there was considerable

variation in winter feeding patterns from year to year, depending to a large extent on the climatic conditions during the previous summer. It would appear that the amount of food within the reserve, and particularly that derived from introduced plants, could not maintain the winter populations described by Harrison, Harrison and Meikle (1967). This is not to say, however, that planting wildfowl food species had been of no practical value. An abundant supply of vegetable food during the second half of summer is likely to be of considerable importance to a breeding population. Furthermore, it is possible that the availability of food in autumn, albeit limited, encouraged overwintering birds to establish themselves in the reserve, which in turn provided a safe roost in the vicinity of alternative feeding grounds. In this respect, increases in the winter duck population may not reflect proportional increases in food production, although certain species, notably Tufted Duck and Pochard, do tend to act as indicators of the productivity of inland freshwater habitats.

The original planting programme was, as stated above, based principally on the findings of viscera analysis. At that time, little was known of the value of each species; this investigation has shown that food plants vary enormously in their gross food production. Certain species, notably alder, cannot be expected to contribute significantly until they have been established for some time, approximately eight years in this case. However, there are species which offer considerable scope for increasing the productivity of wetlands, with respect to wildfowl, within a much shorter period. It is recommended that special efforts should be made to established the following: persicaria (an annual species which rapidly colonises open ground), great water dock, blackberry, amphibious bistort (which, despite low yields, will spread rapidly into quite deep water), reed-grass, and curled and broad-leaved pondweed. The latter two species are most suitable for shallow waters, and could be augmented by other pondweeds, such as fennel-leaved *Potamogeton pectinatus*. These, together with alder, are considered to be among the most useful vegetative components of smaller wildfowl reserves, producing not only considerable quantities of food, but also providing a variety of cover.

In conclusion, it is suggested that the high winter wildfowl population of the Kent Sand and Ballast Reserve has been due mainly to the protection afforded to birds, in the vicinity of feeding grounds. Food production, on the limited scale that has thus far occurred within the reserve, is more likely to have affected the summer population, especially breeding birds. In view of the large number of food plants yet to attain maturity (particularly alder) this situation may be modified in the future.

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Part IV. Expenditure for habitat improvement

A. MEIKLE

Summary

Minimum expenditure involved in the improvement and management of the reserve is itemised for the period 1956-1966. Of a total outlay of £3,945, £3,230 has been assumed by the owners of the Kent Sand and Ballast Company, and £715 was spent by wildfowlers whilst collecting data and establishing plants and wildfowl in the reserve.

An estimate of the basic cost of converting the original gravel pits into a functional experimental wildfowl reserve is given here as it shows just how great our debt of gratitude is to the Kent Sand and Ballast Company in bearing so large a share of the financial burden of this project.

Among the first improvements to be made was the excavation of shallow pools along the margins of each lake. Six pools have been made, each taking approximately three hours to prepare, at a minimum cost of £1 10s. per hour for labour and equipment. Total cost £27.

After excavations in the East lake, it was found necessary to construct spits in some regions, otherwise a great deal of potential loafing and territorial areas would have been lost. Cost of construction varied according to size and location of spits and weather. Seven smaller spits, each taking about ten hours at £3 per hour were made with *in situ* material. Two large spits involved transportation of material each taking 40 hours to complete at a cost of £5 10s. per hour. Total cost of the nine spits: £503, after making allowance for routine work, which would have been done in any case.

An island, carrying several trees, was left in the East lake at a total cost, including 1,800 cu. yds. of saleable material and extra expenditure involved in adjacent excavation, estimated at £800.

Artificial raft islands have been constructed using steel tanks worth at least £10 each. The four rafts, which have proved to be of immense value as nesting sites for geese and great-crested grebes, cost a total of £200, whilst a further £50 has been spent on maintenance.

Of the 4,000 trees now established within the reserve 1,500 have been planted by the company, at an estimated cost of 8d. each. Total cost £50.

Since 1960, a full-time groundsman has been employed for general maintenance within the grounds. Total wages, etc., have amounted to £4,800, one third of which may be attributed to the reserve itself (the company and fishing interests assume the remainder). Total cost £1,600.

This gives a total cost to the reserve which has been borne by the company over the seven years ending December 31st, 1966, of £3,230. What has this very considerable sum achieved? The wildfowl count results, given by Harrison, Harrison and Miekle (1967), speak for themselves. But far more has been achieved than can be analysed in a paper such as this. The reserve has served as a proving ground for many new techniques of management, and will continue to do so, we hope, for many years to come. Valuable information of wide application has been obtained through being able to study wildfowl in relation to their environment at close quarters. And by no means last nor least, the Kent Sand and Ballast Company have shown that gravel extraction need not lead to dangerous and useless tracts of waste land. They have provided a shining example of how those responsible for industrial development and for wildfowl

conservation can combine together with spendid results; indeed, it is widely acknowledged as such by naturalists, scientists, and sportsmen, both in this country and abroad.

In view of the fact that naturalists are beginning to realise that they are going to have to contribute to the cost of conservation and for the privilege of being able to enjoy such facilities as bird watching, it is perhaps not irrelevant to conclude this section with the cost, which has been borne privately in the management of this reserve up to the end of 1966.

Over the 11 years, the average mileage covered has been estimated at 2,000 a year, at a cost of £220. Some 2,500 trees and 2,800 other plants have been put in. Basing the cost of these at 8d. each, this gives a total of £176. The cost of obtaining and rearing a duck to the time of release has been estimated at 10s. In all, 614 Mallard and 24 Gadwall have been reared at a cost of £319, to give a total cost of £715.

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