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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./m^2. (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*	*/m^2*	*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 over-wintering 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