Diet of non-breeding wildfowl *Anatidae* and Coot *Fulica atra* on the Perthois gravel pits, northeast France

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Abstract

Gravel pits are important habitats for wintering waterbirds, yet food selection by wildfowl wintering at these wetlands has seldom been studied. Here we describe the diet of eight dabbling and diving duck species, and also of Coot *Fulica atra*, at the Perthois gravel pits in northeast France. The pits form part of a broader Ramsar area and are in themselves of national importance for several Anatidae. From 343 guts collected, the gross diet of the nine bird species corresponded to that reported in the literature for these waterbirds on other types of inland wetlands, though Pochard *Ayhtya ferina* were almost exclusively granivorous here whereas earlier studies found that they fed more on invertebrates. All nine bird species ingested seeds, often in abundance, though in addition to Pochard only Teal *Anas crecca* and Mallard *A. platyrhynchos* could be considered as being true granivores. Two species (Spiny Naiad *Naïas marina* and Small Pondweed *Potamogeton pusillus*) were consistently among the most consumed seeds in eight out of nine bird species. The importance of these plant species may be typical to gravel pit in this study area. Animal prey was also well represented in the gut samples, and this study especially highlights the importance of Bryozoan statoblasts in waterbird diet. Management implications for gravel pit areas are suggested.

Keywords: gravel pits, diet, ducks, coot, winter, Perthois, France.

The importance of gravel pits as habitats for waterbirds has long been described (Keywood & Melluish 1953; Svedarsky & Crawford 1982). In Great Britain, 140,000 wintering wildfowl (Anatidae), or 7% of the total national counts, were estimated to occur on gravel pits in the 1980s. These habitats were particularly used by Tufted Duck (*Aythya fuligula*), Pochard (*Aythya ferina*) and Gadwall (*Anas strepera*), and to a lesser extent by Teal (*Anas crecca*) and Wigeon (*Anas penelope*) (Owen *et al.* 1986).

France is the third most productive sand and gravel producing country in Europe after Germany and Italy, with c.170 million tons extracted in 2005 (EAA 2006). About half of the sand and gravel is of alluvial origin. Extraction activities therefore create 1,500–2,000 ha of new flooded gravel pits annually (Dasnias 1998). In 2005, the total gravel pit area in France was estimated at 44,000–58,000 ha, equivalent to at least one-third of the area covered by fishponds in the country (Mouronval *et al.* 2005). At both the French and European scale, gravel pits may provide some mitigation for wetland loss or degradation, and also complement existing wetlands, by providing replacement or additional habitat for waterbirds. There is still no overall assessment of the role played by gravel pits as wintering grounds for waterbirds in France, but several regional studies highlight the local importance of these habitats for wildfowl (see for example Santoul *et al.* 2004). For instance, 78% of Tufted Duck, 70% of Coot (*Fulica atra*), 59% of Pochard, 52% of Gadwall and 36% of Mallard (*Anas platyrhynchos*) in the Ile de France region around Paris are found on gravel pits during mid-January counts (Dasnias 1998). In Alsace, northeast France, the gravel pits of the Rhine valley host 18% of wintering Mallard, 16% of Tufted Duck and 6.6% of Pochard of the area (Andres *et al.* 1994).

The carrying capacity of gravel pits depends to a large extent upon the abundance and accessibility of food resources, since these areas may be used not only as day roosts but also as diurnal or nocturnal foraging habitats (Mouronval *et al.* 2005). A better understanding of the diet of waterbirds frequenting gravel pits therefore would provide crucial information for maintaining or improving such habitats for birds. Yet few studies have investigated the diet of non-breeding waterbirds in gravel pit environments, and all of these were in the UK: Street (1975) described the diet of 88 Mallard wintering in a gravel pit network in Northamptonshire, Phillips (1991) analysed the gut contents of three Pochard foraging in Great Linford gravel pits, and Olney (1963, 1967a) analysed the diet of 54 Tufted Duck from a gravel pit in Buckinghamshire and of 16 Mallard from Sevenoaks gravel pits in Kent.

This paper describes the diet of wildfowl and Coot foraging in the Perthois gravel pits in northeast France. The study area was selected because of its importance for waterbirds – the Perthois is part of a Ramsar site ("Etangs de la Champagne Humide") that also includes the large barrage reservoirs of the Champagne region, and the site regularly receives over 100,000 waterbirds during winter or the migration period. The Perthois gravel pits themselves are of national importance for wintering Coot, Mute Swan (*Cygnus olor*), Pochard and Smew (*Mergus albellus*). Moreover, 50% of Tufted Duck and 29% of Goldeneye (*Bucephala clangula*) within the Ramsar area are recorded on the gravel pits in January (Mouronval *et al.* 2005).

Study area

The Perthois area is located in the middle of the vast wet Champagne depression, close to the city of Vitry-le-François, northeast France (48°43´33˝N, 04°35´09˝E). It is a quaternary alluvial plain, where the River Marne deposited clay alluviums. The exploitation of the alluviums led to the creation of approximately 300 flooded gravel pits, with a total surface area of about 760 ha (Mouronval *et al.* 2005 provide a more detailed description of the gravel pits). The oldest were dug by the end of the 19th century, and extraction continues today with, on average, 20 ha of new gravel pits created annually. The average surface area of the gravel pits is 2.9 ha (s.d. ± 2.8, range 0.1–24 ha), and their average depth is around two meters (s.d. ± 0.7) in winter, 1.5 m in summer. Their banks are relatively steep (mean = 37° ± 17.5), but those in the most recent gravel pits tend to have flatter slopes. Hydrophytes are well developed and cover, on average, 34% of the sediment area. Twenty-three species of vascular plants and several stonewort (*Characeae*) species have been described. The shoreline vegetation varies with the age of the gravel pits, with herbaceous plants belonging to the Buckwheat family (*Polygonum* spp.), the Goosefoot family (*Chenopodium* spp.), the Millet family (*Echinochloa* spp.) and Common Spike Rush *Eleocharis palustris* occurring mainly around recently dug pits, whereas rushes *Juncus* spp., sedges *Carex* spp. and Willows *Salix* spp. dominate the shores of the more mature sites. Leisure activities, especially fishing and hunting, are common practices on these gravel pits. The surroundings of these waterbodies mostly consist of cereal and sugar beet fields.

The Perthois gravel pits are used extensively by waterbirds in winter, especially ducks and Coot; 26 different species of Anatidae have been observed at least once within the study area. On average, more than 5,000 individual wildfowl and Coot were counted per month during censuses made between mid-October and mid-March. The counts were made twice a month over this period in winters 2000/01 and 2001/02 (Mouronval *et al.* 2005). The most abundant species were Coot (average over all counts 3,080 individuals, maximum 7,236), Pochard (average 823, maximum 1,202), Mallard (average 669, maximum 1,635), Tufted Duck (average 264, maximum 380) and Shoveler *Anas clypeata* (average 60, maximum 180). Two duck species that occur only in small numbers in France were also present in the Perthois: Smew (average 24 individuals, maximum 83) and Goldeneye (average 18, maximum 52). Conversely, the average number of Teal (37 individuals), Gadwall (24), Wigeon (4) and Pintail *Anas acuta* (4) wintering in the Perthois are insignificant compared to the large numbers recorded on nearby lakes and ponds. The relative abundance of Teal in the hunting bags of wildfowlers shooting over the gravel pits suggests, however, that Teal use these habitats more during the night (as nocturnal foraging areas) than during the day (as roosts), since hunting occurs at dawn or dusk (whilst the birds move between their roosts and foraging areas) or during the night. A comparison of bird densities recorded at ponds in the surrounding area with those recorded at the Perthois gravel pits has shown that the latter are particularly attractive to Coot, Pochard, Tufted Duck and Goldeneye, at least during the day.

Methods

The birds' diet was inferred from the content of their digestive tract (the oesophagus, proventriculus and gizzard), hereafter referred to as the 'gut'. In total, 292 duck guts from eight duck species and 51 Coot guts were collected from October 2000 to January 2001, August 2001 to February 2002 and October 2002 to January 2003 (Appendices 1a,b,c). Three-quarters of these were provided by local hunters. We preferentially collected guts of birds that had been shot in the second half of the night or during early morning, to increase the probability of these birds having foraged at the gravel pits. The remaining birds (quarter of the total sample) were shot by Office National de la Chasse et de la Faune Sauvage (ONCFS) staff under a licence delivered for scientific purposes by the Préfecture of the Marne department, the local administration responsible for issuing exceptional shooting licences for scientific purposes. These were mostly Tufted Duck, Goldeneye and Coot, which essentially forage during the day and are therefore only exceptionally killed by hunters. These birds were shot while they were actively foraging.

For most birds the whole gut was collected 1–7 h after death, and stored in 70% alcohol or 3% formaldehyde solution until analysed. The content of each gut was then separated into animal prey, 'seeds' (i.e. achenes, oogonia and seeds *s.s.*) and vegetative parts of plants.

The identity of animal prey was determined by professional hydrobiologists at the Institut Supérieur d'Agriculture Rhône-Alpes (ISARA) and Centre d'Etude du Machinisme Agricole, du Génie Rural et des Eaux et Forêts (CEMAGREF) laboratories, in most cases to the family taxonomic level, sometimes more precisely. Two measures were used to describe the contribution of animal prey to the birds' diet: (1) the frequency of occurrence (i.e. the number of guts with a particular prey item, given as a proportion of the total number of guts analysed for that bird species), and (2) their average relative abundance within all animal prey (i.e. the number of times that a given prey species was recorded, divided by the total number of animal prey items in each gut, then averaged over all individuals for each bird species).

Seeds were identified by us to the genus or species, except for *Characeae* oogonia which were identified to the family level. Identification was made by comparing seeds from the birds' guts with a reference collection of seeds collected from plants within the Perthois, or with other existing reference collections (Legagneux *et al.* in press). Seeds that were difficult to classify were identified by the Phanerogamy laboratory of the National Museum of Natural History in Paris. The relative contribution of each seed species to the diet of each bird species was assessed by its frequency of occurrence (see above) and by its average relative dry weight. The latter was calculated by dividing the dry weight of each seed species in each gut by the total dry weight of all seeds in the same gut, then taking the average over all individuals for a given bird species. Specific dry weights were taken from Arzel *et al.* (2007), augmented for some species not given by these authors by our drying of a sample of seeds of known number at 60°C for 24 h then weighing the dried sample. For each bird species, the Index of Relative Importance (Pinkas *et al.* 1971) was computed for each seed species. This index accounts for the frequency of occurrence, relative weight and relative abundance (in terms of number), following the formula: IRI = Occurrence (%) * (average dry weight (%) + average number of seeds (%)). IRI therefore is a global and synthetic assessment, summarizing three independent descriptors of an item's presence and abundance within a given bird species. It therefore allows seed species to be ranked in relation to their abundance in the diet of each bird species (Hart *et al.* 2002).

The vegetative parts of plants were determined to the species or genus level, except for *Characeae* and other algae. Their abundance was examined visually and scored from 0 (absence or trace) to 4 (very abundant). The contribution of vegetative parts of plants to the diet was expressed as their frequency of occurrence in the guts (see above) and, for each plant species, we computed their Relative Abundance (hereafter RA), the ratio of its abundance rank to the summed ranks of all plants in each gut. This was then averaged over all guts of a given bird species.

In this paper, diet was determined after analysis of the whole gut. About half of the oesophagi collected were empty, so it was not possible to follow Swanson & Bartonek's (1970) recommendation of analysing food found in different segments of the digestive tract. It is therefore likely that the importance of some hard food items (e.g. achenes) was overestimated, at the expense of soft ones such as invertebrate prey. Some information is however provided in the text whenever possible concerning the content of oesophagi, especially for seeds. Given our relatively small sample size, the diet had to be inferred for the non-breeding season as a whole, without assessing any variation over time (e.g. monthly within the non-breeding season) or in relation to the age or sex of the birds, and should be considered as a preliminary analysis for this habitat type.

To complement the analysis of Shoveler guts provided by hunters, zooplankton samples were collected in February 2001 using a zooplankton net (150 μm mesh size) within the upper 10 centimetres of water in the gravel pit where most Shoveler of the Perthois feed during daylight hours (average density: 10 birds/ha). Similar samples of the zooplankton community (% of different taxa present) were taken for comparison in two neighbouring gravel pits where Shovelers did not or only occasionally fed (0 and 0.16 birds/ha, respectively).

Results

Of the 343 guts collected, 14 were empty and thus not included in the analyses. In total, the guts contained invertebrates from over 42 different families, seeds from over 43 vascular plant species, oogonia from several *Characeae* species and vegetative parts from seven vascular plants, plus several *Characeae* and green algae (Appendices 1a,b,c). Diving ducks had consumed at least 11 more invertebrate families than dabbling ducks. Conversely, dabblers had at least 17 more plant species (either seeds or vegetative parts) in their guts than diving ducks.

Wigeon

Given the small number of Wigeon in the gravel pits of the Perthois, only 14 individuals could be collected, of which 13 had food in their gut. All guts analysed contained vegetative parts of plants. Small Pondweed *Potamogeton pusillus* was present in six of the seven birds for which vegetative parts could be identified (Fig. 1). This plant species had a 60% RA among vegetative parts on average. Less than half of the Wigeon guts contained seeds, and four of them contained less than five seed items. *P. pusillus* seeds were the most frequent, the most abundant and the most contributive in terms of relative weight; they represented 56% of the sum of the IRIs recorded for Wigeon (Appendix 1b). The other seeds mostly came from herbaceous plants from the shore of the gravel pits: *Eleocharis palustris*, Unbranched Bur-reed *Sparganium emersum*, Sea Club-rush *Scirpus maritimus* and Curlytop Knotweed *Polygonum lapathifolium*. Animal prey was rare: two birds contained statoblasts of the Bryozoan *Cristatella mucedo* and one a Water Louse *Asellus aquaticus*. A third bird had c. 500 Lepidoptera larvae, of the Beautiful China-mark Moth *Nymphula stagnata*. However, these larvae were within vegetative parts of *P. pusillus*.

Gadwall

Seventeen Gadwall guts were collected, which all contained food. Fourteen of these (82%) contained seeds, most often in small numbers (< 10 seeds in seven of the guts, though the gut of one individual contained close to 700 *Potamogeton pusillus* seeds) (Fig. 1). The most important seeds in the Gadwall's diet were *Eleocharis palustris*, *Potamogeton pusillus* and *Naïas marina*, representing 60% of the IRIs recorded for Gadwall (Appendix 1a). Ten birds (58.8%) had ingested vegetative parts of plants, all in limited quantities. Green algae species were the most important in terms of both frequency of occurrence and RA (c. 40% of the total vegetative parts), followed by the waterweed *Elodea* spp. leaves and duckweeds *Lemna* spp. Animal prey was not frequent nor diverse: five birds contained 2–110 *Cristatella mucedo* statoblats, and one bird contained one mollusc (from the *Pisidium* genus) and one non-biting midge (*Chironomidae* spp.) larvae.

Mallard

Seventy-seven of the Mallard guts contained food, 97.5% of these containing seeds, often in large numbers (Fig. 1). At least 36 seed species were found, of which seven accounted for 93% of the IRIs recorded for Mallard (Appendix 1a). *Naïas marina* and *Potamogeton pusillus* seeds were particularly important in terms of frequency of occurrence and of abundance (whether expressed as numbers or as weight); they represented three-quarters of the total IRIs. Spiked Water-milfoil *Myriophyllum spicatum*, Fennel-leaved Pondweed *Potamogeton pectinatus*, *Polygonum* spp., *Eleocharis palustris*

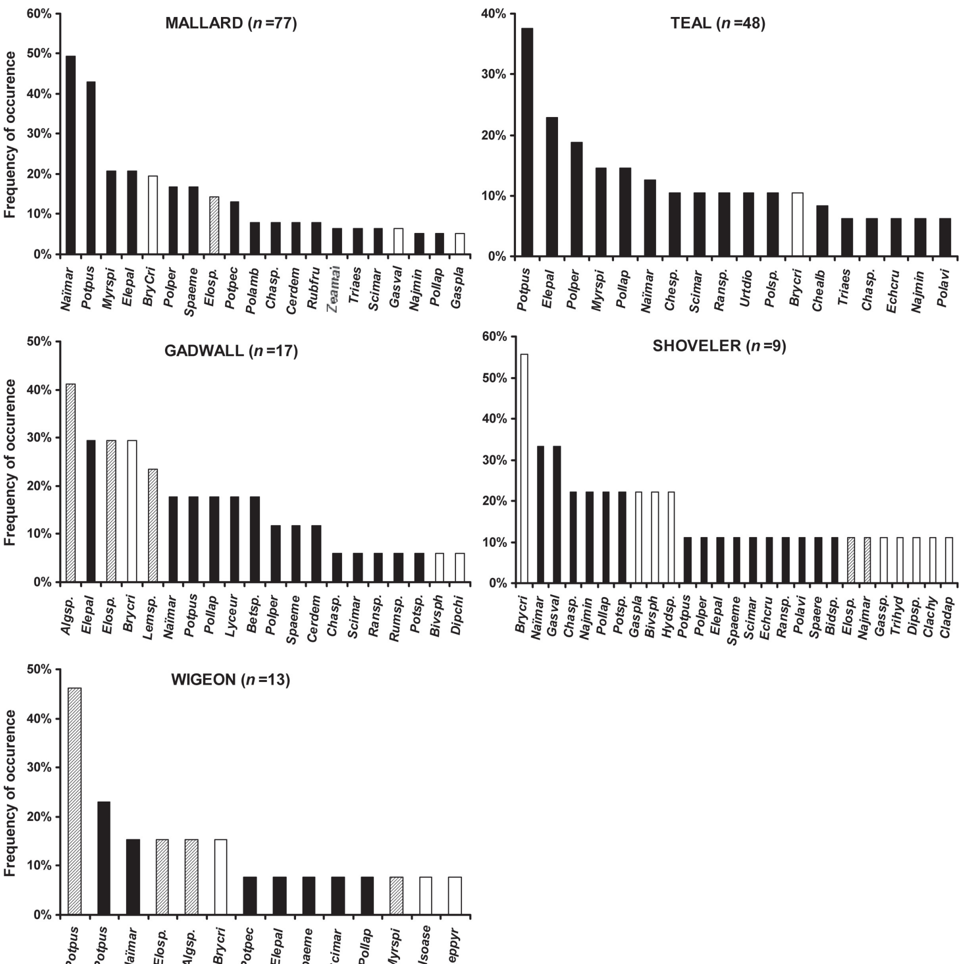

Figure 1. Frequency of occurrence of the main food items (occurrence > 5%) in the diet of Perthois dabbling ducks. Numbers in brackets (i.e. sample sizes) are the number of guts containing food for each duck species. Food species names from Appendix 1 are abbreviated (e.g. Naïmar for *Naïas marina*, Potsp. for *Potamogeton* spp.). Black columns = seeds, white columns = animal prey, dashed columns = vegetative parts of plants.

and *Sparganium emersum* were also well represented, *Polygonum* spp. seeds being found in 35% of birds. Seeds from three cereals (mostly Wheat *Triticum aestivum*) were also found, in 11.6% of Mallard guts. The overall importance of cereals in the Mallard diet is however difficult to assess given these were mostly represented by very large numbers of *Triticum aestivum* and Maize *Zea mais* in only six birds, of which three came from a gravel pit where hunters used cereals as bait for wildfowl along the shoreline. Vegetative parts of at least six plant species were found as traces in over 60% of the birds. One-third of the guts contained animal prey. Statoblasts of *Cristatella mucedo* were the most frequent prey and, on average, represented more than half the number of animal items recorded for Mallard. One bird contained 890 of these statoblasts, and several birds contained several hundred. Molluscs, especially of genera *Valvata* and *Gyraulus*, were found in 11.7 % of the birds and represented 15.5% of the number of invertebrate prey. Insect larvae from various families were found, but always in small numbers and in only 10% of the guts.

Teal

Of the 55 Teal collected 48 (87%) had ingested food and all of their guts contained seeds. Seeds from at least 33 plant species were found, of which approximately one-third accounted for 90% of the total IRIs. *Potamogeton pusillus*, Persicaria *P. persicaria* and *Eleocharis palustris* seeds were by far the most frequent (Fig. 1), and were the most important in terms of both numbers and weight, accounting for 67% of the IRIs (Appendix 1a). The *Polygonum* genus, with at least four different species, was present in 54% of the guts, representing 17.5% of the total number of seeds and 19.0% of their weight on average. *Myriophyllum spicatum* seeds were among the most frequent, but contributed only marginally to the overall diet because they were present in small numbers. Four Teal had ingested very large numbers of cereal *Triticum Aestivum* and *Zea mais* seeds. Only four birds contained fragments of vegetative parts of plants, which could not be identified. Less than one-quarter of the Teal guts contained animal prey. Diptera Fly larvae (1–18 items) were found in 12.5% of the birds, and *Cristatella mucedo* statoblasts (1–276 items) in 10.4% of these. These statoblasts represented, on average, 40% of the number of animal prey.

Shoveler

The nine Shoveler guts collected all contained food. Fourteen species of seeds and *Characeae* oogonia were identified in eight of the guts, but none of these was frequent and most were not abundant (Fig. 1). *Naïas marina*, *Eleocharis palustris*, Beggaticks from genus *Bidens*, *Scirpus maritimus*, *Polygonum lapathifolium*, *Potamogeton pusillus*, *Characeae* oogonia and Branched Bur-reed *Sparganium erectum* were the most important seed species, representing more than 90% of the total IRIs (Appendix 1b). Animal prey was found in eight of the Shoveler guts (89%). Six birds had ingested bivalve and gastropod molluscs, especially from the genera *Pisidium*, *Valvata* and *Gyraulus*. These represented 37% of animal prey on average. More than half of the guts contained *Cristatella mucedo* statoblasts (1–26 items), which represented 23% of animal prey. Cladocerans were found in only one bird (in both ephippia and adult stages), the adult Cladocerans being mostly *Eurycercus lamellatus*. Two Shovelers contained more than 50 Water Mites *Hydrachna* spp. each, which represented 22% of the prey on average. A few fragments of *Naïas marina* vegetative parts were found in one bird and of *Elodea* spp. in another one.

The qualitative analysis of the zooplankton community in the Perthois gravel pits provided additional indirect information on the diurnal diet of the Shoveler. In the gravel pit where most wintering Shoveler fed (average density: 10 birds/ha), 90% of zooplankton were large microcrustacea, c. 3 mm long: Calanoid Copepods *Acanthodiaptomus denticornis*, Cyclopoid Copepods *Cyclops vicinus* and Cladocerans *Daphnia longispina*. Small (0.2–0.6 mm) Daphnidae *Bosmina longirostris* represented 9% of the community, and rotifers of less than 1 mm represented *c.* 1% of the community. In the gravel pit seldom used by Shoveler (0.16 birds/ha), 90% of the zooplankton were small (1–2 mm) Daphnidae Cladocerans *Daphnia galatea*, 9% were large *Cyclops vicinus* and 1% were small (0.5–1.3 mm) Chydoridae Cladocerans. Finally, in the gravel pit where Shoveler did not feed, the community was composed of over 90% Rotifer *Asplancha priodonta* of very small size (<<1 mm), and less than 10% Cyclopoid Copepods *Acanthocyclops robustus*.

Pochard

Sixty-three Pochard (95% of collected birds) contained food. All guts contained seeds, often in very large numbers. Seeds from at least 18 plant species were identified. Among these, three accounted for 95% of the IRIs recorded for Pochard: *Naïas marina*, *Characeae* oogonia and *Potamogeton pusillus* (Appendix 1c). The very large (4 x 2.5 mm) *Naïas marina* seeds were found in 79% of the birds (Fig. 2), and alone represented 61% of the total IRIs recorded for Pochard. One bird contained 1,383 of these seeds. Although far less important, *Potamogeton pectinatus* and Shining Pondweed *P. lucens* seeds were also frequent, representing 5.2% and 3.5% of the relative weight of seeds respectively. These five taxa were also the most important on considering only the oesophagi of 24 Pochard for which this part of the gut was not empty. However, in the oesophagi, *Characeae* oogonia had a 2.7 times higher IRI than *Naïas marina* seeds. Oogonia were found in more than half of the oesophagi and represented on average 40% of relative seed weight. One bird had more than 10,000 of these in its oesophagus. Vegetative parts of plants were found in approximately half of the guts, but only as traces. It is most likely that these were ingested incidentally while the birds were foraging on seeds. One-third of the birds contained animal prey. These were mostly *Cristatella mucedo* statoblasts, which accounted for 85% of the total number of invertebrates, including 400 found in the gut of a single bird.

Goldeneye

Only seven Goldeneye guts were analysed, but all were collected while the birds were actively foraging, and hence contained food. All guts contained seeds from at least eight plant species. Seven of these were hydrophytes and one (*Polygonum persicaria*) was a typical wetland herbaceous species.

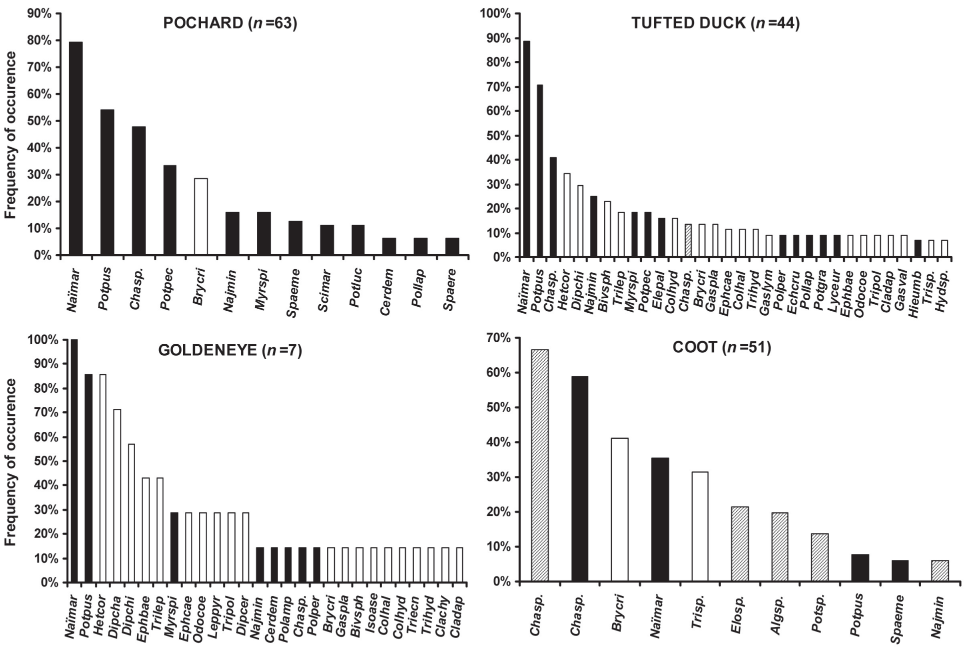

Figure 2. Frequency of occurrence of the main food items (occurrence > 5%) in the diet of Perthois diving ducks and Coot. Numbers in brackets (i.e. sample sizes) are the number of guts containing food for each bird species. Food species names from Appendix 2 are abbreviated (e.g. Naïmar for *Naïas marina*, Potsp. for *Potamogeton* spp.). Black columns = seeds, white columns = animal prey, dashed columns = vegetative parts of plants.

Naïas marina and *Potamogeton pusillus* formed the bulk of the seeds (Fig. 2) and represented 95% and 4% of the IRIs recorded for Goldeneye, respectively (Appendix 1c). *Naïas marina* was also the only seed found in the oesophagi of the four Goldeneye with seeds in this part of the gut. No bird contained visible vegetative plant parts. Conversely, 20 invertebrate families were identified in Goldeneye, which all had some animal prey, generally in large numbers. Diptera, especially Phantom Midges *Chaoboridae* and *Chironomidae* larvae, were found in six of the seven birds and together represented 68% of invertebrate prey. Planktonic larvae of the *Chaoborus* genus were found in five Goldeneye guts, sometimes in large numbers (up to 845 items in a single gut). *Ephemeroptera* (mainly Mayflies from the genera *Caenis* and *Cloeon*) and Caddisflies *Trichoptera* from four families were relatively frequent and abundant. They represented on average 11% and 10% of the relative number of invertebrates. Water Boatmen *Corixidae* (notably genus *Sigara*) were observed in six out of seven birds, but never in large numbers. One bird contained 11 *Cristatella mucedo* statoblasts.

Coot

The 51 Coot guts all contained food, 82% of them containing seeds from at least 13 plant species. Among these, *Characeae* oogonia and *Naïas marina* seeds were by far the most important in terms of frequency of occurrence (Fig. 2), relative number and relative weight. Together, they accounted for 98% of the IRIs recorded for Coot (Appendix 1b). The *Characeae* IRI alone represented 75% of the total IRIs. Separate analysis of the oesophagus of the eight birds with food in this part of their gut provided a similar result. *Potamogeton pusillus* was the third most important species (6.2% of relative seed weight on average). Vegetative parts from at least five plant species were found in 94% of the birds, and these were often abundant. *Characeae* were present in two-thirds of the birds, with a 60% RA on average. *Elodea* spp. leaves and green algae were the main plants consumed after *Characeae*. Approximately half of the Coot had ingested animal prey. *Cristatella mucedo* statoblasts were present in 40% of the birds and represented on average 63% of the number of prey. Trichoptera, especially micro-caddisflies *Hydroptilidae* of genus *Oxyethira*, were also found in 31% of the guts, and represented 36% of the animal prey.

Tufted Duck

Of the 45 Tufted Duck guts collected, only one was empty. Forty-three of them contained seeds, from a total of at least 24 plant species, most of these in large numbers. *Naïas marina* and *Potamogeton pusillus* seeds were found in 89% and 70.5% of the guts, respectively (Fig. 2). They represented more than 85% of seed weight on average, and 94% of the total IRIs (Appendix 1c). *Characeae* oogonia too were frequent (41% of guts), but only represented 3% of seed weight on average, and 4.4% of the IRIs. These three taxa were also the most important when only oesophagi were considered, for the 26 oesophagi which contained seeds, with *Characeae* still being of least importance despite comprising on average 9% of seed weight. Fragments of vegetative parts of plants, notably *Characeae*, were found in small amounts in about one-third of the birds. Conversely, three-quarters of the Tufted Duck contained animal prey, in variable numbers (1–530 items). Invertebrates from at least 31 families were identified, but molluscs were the taxa that contributed most to the diet (present in 41% of the guts and representing 30.5% of animal prey on average). The most frequent genera were *Gyraulus*, *Valvata* and Pond Snails *Lymnae* for gastropods, and *Pisidium* and *Sphaerium* for bivalves. Close to 30% of the guts also contained *Chironomidae* (which represented 16.5% of the prey on average), and 27% contained Trichoptera (especially Long-horned Caddisflies *Leptoceridae*, *Hydroptilidae* and Snare-making Caddisflies *Polycentropidae*), which represented on average 15% of the number of prey. *Cristatella mucedo* statoblasts were found in 14% of the birds, but represented only 7.4% of the total number of animal prey.

Discussion

Overall diet for each species

The contribution of the different food species to the birds' diet has been analysed within food types (i.e. animal prey, seeds and vegetative parts of plant), and using different measures (for instance, the relative number of items for animal prey, and relative dry weight for seeds). The gross diet for each species therefore can be described only as the frequency with which each type of food occurred in the gut. It should also be noted that the analyses considered the whole digestive tract, which overestimates the proportion of hard items in the diet (Swanson & Bartonek 1970), especially seeds but also, in our case, Bryozoan statoblasts. Statoblasts are resistant structures (developed to survive drought or frost) whose cells are encompassed in a very strong sclerified capsule (Tachet *et al.* 2000), so their persistence in the digestive tract is analogous to that of seeds rather than to invertebrates.

Pochard and Teal appeared to be almost exclusively granivorous in the Perthois gravel pits. Mallard guts also contained mainly seeds, though molluscs and the vegetative parts of plants were found in several individuals. Wigeon appeared to be mostly herbivorous, as were Gadwall and Coot despite the fact that the diet of these latter two species also included seeds and, for Coot, Trichoptera insects. The Trichoptera were mostly of the genus *Oxyethira*, which are strongly associated with macrophytes, providing the insects with both habitat and food (Tachet *et al.* 2000). It is therefore likely that the insects were ingested incidentally by Coot whilst foraging on the plants. Shoveler, Tufted Duck and Goldeneye were essentially benthivorous; 75–100% of individuals had macroinvertebrates in their gut, depending on the species, compared with <31% of individuals for any of the other bird species analysed (statoblasts excluded). However, these three ducks also consumed seeds very frequently, especially Tufted Duck which had the most diversified diet. Other studies have shown that, where present, Zebra Mussels *Dreissena polymorpha* form an important part of Tufted Duck diet (Olney 1963; Thomas 1982), but these molluscs were not encountered in the Perhois gravel pits.

The diets recorded for the nine waterbird species in the Perthois gravel pits thus generally correspond with earlier reports on duck and Coot feeding at inland wetlands (Olney 1963, 1967a,b, 1968; Olney & Mills 1963; Nilsson 1972; Street 1975; Campredon 1982; Paulus 1982; Thomas 1982; Allouche & Tamisier 1984; Draulans & Vanherck 1987). However, the Pochard in our study area were more specialist granivores than at other freshwater habitats, where a non-negligible proportion of the diet can consist of molluscs (Thomas 1982) or Chironomid larvae (Olney 1968). Indeed, it is known that when inland waterbodies lack macrophytes, Pochard can feed almost exclusively on macroinvertebrates (Phillips 1991; Winfield & Winfield 1994). In the Perthois, hydrophytes appear to be sufficiently abundant for Pochard to rely almost entirely on their seeds. By eating very few invertebrates, Pochard avoid competition with Tufted Duck and Goldeneye occurring on the same gravel pits.

Seeds

Although seeds from many plant species were identified in the samples, only a few contributed substantially to the diet of duck and Coot in the Perthois gravel pits. *Naïas marina* and *Potamogeton pusillus* seeds were both important, and had one of the three highest IRIs in eight of nine bird species. *Naïas marina* is cited by Agami & Waisel (1986) as being used by waterbirds, especially Mallard. The analysis of wintering duck diet in Brenne (P. Legagneux, pers. comm.) and at the Dombes fishponds (Curtet *et al.* 2004), in France, also highlights the importance of this seed species for Mallard, Pochard and Tufted Duck. However, *Naïas marina* was of particular importance in the Perthois, in comparison with reports from other the study areas, most probably because the plant is very abundant in these gravel pits. Similarly, to our knowledge there are no other reports of *Potamogeton pusillus* being an important food for waterbirds, yet it was frequently found in the birds' diet at the Perthois. Given that dabbling ducks do not dive to feed, it was interesting to find that seeds from these plants, which grow in relatively deep water, formed a major part of their diet. It is likely that the dabbling ducks fed on the seeds as they accumulated along the banks of waterbodies, after being washed ashore by the wind (see Thomas 1982). This is particularly likely given that most dabbling ducks were shot in autumn and winter, when the hydrophyte beds decayed.

Characeae oogonia also formed a large part of the diet for three diving species: Pochard, Coot and, to a lesser extent, Tufted Duck. The importance of *Characeae* oogonia in the Pochard diet has already been highlighted by Olney (1968), and by Thomas (1982) for the Ouse Washes. In the latter case the birds were assumed to have been feeding at nearby gravel pits. Extensive *Characeae* beds can indeed occur in gravel pits (Kusters 2000). Fox *et al.* (1994) related the presence of Pochard wintering at the Cotswald Water Park, England, to the existence of *Chara* spp. in the gravel pit complex at the site.

A few seed species were prevalent the diet of all the dabbling duck in the Perthois: *Eleocharis palustris*, *Polygonum persicaria* and *P. lapathifolium*. These were already known to be an important food for Gadwall, Teal, Shoveler, and Mallard, as well as for Pochard (Olney 1967a, 1967b; Street 1975; Thomas 1982; Paulus 1982; Lanchon-Aubrais 1992; Curtet *et al.* 2004; P. Legagneux, pers. comm.). The few results from the oesophagi-only samples suggest that cereals form a non-negligible part of the Mallard diet, supporting earlier studies which found that these and other non-natural foods (e.g. potatoes) are also sought by waterbirds (Street 1975; Thomas 1982; Curtet *et al.* 2004).

Despite having much in common, the composition of the seeds in the diet differed markedly between diving ducks and dabbling ducks. The former had a diet of low diversity (2–3 seed species accounted for >90% of the IRIs recorded for each duck species), and these were almost exclusively seeds from hydrophytes growing in deep water. Conversely, the dabbling duck diet was more diverse (7–10 species were needed to account for 90% of the total IRIs) and, in addition to the hydrophyte seeds, also included seeds from herbaceous plants growing on the shorelines. The diversity in the dabbling duck diet is not surprising and corresponds to the literature, but the extent to which these birds feed on the seeds of deep-water hydrophytes (especially *Naïas marina* and *Potamogeton pusillus*) has not, to our knowledge, been reported before.

Vegetative parts of plants

The most commonly observed plants in the diet of the typical herbivores (Coot and Gadwall) were, logically, those that retain green parts in autumn and winter in the study area, such as *Characeae*, *Elodea* and green algae. For Gadwall, the results support those of earlier studies, which describe the importance of algae as food for this species (Thomas 1982; Paulus 1982; Allouche & Tamisier 1984). Conversely, the frequency of *Characeae* in the diet of Coot at the Perthois may reflect the gravel pit habitat. Kusters (2000), and also Santoul & Tourenq (2002), found that there was an association between Coot abundance in winter and the presence of extensive *Characeae* beds at gravel pits, whereas in other types of wetland (e.g. lakes, marshes) Coot feed mainly on vascular plants (*Potamogeton* spp., *Zannichelia* spp., and grasses such as *Glyceria* spp. and *Agrostis* spp.) or on non-*Characeae* algae (Thomas, 1982; Allouche & Tamisier 1984; Draulans & Vanherck 1987).

Animal prey

The two benthivorous ducks had differing diets. Tufted Duck were found to have fed mainly on molluscs and Chironomid larvae, whereas Goldeneye took Chaoboridae and Ephemeroptera larvae. Both duck species also ingested Trichoptera larvae, the relative abundance (representing 27% and 10% of invertebrates found in the birds' guts) being non-negligible in each case. Tufted Duck diet in the Perthois was very similar to that described elsewhere in the literature, including at gravel pits; conversely, Goldeneye in the Perthois appeared to feed to a much lesser extent on Chironomid larvae than at other site (Olney 1963; Olney & Mills 1963; Nilsson 1972; Thomas 1982; Winfield & Winfield 1994).

The frequency of animal prey in Shoveler guts (in eight of nine birds collected from the Perthois), and the finding that pits where the Shoveler fed contained a much higher proportion of large microcrustacea than those where the duck seldom occurred, suggests that the Shoveler diet consisted mainly of large zooplankton prey and molluscs, as reported elsewhere (Thomas 1982; Euliss & Jarvis 1991).

The abundance of *Cristatella mucedo* statoblasts in most ducks is notable. These statoblasts have previously been recorded in small numbers in duck guts (Sánchez *et al.* 2000; Figuerola *et al.* 2003), but this is the first time they have been shown to be important as food items. Indeed, this prey was found in the guts of all nine bird species, where it represented 5–96% of the total number of animal prey recorded for each species. A total of 3,650 statoblasts were found during the study, whereas only 1,858 *Chaoboridae* larvae, the second most abundant prey, were recorded. This provides further support to the hypothesis, based on genetic data, that migratory wildfowl are responsible for dispersing this species over long distances (Freeland *et al.* 2000, Figuerola *et al.* 2005), even if many statoblasts may not survive the passage through the ducks' digestive tract (Charalambidou *et al.* 2003).

Food availability in the Perthois gravel pits

The availability of the main foods recorded in the diet of duck and Coot in the Perthois gravel pits could vary along ecological succession gradients. Ecological succession can progress relatively quickly within gravel pits and is also influenced by human activities in these habitats.

Among the three hydrophytes found to be most important for waterbirds, *Potamogeton pusillus* and *Characeae* are annual pioneer plants with high dispersion abilities. These therefore can colonise rapidly new ponds with bare sediment and become abundant, or even dominant, within the plant community. However, these phases are often transitory, so such plant communities generally disappear after a few years, being replaced by other vascular plants (Wood 1950; Danell & Sjöberg 1982; Barrat-Segretain & Amoros 1996; Beltman & Allegrini 1997; Bornette, pers. comm.). *Naïas marina* is also an annual plant, which relies entirely on its seed production to maintain itself or to colonise new areas. According to Handley & Davy (2002), *Naïas marina* seeds can grow roots only in soft sediment with a low cohesive strength. This could limit the establishment of the plant in gravel pits, because pit sediments are mostly a mix of gravel and clay, at least when the pit is new.

In general, the composition and abundance of the hydrophyte bed is likely to be affected (directly or indirectly) by the gradual eutrophication of the environment and by the development of fish populations (Blindow 1992; Palmer *et al.* 1992; Petr 2000). The shore plants that we found to be most important to waterbirds, especially to dabbling ducks, are also typical of transitory stages in the ecological succession. In gravel pits, *Polygonum persicaria*, *P. lapathifolium* and *Chenopodium* spp. are annual species typical of bare and disturbed substrates that become established during and immediately after the extraction phase. When there is no further disturbance of the sediment these are quickly replaced by perennial herbaceous species such as *Carex* spp., *Juncus* spp. and ligneous species such as the White Willow *Salix alba*. *Eleocharis palustris*, an important food for the dabbling ducks, is also a perennial species probably not affected by sediment disturbance, but it disappears from gravel pit shores of over time because of competition with taller perennial plants, especially *Salix alba* (Mouronval *et al.* 2005). Shading limits *Eleocharis* growth (Olney 1967b), and other herbaceous plants that could produce seeds for waterbirds may also be affected by shading in the Perthois, since two-thirds of the gravel pits have trees along at least half of their shoreline.

Aquatic insects important for the diving ducks' diet (notably *Chironomidae* and *Ephemeroptera*) also tend to be more abundant and diverse in young gravel pits, and their populations to decrease with time. This decrease could be partly due to the absence of disturbance once extraction has ceased (which gradually leads to a more homogeneous habitat structure), and partly to the development of fishing activity, including the introduction of fish and baiting which in turn lead to the predation of macroinvertebrates and an increase in the organic matter load (Carteron 1985; Boet 1987). The negative impact of fishes (especially Cyprinids) on macroinvertebrate communities (including molluscs) as well as on hydrophyte stands has been highlighted by many authors (review in Bouffard & Hanson 1987). For example, Phillips (1992) showed that fish removal from a gravel pit of Great Linford quickly led to a massive increase in the abundance of hydrophytes, molluscs and Chironomids. In the Perthois, cyprinids (notably Carp *Cyprinus carpio*, Roach *Rutilus rutilus* and Tench *Tinca tinca*) are highly abundant in c. 75% of gravel pits, and their impact on waterbird food sources (hydrophytes and macroinvertebrates) is considered to be particularly important. A study of the relationships between waterbird communities and gravel pit characteristics in the Perthois indeed demonstrated that, as gravel pits get older, waterbird community richness and density decreases dramatically, in particular in relation to an increasing total fish biomass (Mouronval *et al.* 2005).

It seems, therefore, that current levels of food availability for waterbirds in the Perthois gravel pits can be maintained only if management procedures are introduced to delay the ecological succession, enabling the gravel pits to remain in a relatively young phase for as long as possible. Land management should include regular disturbance of the sediment along the shoreline to prevent the installation of woody plants. For areas of open water, we suggest that the introduction of fish should be banned in gravel pits where wildfowl conservation is a priority. As a minimum requirement, fish populations should be kept at low densities, particularly benthivorous fishes which forage in sediment and the lower part of the water column such as Carp, Bream *Abramis brama*, Roach and Tench. Where pioneer hydrophyte stands have disappeared, mechanical perturbation of submerged sediments could be considered. Although this has not yet been tested, it may allow conditions to return to those immediately following the gravel extraction period in providing bare sediment where pioneer plants can develop more easily. This would support the hypothesis that regular environmental disturbance helps pioneer plants with low competitive ability by removing dominant plants, and be analogous to the droughts in Mediterranean wetlands allowing stoneworts to develop more easily. All these measures could enhance, or at least maintain over time, the carrying capacity of the Perthois gravel pits and other inland wildfowl habitats.

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Appendix 1

Wintering dabbling duck (a,b), Coot (b), and diving duck (c) diet in Perthois gravel pits after analysis of gut contents. Numbers in brackets (i.e. sample sizes) are the number of guts analysed per species. Relative abundance (mean ± s.e.) is expressed as relative mass for seeds, as RA for vegetative parts of plants (see text for calculation), and as the relative number of items for invertebrates. The index of relative importance (IRI) is also provided for seeds. For each species and each food type the gross frequency of occurrence is given, together with the number of gut samples containing the food type. Tr = traces of the food item recorded.

Appendix 1a

	MALLARD *Anas platyrhynchos* (*n* = 77)			**TEAL *Anas crecca* (*n* = 48)**			**GADWALL *Anas strepera* (*n* = 17)**		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Seeds	**Occurrence = 97.4% (75 guts)**			**Occurrence = 100.0% (48 guts)**			**Occurrence = 82.3% (14 guts)**		
Naïas marina	49.3	27.0±4.4	**0.233**	12.5	6.6±3.2	**0.013**	17.6	17.6±9.9	**0.063**
Naïas minor	5.2	0.7±0.7	**0.001**	6.2	3.5±2.0	**0.005**			
Potamogeton pusillus	42.9	14.2±3.3	**0.149**	37.5	12.7±4.0	**0.109**	17.6	17.1±9.6	**0.065**
Potamogeton pectinatus	13.0	7.1±2.6	**0.017**	4.2	2.1±1.9	**0.002**			
Potamogeton lucens	2.6	0.9±0.7	**0.000**						
Potamogeton natans	3.9	0.1±0.1	**0.000**						
Potamogeton nodosus	1.3	1.0±1.0	**0.000**						
Potamogeton gramineus				2.1	2.1±2.1	**0.001**			
Potamogeton spp.	2.6	0.1±0.1	**0.000**				5.9	4.7±4.7	**0.005**
Characeae spp.	7.8	1.6±1.4	**0.004**	6.2	0.2±0.2	**0.001**	5.9	0.1±0.1	**0.000**
Myriophyllum spicatum	20.8	4.1±1.6	**0.023**	14.6	1.2±1.1	**0.004**			
Ceratophyllum demersum	7.8	1.3±0.7	**0.001**				11.8	10.9±7.7	**0.024**

Appendix 1a *(continued)*

	MALLARD ***Anas platyrhynchos*** **(*n* = 77)**			**TEAL** ***Anas crecca*** **(*n* = 48)**			**GADWALL** ***Anas strepera*** **(*n* = 17)**		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Seeds	**Occurrence = 97.4% (75 guts)**			**Occurrence = 100.0% (48 guts)**			**Occurrence = 82.3% (14 guts)**		
Eleocharis palustris	20. 8	2.4±1.1	**0.013**	22.9	9.7±3.9	**0.045**	29.4	12.9±7.8	**0.070**
Polygonum persicaria	16.9	5.6±2.1	**0.020**	18.7	13.3±4.5	**0.047**	11.8	0.5±0.4	**0.001**
Polygonum lapathifolium	5.2	0.4±0.2	**0.001**	14.6	2.7±2.1	**0.009**	17.6	10.2±6.1	**0.029**
Polygonum amphibium	7.8	4.0±2.2	**0.006**	4.2	2.1±2.1	**0.002**			
Polygonum aviculare	3.9	0.1±0.1	**0.000**	6.2	0.1±0.1	**0.000**			
Polygonum spp.				10.4	0.9±0.7	**0.001**			
Sparganium emersum	16.9	4.0±1.7	**0.013**	4.2	2.2±2.1	**0.002**	11.8	10.9±7.8	**0.023**
Sparganium erectum	2.6	0.3±0.3	**0.000**	4.2	1.9±1.8	**0.001**			
Echinochloa crus-galli	3.9	1.7±1.1	**0.002**	6.2	0.9±0.6	**0.001**			
Scirpus maritimus	6.5	1.7±1.1	**0.002**	10.4	4.9±2.7	**0.010**	5.9	0.5±0.5	**0.000**
Scirpus lacustris	3.9	1.0±0.9	**0.001**	4.2	1.6±1.6	**0.001**			
Chenopodium album				8.3	6.5±3.3	**0.011**			
Chenopodium spp.				10.4	4.2±2.8	**0.010**			
Rumex maritimus	1.3	0.0±0.0	**0.000**						
Rumex spp.	3.9	0.4±0.4	**0.000**	4.2	4.2±2.9	**0.003**	5.9	6.3±6.3	**0.008**
Carex pseudocyperus	1.3	0.0±0.0	**0.000**	4.2	0.5±0.4	**0.001**			
Lycopus europaeus	1.3	0.1±0.1	**0.000**	2.1	0.0±0.0	**0.000**	17.6	3.9±2.3	**0.025**

Juncus inflexus	1.3	0.0±0.0	**0.000**						
Juncus spp.				2.1	0.1±0.1	**0.000**			
Hieracium umbellatum	2.6	0.5±0.5	**0.000**	2.1	0.2±0.2	**0.000**			
Hippuris vulgaris	2.6	0.1±0.1	**0.000**	2.1	0.0±0.0	**0.000**			
Ranunculus spp.	2.6	2.5±1.8	**0.001**	10.4	3.1±2.2	**0.007**	5.9	0.7±0.7	**0.001**
Bidens spp.				2.1	0.0±0.0	**0.000**			
Roripppa amphibia				4.2	0.0±0.0	**0.000**			
Stellaria holostea				4.2	0.1±0.0	**0.000**			
Reseda luteola	2.6	0.1±0.1	**0.000**						
Urtica dioica	1.3	0.1±0.1	**0.000**	10.4	3.1±2.1	**0.008**			
Veronica anagalis-aquatica	1.3	1.0±1.0	**0.000**						
Poa annua				4.2	0.0±0.0	**0.000**			
Avena sativa	2.6	1.3±1.1	**0.000**						
Triticum aestivum	6.5	3.8±2.1	**0.005**	6.2	4.1±2.9	**0.004**			
Zea maïs	6.5	6.2±2.7	**0.006**	4.2	4.1±2.9	**0.003**			
Rubus fructicosa	7.8	0.6±0.3	**0.001**	2.1	0.7±0.7	**0.000**			
Betula spp.							17.6	3.7±3.7	**0.018**
Alnus glutinosa	1.3	0.0±0.0	**0.000**						
Viburnum spp.	3.9	3.9±2.2	**0.002**						
Unknown	7.8			8.3					
Vegetative parts	**Occurrence = 63.6% (49 guts)**			**Occurrence = 8.3% (4 guts)**			**Occurrence = 58.8% (10 guts)**		
Characeae spp.	2.6	Tr							
Elodea spp.	14.3	Tr					29.4	32.2±12.3	
Algae spp.							41.2	41.2±12.4	

Appendix 1a *(continued)*

	MALLARD ***Anas platyrhynchos*** **(*n* = 77)**			**TEAL** ***Anas crecca*** **(*n* = 48)**			**GADWALL** ***Anas strepera*** **(*n* = 17)**		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Vegetative parts	**Occurrence = 63.6% (49 guts)**			**Occurrence = 8.3% (4 guts)**			**Occurrence = 58.8% (10 guts)**		
Lemna spp.							23.5	26.7±12.5	
Potamogeton pusillus	1.3	Tr							
Myriophyllum spicatum									
Naïas marina	1.3	Tr							
Naïas minor	1.3	Tr							
Zea maïs	3.9	Tr							
Unknown	39.0	Tr		8.3	Tr		29.4		
Invertebrates	**Occurrence = 33.8% (26 guts)**			**Occurrence = 23.0% (11 guts)**			**Occurrence = 29.4% (5 guts)**		
Bryozoa Cristatellidae (statoblasts)	19.5	53.5±9.3		10.4	39.8±15.5		29.4	96.0±4.1	
Oligochaeta Lumbricidae	1.3	2.6±2.6		4.2	20.0±13.3				
Oligochaeta spp.				2.1	9.1±9.1				
Gastropoda Valvatidae	6.5	12.9±6.4							
Gastropoda Planorbidae	5.2	2.5±1.6							
Gastropoda Vertiginidae				2.1	3.7±3.7				

Gastropoda spp.						
Bivalva Sphaeridae	1.3	0.2±0.2			5.88	0.1±0.1
Isopoda Asellidae	1.3	1.3±1.3				
Odonata Coenagrionidae	1.3	3.8±3.8				
Odonata spp.	1.3	3.8±3.8				
Thysanoptera	1.3	3.3±3.3				
Megaloptera Sialidae	1.3	0.2±0.2				
Lepidoptera Pyralidae	1.3	3.8±3.8				
Coleoptera Anobidae	1.3	0.5±0.5				
Coleoptera spp.	1.3	3.8±3.8				
Trichoptera Hydroptilidae						
Diptera Psychodidae			4.2	15.0±10.7		
Diptera Ceratopogonidae			2.1	0.1±0.1		
Diptera Chironomidae	1.3	3.8±3.8	4.2	10.0±9.4	5.88	3.9±3.9
Diptera Stratiomydae			2.1	0.9±0.9		
Diptera Ephrydidae			2.1	0.5±0.5		
Diptera spp.			2.1	0.6±0.6		
Cladocera Chydoridae						
Cladocera Daphniidae (ephippia)						
Hydrachna spp.	1.3	3.8±3.8	4.2	0.2±0.2		
Unknown			6.2			

Appendix 1b

	SHOVELER ***Anas clypeata*** **(*n* = 9)**			**WIGEON** ***Anas penelope*** **(*n* = 13)**			**COOT** ***Fulica atra*** **(*n* = 51)**		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Seeds	**Occurrence = 88.9% (8 guts)**			**Occurrence = 46.1% (6 guts)**			**Occurrence = 82.3% (42 guts)**		
Naïas marina	33.3	9.2±6.1	**0.036**	15.4	15.6±12.3	**0.031**	35.3	35.3±6.8	**0.208**
Naïas minor	22.2	0.0±0.0	**0.000**				4.0	2.0±2.0	**0.001**
Potamogeton pusillus	11.1	6.3±5.4	**0.021**	23.1	25.3±15.8	**0.152**	7.8	6.2±3.6	**0.009**
Potamogeton pectinatus				7.7	1.5±1.5	**0.002**	2.0	0.1±0.1	**0.000**
Potamogeton spp.	22.2	3.8±3.5	**0.015**						
Characeae spp.	22.2	25.0±16.4	**0.111**				58.9	49.8±7.4	**0.654**
Ceratophyllum demersum							3.9	1.0±0.9	**0.001**
Eleocharis palustris	11.1	12.5±12.5	**0.028**	7.7	16.7±16.7	**0.026**	2.0	0.0±0.0	**0.000**
Polygonum persicaria	11.1	0.0±0.0	**0.000**						
Polygonum lapathifolium	22.2	4.3±4.1	**0.023**	7.7	16.7±16.7	**0.026**	2.0	0.2±0.2	**0.000**
Polygonum amphibium							20.0	0.1±0.1	**0.000**
Polygonum aviculare	11.1	1.3±1.3	**0.003**						
Polygonum spp.							20.0	0.1±0.1	**0.000**
Sparganium emersum	11.1	0.0±0.0	**0.000**	7.7	13.5±13.5	**0.022**	6.1	2.6±1.8	**0.004**
Sparganium erectum	11.1	10.1±10.1	**0.020**						
Echinochloa crus-galli	11.1	1.1±1.1	**0.002**				2.0	2.2±2.2	**0.001**
Scirpus maritimus	11.1	11.4±11.4	**0.025**	7.7	10.7±10.7	**0.012**	3.9	0.5±0.4	**0.001**
Chenopodium album							2.0	0.0±0.0	**0.000**
Ranunculus spp.	11.1	2.4±2.4	**0.007**						
Bidens spp.	11.1	12.5±12.5	**0.028**						
Unknown	11.1			15.4			11.7		

Vegetative parts	Occurrence = 22.2% (2 guts)		Occurrence = 100.0% (13 guts)		Occurrence = 94.1% (48 guts)	
Characeae spp.					66.7	58.8±6.2
Elodea spp.	11.1	Tr	15.4	9.0±6.3	21.6	18.1±5.3
Algae spp.			15.4	20.4±14.6	19.6	16.2±4.9
Potamogeton pusillus			46.1	59.2±17.2		
Potamogeton spp.					13.7	3.4±1.3
Myriophyllum spicatum			7.7	11.4±11.4	4.0	0.8±0.6
Naïas marina	11.1	Tr			5.9	2.6±1.5
Unknown			46.1		9.8	
Invertebrates	**Occurrence = 88.9% (8 guts)**		**Occurrence = 23.1% (3 guts)**		**Occurrence = 49.0% (25 guts)**	
Bryozoa Cristatellidae (statoblasts)	55.6	23.0±12.0	15.4	33.6±33.2	41.2	63.2±0.1
Gastropoda Valvatidae	33.3	15.7±9.8				
Gastropoda Planorbidae	22.2	8.0±6.2				
Gastropoda spp.	11.1	0.4±0.4				
Bivalva Sphaeridae	22.2	13.1±12.4				
Isopoda Asellidae			7.7	33.3±33.3		
Lepidoptera Pyralidae			7.7	33.1±33.1		
Trichoptera Hydroptilidae	11.1	9.2±9.1				
Trichoptera spp.					31.4	36.3±0.1
Diptera spp.	11.1	0.3±0.3			2.0	0.0±0.0
Cladocera Chydoridae	11.1	2.7±2.7				
Cladocera Daphniidae (ephippia)	11.1	4.8±4.8				
Hydrachna spp.	22.2	22.9±15.0				

Appendix 1c

	POCHARD *Aythya ferina* (*n* = 63)			**TUFTED DUCK** *Aythya fuligula* (*n* = 44)			**GOLDENEYE** *Bucephala clangula* (*n* = 7)		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Seeds	**Occurrence = 100.0% (63 guts)**			**Occurrence = 97.7% (43 guts)**			**Occurrence = 100.0% (7 guts)**		
Naïas marina	79.4	53.5±5.3	**0.696**	88.6	64.2±5.2	**0.917**	100.0	96.5±1.5	**1.800**
Naïas minor	15.9	0.3±0.2	**0.003**	25.0	0.5±0.4	**0.007**	14.3	0.5±0.5	**0.008**
Potamogeton pusillus	54.0	7.0±2.2	**0.098**	70.4	21.3±4.6	**0.411**	85.7	1.0±0.5	**0.077**
Potamogeton pectinatus	33.3	5.2±2.2	**0.027**	18.2	1.2±0.7	**0.003**			
Potamogeton lucens	11.1	3.5±2.0	**0.008**	2.3	0.0±0.0	**0.000**			
Potamogeton natans	1.6	0.0±0.0	**0.000**						
Potamogeton gramineus				9.1	0.4±0.2	**0.001**			
Potamogeton spp.	1.6	0.0±0.0	**0.000**						
Characeae spp.	47.6	20.6±4.3	**0.272**	40.9	3.0±1.7	**0.062**	14.3	0.0±0.0	**0.001**
Myriophyllum spicatum	15.9	1.5±1.4	**0.006**	18.2	0.2±0.1	**0.001**	28.6	0.1±0.1	**0.003**
Ceratophyllum demersum	6.3	2.0±1.5	**0.002**	4.5	0.4±0.4	**0.000**	14.3	1.3±1.3	**0.003**
Eleocharis palustris	1.6	0.0±0.0	**0.000**	15.9	0.1±0.1	**0.001**			
Polygonum persicaria	1.6	0.0±0.0	**0.000**	9.1	0.7±0.7	**0.002**	14.3	0.0±0.0	**0.000**
Polygonum lapathifolium	6.3	0.8±0.6	**0.001**	9.1	0.2±0.2	**0.000**			
Polygonum amphibium							14.3	0.5±0.5	**0.002**
Polygonum spp.	1.6	0.0±0.0	**0.000**						

Sparganium emersum	12.7	1.9±1.6	**0.006**	2.3	0.1±0.1	**0.000**			
Sparganium erectum	6.3	0.6±0.4	**0.001**	2.3	0.0±0.0	**0.000**			
Echinochloa crus-galli				9.1	0.2±0.2	**0.001**			
Scirpus maritimus	11.1	2.6±1.7	**0.006**	2.3	1.0±1.0	**0.000**			
Scirpus lacustris				2.3	0.1±0.1	**0.000**			
Chenopodium rubrum	3.2	0.1±0.0	**0.000**						
Chenopodium album				2.3	0.0±0.0	**0.000**			
Lycopus europaeus				9.1	0.0±0.0	**0.001**			
Hieracium umbellatum				6.8	0.0±0.0	**0.000**			
Ranunculus spp.				2.3	0.0±0.0	**0.000**			
Urtica dioica	4.8	0.0±0.0	**0.000**						
Zea maïs				4.5	2.4±1.8	**0.001**			
Betula spp.				2.3	2.3±2.3	**0.001**			
Viburnum spp.	1.6	0.1±0.1	**0.000**	2.3	1.4±1.4	**0.000**			
Unknown	11.1			9.1					
Vegetative parts	**Occurrence = 49.2% (26 guts)**			**Occurrence = 36.4% (16 guts)**			**Occurrence = 0%**		
Characeae spp.	3.2	Tr		13.6	Tr				
Elodea spp.	3.2	Tr							
Naïas marina	1.6	Tr		2.3	Tr				
Naïas minor				2.3	Tr				
Potamogeton pusillus				4.5	Tr				
Potamogeton spp.				2.3	Tr				
Unknown	41.3	Tr		11.4	Tr				

Appendix 1c *(continued)*

	POCHARD *Aythya ferina* (*n* = 63)			**TUFTED DUCK** *Aythya fuligula* (*n* = 44)			**GOLDENEYE** *Bucephala clangula* (*n* = 7)		
	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI	Occurrence (%)	Relative Abundance (%)	IRI
Invertebrates	**Occurrence = 33.3% (21 guts)**			**Occurrence = 75.0% (33 guts)**			**Occurrence = 100.0% (7 guts)**		
Triclada Planariidae				2.3	3.2±3.2				
Bryozoa Cristatellidae (statoblasts)	28.6	85.7±7.8		13.6	7.4±4.4		14.3	4.8±4.8	
Oligochaeta spp.				2.3	0.0±0.0				
Gastropoda Valvatidae				9.1	4.6±3.8				
Gastropoda Bithyniidae				2.3	0.1±0.1				
Gastropoda Hydrobiidae				2.3	3.3±3.3				
Gastropoda Planorbidae				13.6	2.7±2.6		14.3	0.0±0.0	
Gastropoda Lymnaeiade				9.1	5.5±3.9				
Gastropoda spp.				4.5	7.7±5.3				
Bivalva Sphaeridae				22.7	6.7±3.9		14.3	0.1±0.1	
Isopoda Asellidae				4.5	1.3±1.3		14.3	0.1±0.1	
Ephemeroptera Baetidae				9.1	0.2±0.2		42.9	10.8±9.8	
Ephemeroptera Caenidae				11.4	0.4±0.2		28.6	1.0±0.9	
Odonata Platycnemididae				2.3	0.6±0.6				
Odonata Coenagrionidae				9.1	1.6±1.1		28.6	0.2±0.1	

Odonata Aeshnidae			2.3	0.0±0.0		
Odonata Libellulidae			4.5	1.0±1.0		
Psocoptera spp.	1.6	4.8±4.8				
Heteroptera Corixidae			34.1	0.8±0.4	85.7	2.0±1.0
Lepidoptera Pyralidae	1.6	4.8±4.8	4.5	0.1±0.1	28.6	0.1±0.1
Coleoptera Haliplidae			11.4	1.7±0.8	14.3	0.0±0.0
Coleoptera Dysticidae			2.3	0.2±0.2		
Coleoptera Hydrophilidae			15.9	1.0±1.0	14.3	0.9±0.9
Coleoptera spp.			2.3	3.8±3.8		
Trichoptera Polycentropodidae			9.1	0.4±0.3	28.6	0.3±0.2
Trichoptera Ecnomidae			2.3	0.0±0.0	14.3	0.0±0.0
Trichoptera Hydroptilidae			11.4	1.6±1.1	14.3	9.5±9.5
Trichoptera Leptoceridae			18.2	7.8±3.8	42.9	1.1±0.9
Trichoptera Molannidae			2.3	0.1±0.1		
Trichoptera spp.			6.8	5.1±3.4		
Diptera Chaoboridae					71.4	42.8±18.8
Diptera Ceratopogonidae					28.6	0.6±0.5
Diptera Chironomidae	1.6	4.8±4.8	29.5	16.6±5.2	57.1	25.1±15.3
Diptera Tipulidae			4.5	0.1±0.0		
Cladocera Chydoridae			4.5	1.9±1.8	14.3	0.2±0.2
Cladocera Daphniidae			9.1	8.3±4.8	14.3	0.5±0.5
Hydrachna spp.			6.8	3.9±3.8		
Unknown			33.3			