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Isotopic niches of the Northern shoveler *Spatula clypeata* in spring migratory stopover sites in the Marais Breton, France

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Isotopic niches of the Northern shoveler *Spatula clypeata* in spring migratory stopover sites in the Marais Breton, France

Abstract

The Northern shoveler, *Spatula clypeata*, makes several migratory stopovers to reach its breeding site in the best conditions. These stopovers allow the species to replenish their reserves. Therefore, feeding efficiency at such sites is essential. Despite its importance, few studies have been conducted on the spring ecology of the shoveler, particularly on its diet at stopover sites. Therefore, this study focused on the Northern shoveler's feeding habit during its spring migratory stopover in the Marais breton (MB), a wetland situated in Vendée (France, Atlantic coast). The shoveler's plasma and potential food resources were studied using a stable carbon and nitrogen isotope analysis. The study showed the shovelers feed primarily on microcrustaceans, especially Cladocera and Copepoda; Chironomidae larvae, Corixidae, Hydrophilidae larvae, and particulate organic matter. This last food source, the POM, had never been highlighted before.

Keywords

Anatidae, stopover, freshwater invertebrates, isotopic niche, carbon, nitrogen, isotopic mixing model.

Introduction

The Northern shoveler, *Spatula clypeata* (hereafter, shoveler), diet contains mostly freshwater invertebrates throughout the year and certain seeds in the winter [1,2]. The spring diet primarily consists of freshwater invertebrates due to egg production [3] and the need to address migration costs [4]. While animal food resources contain the highest protein and amino acid content, they are easily available and require a long feeding time [5,6]. However, few studies have been conducted on the spring ecology of the shoveler, particularly on its diet at stopover sites. Some studies have shown the importance of the stopover sites and their food resources in the survival of these migratory birds [1,7]. Extant literature on the shoveler's diet has focused on the digestive system content, specifically the contents of the crop and/or gizzard [3]. However, many invertebrates are digested within 10 minutes and are therefore unidentifiable. Studies on the shoveler's digestive system show the presence of small crustaceans easily digested as cladocerans, ostracods and copepods [8]. To overcome this bias, methods such as stable carbon and nitrogen isotope analysis and DNA analysis can be used.

Through the DNA analysis of faeces, a genetic DNA dataset of the consumed individuals can be accessed. The diet of a sampled individual can be ascertained by determining the species to which the sequences belong. However, this technique could not be implemented in this study because it was not possible to obtain dead individuals during the study period.

In trophic studies, heavier isotopes of a given element increase in abundance relative to the lighter isotopes through isotope discrimination. Early laboratory studies have shown that for carbon (C), the isotope ratios of consumers are typically similar to those of their diet [9]. Because this ratio rarely changes (approximately + 1 ‰), it is commonly used to assess the carbon source as the carbon transfers through food webs [9,10]. In contrast, the nitrogen (N) isotope ratios are 3 to 4 ‰ relative to their diet [11,12]. Therefore, the nitrogen isotope ratio is

commonly used to estimate trophic positions and the carbon isotope ratio to determine the origin of the food resource. Based on the premise that ‘you are what you eat’ [10], diet reconstruction studies use the difference in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (for carbon and nitrogen, respectively) between consumers and their resources, called trophic enrichment factor (TEF). The isotopic signatures differ depending on the consumer class and tissue analysed. In birds, the feather or claw signature corresponds to the diet during tissue formation [13], whereas blood plasma provides short-term dietary information from approximately a week [14]. Finally, this method has the advantage of being non-invasive and non-lethal for the bird.

To determine the shoveler’s diet during spring migratory stopover, the isotopic markers of the plasma of 11 individuals and their potential food resources – freshwater invertebrates, but also Particulate Organic Matter (POM) in the water column, Sediment POM (SPOM), and other predatory organisms participating in the food chain such as fish – were used when the trophic levels were known.

Materials and methods

Study sites

This study examined the diet of the shovelers at the Marais breton (MB) wetland in the Atlantic coast, Vendée (France) (Fig. 1), on stopover sites during their spring migratory migration. The MB is spread across approximately 32,000 ha. The capture site is a pond 4 km from the ocean, located in center of the MB, and entirely made of freshwater and does not communicate with the hydraulic network (i.e. the ditches).

Timing and field sampling of the shovelers and prey

Eleven shovelers were captured for the analysis of their dietary composition (Fig. 1). The individuals sampled in this study were mainly juveniles (less than two years old; $n = 9$). Since shovelers reproduce from the second year of their life [15], these individuals were determined to be in the pre-breeding migration period. The individuals were captured using cage traps with a live pair (male and female) as decoys. A camera (NATURACAM – STDX2) was positioned near each trap to monitor the presence of birds in the traps, which were activated every day from March 01 to April 10, 2021. The authorization for the captures was obtained from the Center for Research on the Biology of Bird Populations (CRBPO, National Museum, permit no. PP1821). Each individual's age and sex were determined based on their plumage [16] and their biometric measurements (wing length, tarsus length, bill length, and body mass) taken. A metal ring with a unique identifier was placed on a leg of each captured individual. As this study was part of a research project, 22 individuals were equipped with GPS/GSM tags, which made it possible to follow their movement and to check if they only used freshwater habitat or if they used marine habitat. The tagged individuals only visited freshwater areas and did not go into the ocean (Moreau, pers. comm). Finally, c. 1.0 ml blood with capillary was collected from the ulnar wing vein from each individual. All the blood samples were then centrifuged (10 min at 3,500 rpm) to retain only the plasma, which was frozen at -20°C .

Before the captures, samples of the dominant freshwater invertebrates and fish at study site were collected (Fig. 1). Freshwater invertebrates larger than $200\mu\text{m}$ were sampled using two methods – a corer for the invertebrates from the sediment and a plankton net for the invertebrates and little fish from the water – and frozen at -20°C . Simultaneously, POM and SPOM were sampled to determine the food web baseline. For the former, a water sample was filtered using decarbonated (4h at 450°C) 47 mm GF/F glass fibre filters ($0.7\mu\text{m}$ porosity) and a filtration device with a hand pump. The filters were then dried at 45°C in a conventional

oven. For the SPOM, the first 5 cm of the sediment was sampled using a corer. These samples were then frozen until the analyses.

Laboratory sample preparation

The freshwater invertebrates were classified by taxa. The samples of these invertebrates (n = 25 samples of 17 taxa; whole organism), plasma (n = 12, one shoveler was recaptured), and SPOM (n = 3) were freeze-dried and then crushed. Sediment and some freshwater invertebrate samples (fish and Physidae) were analysed before and after decarbonisation with HCl (0.5 N) to obtain the corrected value of the carbon stable isotopes. For POM (n = 3), three replicates were made on each filter. Stable carbon and nitrogen isotope ratios were determined in the plasma, freshwater invertebrates, POM, and SPOM samples. Analyses were performed in tin capsules for masses between 0.2 and 0.6 mg dry weight. Measurements were performed using an elemental analyser (EA Isolink, Thermo Scientific, Milan, Italy) coupled with an isotope ratio mass spectrometer (Delta V Plus with a Conflo IV interface, Thermo Scientific, Bremen, Germany). The instrument was calibrated using certified reference materials (USGS-61 and USGS-63).

Stable isotope analysis

All the analyses were performed in R version 4.1.3 [17] using the packages ‘SIBER’ [18] and ‘simmr’[19]. The isotopic values of 17 freshwater invertebrate taxa, POM, and SPOM were analysed, but only freshwater invertebrate taxa and POM were used to analyse the food web structure (Table 1). SPOM was excluded because their $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values varied significantly from those of the shoveler.

The stable isotope ratios of the shovelers’ plasma were analysed to determine the species’ trophic niche. The standard ellipse areas corrected for small sample sizes (SEAc) was

calculated. Then, the posterior estimates of the Bayesian standard ellipse area (SEAB) (n = 10,000 iterations) was calculated to obtain a range of probable values (95 %, 75 %, and 50 %) for the calculated standard ellipse.

Finally, to examine the relationship between the prey and group them by the isotopic niche, a hierarchical cluster analysis (HCA) was conducted using stable isotope data of the potential shoveler preys; this helped define the similar groups of resources. The HCA established four isotopic clusters that were incorporated into a Bayesian stable isotope mixing model to estimate the shovelers' diet composition. Each cluster's relative contribution was estimated. Furthermore, the TEF of -0.5‰ (± 0.5) for carbon and 4.5‰ (± 1) for nitrogen between potential prey (whole organisms) and shoveler plasmas were used. Since no previous analyses have been conducted on the isotopic markers of freshwater invertebrates and the shoveler, several preliminary several tests were conducted to use the most appropriate TEF and obtain the best Bayesian stable isotope mixing model (Table 1).

Results

Stable isotope values of shovelers, invertebrates, POM, and SPOM

Overall, 11 plasma isotopic samples from 9 juveniles and 2 adults (Table 2; 1 female and 10 males) were analysed. The $\delta^{13}\text{C}$ values ranged from -31.5‰ (adult male) to -23.9‰ (juvenile male) and the $\delta^{15}\text{N}$ values from 8.9‰ (juvenile male) to 13.6‰ (juvenile male). However, the isotopic niche estimated by the standard ellipses was large in the MB (10.2‰^2) (Fig. 2).

In determining the origin of a taxa, the $\delta^{13}\text{C}$ values ranged from -27.8‰ (Cladocera) to -21.6‰ (Ostracoda) (Table 1, Fig. 3). In estimating the trophic position in the food web, the POM and SPOM correspond to the source at the food web baseline. The POM had $\delta^{15}\text{N}$ mean values of 9.0‰ . The SPOM had lower $\delta^{15}\text{N}$ values (6.2‰) than the POM. Overall, in the MB, the

$\delta^{15}\text{N}$ values ranged from 5.2 ‰ (Gammaridae) to 12.2 ‰ (Fish). With $\delta^{15}\text{N}$ values of approximately 12.0 ‰, the Hydracarina and fish were at the same level as the shovelers and located at the top of the food web. All other taxa had $\delta^{15}\text{N}$ values below 10 ‰.

Shovelers' diet composition

To determine the diet composition, trophic groups were defined using an HCA. The preys were grouped by trophic guilds, size, or microhabitat, but none of these factors was discriminating. The tests found four trophic clusters (Table 1). The isotopic niche of the shovelers was analysed using a mixing model and the HCA results (Fig. 4). The predictive model explained 62.5% of the shovelers' diet. Several tests were conducted to use the most appropriate TEF between the prey and the shoveler plasmas (Appendix A). The shovelers fed mainly on microcrustaceans, insects and POM (Fig. 5). In terms of the contributions (% median [% quartile 1 – % quartile 3]) of the dietary sources, shovelers fed mainly on cluster B (80.0 % [69.6 % - 87.2 %]). Clusters C, A, and D represented 6.7 % [3.4 % - 12.7 %], 5.8 % [3.0 % - 10.6 %], and 4.7 % [2.6 % - 8.1 %] of their diet, respectively. Cluster B gathered Chironomidae larvae, Cladocera, Copepoda, Corixidae, Hydrophilidae larvae, and POM. The birds least preferred Clusters D, which mainly contained predators (Hydracarina, Hirudinea and fish).

Discussion

The objective of this study was to determine the shoveler's diet during spring migratory stopover using the isotopic markers of the plasma of 11 individuals and their potential food resources – freshwater invertebrates. We also aim to evaluate the potential contribution of Particulate Organic Matter (POM), Sediment POM (SPOM), and other predatory organisms participating in the food chain. Our study revealed that the shovelers fed mainly on

Chironomidae larvae, Cladocera, Copepoda, Corixidae, Hydrophilidae larvae, and unexpectedly from POM.

Shoveler and invertebrate communities

The difference between the maximum and minimum $\delta^{15}\text{N}$ values within a community defines the full range of its trophic levels [20]. According to the $\delta^{15}\text{N}$ values, the shoveler fed on several trophic levels (organic matter, filter, omnivore, predator). Concerning the potential prey, the $\delta^{15}\text{N}$ value of the POM (9.0 ‰) and SPOM (6.2 ‰) formed the baseline while predatory taxa such as Hydracarina (11.8 ‰) were at the top of the food web.

The $\delta^{13}\text{C}$ value range provides an index of variation in resource use at the food web baseline [20]. Accordingly, based on the $\delta^{13}\text{C}$ values, the shovelers fed on a diversified basal resource. However, the $\delta^{13}\text{C}$ values confirmed that all the individuals fed on the prey in freshwater systems. The $\delta^{13}\text{C}$ values of the primary producers tend to vary with several parameters. Therefore, $\delta^{13}\text{C}$ is used to determine the importance of different carbon pools to a consumer. For example, the $\delta^{13}\text{C}$ value of marine algae is much higher than that of freshwater plants largely due to the differences in the carbon sources used for primary production in the two systems [21]. Such differences in the stable isotope ratios of primary producers are reflected in the tissues of the primary consumers and persist at all trophic levels [21].

Potential diet of the shoveler at the spring migratory stopover

The shovelers' diet is mainly composed of invertebrates in all the phases of their life cycle [22,23]. Their bill, which is shaped like a spoon and tightly packed with lamellae (21.5 ± 2.4 lamellae/cm² [24]), helps sieve for food by filtering the water. Thus, with a specific food niche, shovelers feed mainly on epigeous prey and not on benthic prey and SPOM. Their food source includes POM and microcrustaceans (Cladocera and Copepoda), that is, small-sized sources, as

well as Chironomidae larvae, Corixidae and Hydrophilidae larvae. Furthermore, the least popular food resources were predators (Hydracarina, Hirudinea and fish).

POM contains particles suspended in the water column and all living (algae, invertebrates, bacteria, protozoa, etc.) and non-living (amorphous organic matter, detritus, etc.) material [25]. They are an important food resource for many filter-feeding invertebrates [26]. However, no study has shown the importance of POM in the shovelers' diet, as most studies have focused on the digestive tract, wherein POM is not identifiable. Using isotopic markers, this study shows that POM, which is ingested in large proportions because of the shoveler's filter-feeding method, is an essential part of the bird's diet. Cladocera, Copepoda, and Pleidae, small organisms measuring 0.1 to 2.5 mm [24,27], are also part of the shoveler's diet, adapted to its filtering mechanism. Thus, the shovelers can select feeding sites where their preferred prey predominates but not their prey. While prey size can affect prey selection, the individuals choose prey according to their energy values and availability to maximize the net energy intake. Furthermore, Cladocerans and copepods are widespread and present in all freshwater habitats [28,29]. They are generally most abundant in wetlands, in both summer and winter [29,30], thus facilitating their capture by filter-feeding predators. Copepods and cladocerans meet the expectations of migration-related energy requirements [31] with an average high energy value of 5,767 cal/g dry weight and 5,056 cal/g dry weight, respectively [27].

The present study also showed that the shoveler feed on Corixidae. These organisms of a size between 7.6 and 12.5 mm are very rich in proteins, between 58 and 71 % [27]. At the superfamily level, Corixoidea is the most abundant group of insects in a variety of freshwater habitats worldwide [32]. However, although their biomass is high, the importance of Corixidae in aquatic ecosystems is frequently underestimated. Eldridge (1990) [33] showed that hemipterans constitute a small portion of the shovelers' diet, but none specifically identified Corixidae as a food source.

The larvae of Hydrophilidae also are part of the trophic niche of the shoveler. Hydrophilidae are distributed worldwide and are common in freshwater habitats [34]. However, although Hydrophilidae appear to be present in the isotopic niche of the shoveler, this taxon is a predator and its $\delta^{15}\text{N}$ value appears to be low (7.5 ‰) compared to another study that obtained values between 13.9 and 18.5 [35]. In contrast, the $\delta^{15}\text{N}$ values obtained in this last study for Chironomidae (ranged from 5.9 to 22.7 ‰) and Corixidae (ranged from 7.4 to 20.1 ‰) are similar to this study (respectively 8.3 ± 1.5 ‰ and 7.9 ± 1.7 ‰).

Finally, the last potential food source for the shoveler is Chironomidae larvae. This family is the most widely distributed and abundant group of insects in freshwater [36,37]. Such aquatic invertebrates are protein-rich taxa (56 %) compared to plants such as maize (5.7 % protein) [8]. All taxa belonging to the shoveler isotopic niche are common freshwater taxa and relatively abundant. This shows that the shoveler would preferentially feed on small and abundant prey and therefore more easily captured by this filter-feeding duck species.

Limits

In this study, the predictive model obtained from the analysis of potential food sources explained 67 % of the shoveler's diet. A trophic enrichment factor (TEF) of -0.5 ‰ (± 0.5) for carbon and 2.5 ‰ (± 1) for nitrogen was used between potential prey and shoveler plasmas, but no previous analysis had been conducted on TEF. The literature review by Caut et al. (2009) [38] estimated the carbon and nitrogen discrimination factor for bird plasma (carbon: -0.08 ‰ ± 0.38 ; nitrogen: 2.82 ‰ ± 0.14) and freshwater organisms (carbon: 1.33 ‰ ± 0.07). Therefore, the predictive model needs to be improved with further analyses of carbon and nitrogen TEF values for shovelers and freshwater invertebrates.

Another limitation was that 37.5 % of the sample could not be explained. It is possible that 37.5 % of the diet that was not explained contained plant resources. Indeed, in March, plant matter

can represent 30% of the shoveler's diet [39]. Therefore, since the plasma samples were taken in March, it is possible that 37.5 % of the diet that was not explained contained plant resources. In addition, the $\delta^{13}\text{C}$ values of the shovelers were lower than those of most potential prey. Under oxic conditions, methane can be incorporated into food webs via methane-oxidizing bacteria for carbon and energy source [40]. Isotopic fractionation during this methane oxidation depletes the consumed carbon of $\delta^{13}\text{C}$ [41], making the carbon isotopic value of the bacteria significantly negative and distinct from other carbon sources in aquatic environments. The sampled shovelers may have fed on this type of bacteria, which was not sampled.

Furthermore, the study could not determine how long the individuals were present in the MB. As the individuals were on a migratory stopover, they could have been there for several days or just arrived. Thus, they may have fed on other freshwater invertebrate taxa or the same taxa without the same isotopic value. Moreover, eutrophication, agricultural intensification, urban development, and wastewater can affect the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values [20,42], and the shovelers are regular visitors to constructed wetlands [43]. This may also account for the unexplained 37.5 %.

Finally, this study did not conduct tests between different ponds. According to Inger and Bearhop (2008) [20], problems in analysing the diets of avian communities using stable isotope analysis include a lack of information on the scales of isotope heterogeneity. Small-scale heterogeneities, such as the local hydrological heterogeneity, may influence isotope gradients and thus explain part of the variation. Accordingly, if the ponds of the same wetland considered in this study do not have the same isotopic value and the shovelers used other sites for feeding, it may also account for the 37.5 %.

Conclusion

This study found freshwater microcrustaceans, especially Cladocera and Copepoda; Chironomidae larvae; Corixidae; Hydrophilidae larvae; and POM to be the main food resources of the shoveler. These resources contribute to meet its high energy requirements during spring migration. However, the study could not explain 37.5 % of the diet, which may include the vegetation and seeds that were not examined in the diet. Thus, to improve the study results, future research should consider vegetation into the model. It would also be appropriate to sample potential sources in several ponds in the MB to compare the isotopic values within wetland and also reproduce this study in other sites and other latitudes. Finally, increasing the sample size, that is, including more adults and females, can improve the robustness of the analysis.

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Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Appendix A. Results of the tests that were carried out in order to use the most appropriate TEF between the plasmas of the shoveler and these potentials preys.

Reference	TEF $\delta^{13}\text{C}$	TEF $\delta^{15}\text{N}$	SD TEF $\delta^{13}\text{C}$	SD TEF $\delta^{15}\text{N}$	% Model explained
N01	-0,5	1	0,5	1	29,0 %
N02	-0,5	2	0,5	1	29,0 %
N03	-0,5	3	0,5	1	33,0 %
N04	-0,5	3,5	0,5	1	42,0 %
N05	-0,5	4	0,5	1	50,0 %
N06	-0,5	4,5	0,5	1	62,5 %
N07	-0,5	5	0,5	1	54,0 %
N08	0	1	0,5	1	29,0 %
N09	0	2	0,5	1	29,0 %
N10	0	3	0,5	1	29,0 %
N11	0	3,5	0,5	1	37,5 %
N12	0	4	0,5	1	46,0 %
N13	0	4,5	0,5	1	50,0 %
N14	0	5	0,5	1	50,0 %
N15	0,5	1	0,5	1	29,0 %
N16	0,5	2	0,5	1	29,0 %
N17	0,5	3	0,5	1	29,0 %
N18	0,5	3,5	0,5	1	29,0 %
N19	0,5	4	0,5	1	33,0 %
N20	0,5	4,5	0,5	1	46,0 %
N21	0,5	5	0,5	1	46,0 %
N22	1	1	0,5	1	29,0 %
N23	1	2	0,5	1	29,0 %
N24	1	3	0,5	1	29,2 %
N25	1	3,5	0,5	1	29,0 %
N26	1	4	0,5	1	33,0 %
N27	1	4,5	0,5	1	46,0 %
N28	1	5	0,5	1	46,0 %

Tables

Table 1. Trophic cluster (CAH) and removed taxa. Considering the TEF values, the removed taxa had $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values too far away from the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of the shoveler and therefore cannot be included in the diet of this species. Trophic position, size and microhabitat were based on Tachet et al. (2010) and Moreau et al. (2021). L = Larvae.

Trophic clusters	Taxa	Trophic position	Size (mm)	Microhabitat	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
A	Ceratopogonidae L	Omnivore	10-20	Mixed	$-23,5 \pm 0,2$	$9,5 \pm 0,4$
A	Naucoridae	Predator	10-20	Vegetation	$-22,2 \pm 1,5$	$8 \pm 0,6$
A	Noteridae	Predator	2.5-10	Vegetation	$-22,4 \pm 0$	$8,8 \pm 0$
A	Ostracoda	Filter	<2.5	Mixed	$-21,6 \pm 0$	$8,9 \pm 0$
A	Physidae	Detritivore	10-20	Vegetation	$-22,8 \pm 0,6$	$7,6 \pm 1,3$
B	Chironomidae L	Omnivore	>20	Mixed	$-26,4 \pm 2,1$	$8,3 \pm 1,5$
B	Cladocera	Filter	<2.5	Open water	$-27,8 \pm 0$	$7,7 \pm 0$
B	Copepoda	Filter	<2.5	Open water	$-26,5 \pm 0$	$8,9 \pm 0$
B	Corixidae	Omnivore	10-20	Vegetation	$-25,6 \pm 0,3$	$7,9 \pm 1,7$
B	Hydrophilidae L	Predator	>20	Vegetation	$-25,6 \pm 0$	$7,5 \pm 0$
B	POM	OM	<2.5	Open water	$-26,1 \pm 0$	$9 \pm 0,4$
C	Culicidae L	Omnivore	10-20	Vegetation	$-20,1 \pm 0$	$6,9 \pm 0$
C	Ephemeroptera	Detritivore	10-20	Mixed	$-23,1 \pm 0$	$6,4 \pm 0$
C	Gammaridae	Omnivore	>20	Mixed	$-22,6 \pm 0$	$5,2 \pm 0,9$
C	Pleidae	Omnivore	2.5-10	Vegetation	$-21,7 \pm 0$	$6,1 \pm 0$
D	Hirudinea	Predator	>20	Mixed	$-22,6 \pm 0$	12 ± 0
D	Hydracarina	Predator	2.5-10	Mixed	$-26,1 \pm 0$	$11,8 \pm 0$
D	Fish	Predator	>20	Vegetation	$-21,8 \pm 1,6$	$12,2 \pm 1,3$
Remove	SPOM	OM	<2.5	Open water	$-26,4 \pm 0,3$	$6,2 \pm 0,4$

Table 2. Data of the 11 shovelers captured in the MB during the year 2021. M=Male, F=Female, Juv=Juvenile, Ad=Adult. Individual ‘S402’ was captured (S402_1) and recaptured (S402_2).

Id	Capture date	Wetland	Sex	Age	Bodymass (g)	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
S371	01 March 2021	MB	M	Juv	515	-28.0	8.9
S372	02 March 2021	MB	M	Juv	580	-28.1	10.6
S402_1	03 March 2021	MB	M	Juv	570	-28.8	13.6
S402_2	05 March 2021	MB	M	Juv	562	-28.2	13.3
S403	05 March 2021	MB	M	Ad	640	-28.4	12.3
S404	05 March 2021	MB	F	Juv	550	-29.9	12.1
S405	08 March 2021	MB	M	Juv	525	-29.4	12.7
S407	11 March 2021	MB	M	Juv	575	-24.7	13.6
S408	11 March 2021	MB	M	Juv	580	-27.9	13.4
S410	16 March 2021	MB	M	Ad	577	-31.5	12.7
S411	17 March 2021	MB	M	Juv	592	-30.0	13.4
S412	19 March 2021	MB	M	Juv	585	-23.9	11.6

Figures

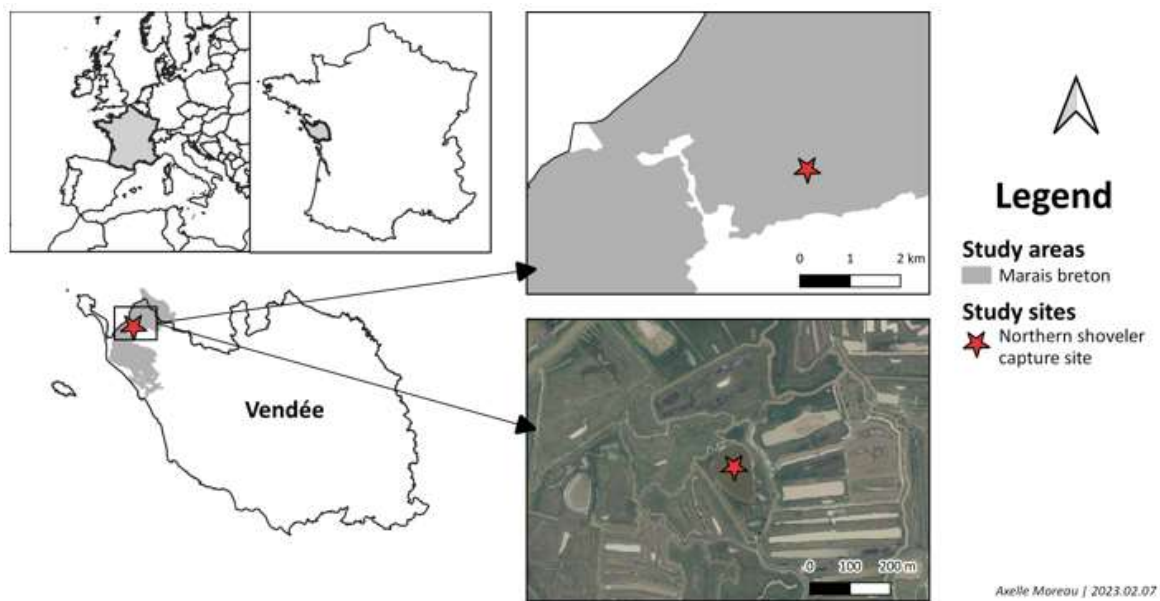


Figure 1. Localization and picture of the study site of the shoveler situated in the MB. This wetland is located on the Atlantic coast, in Vendée (France).

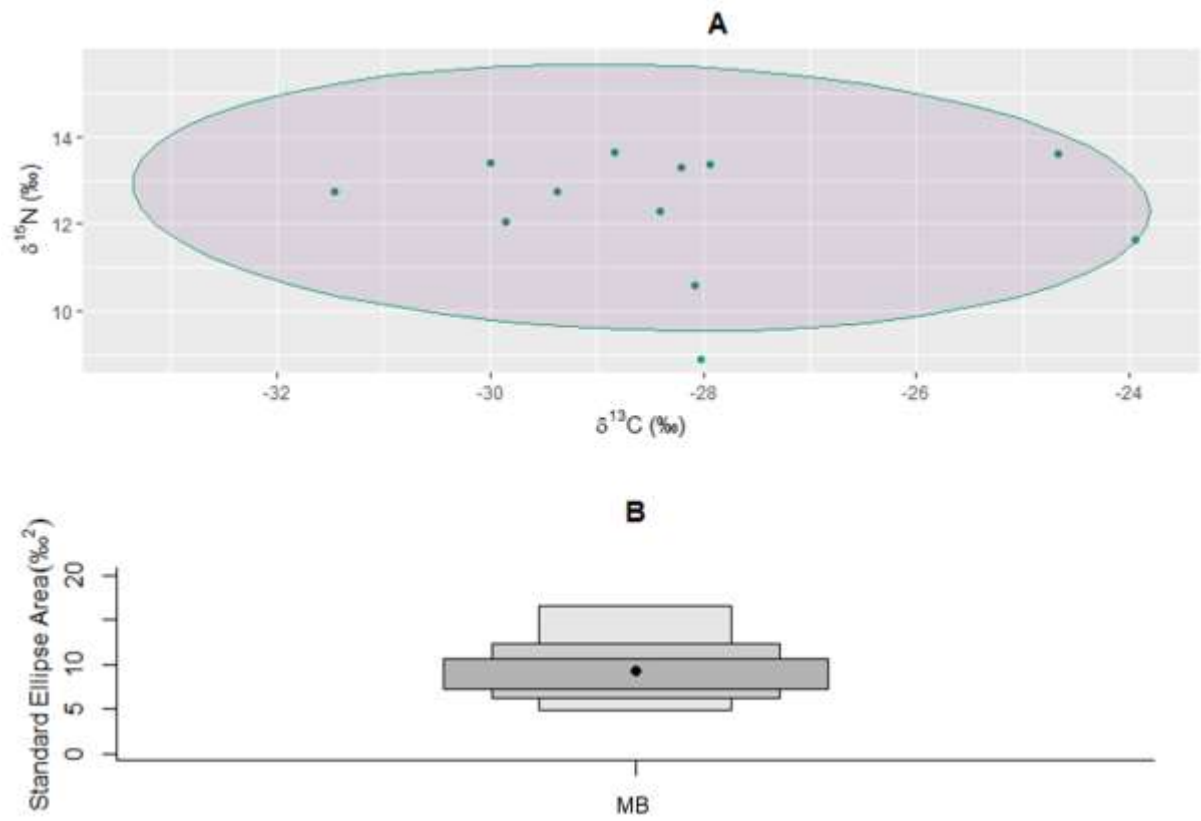


Figure 2. (A). Stable isotope Bayesian ellipses (solid lines) depict trophic niche breadth and overlap on SEAc analysis for shovelers from MB. Each point represents an individual duck. (B). Posterior estimates of the Bayesian standard ellipse area (SEAB) for shovelers from MB.

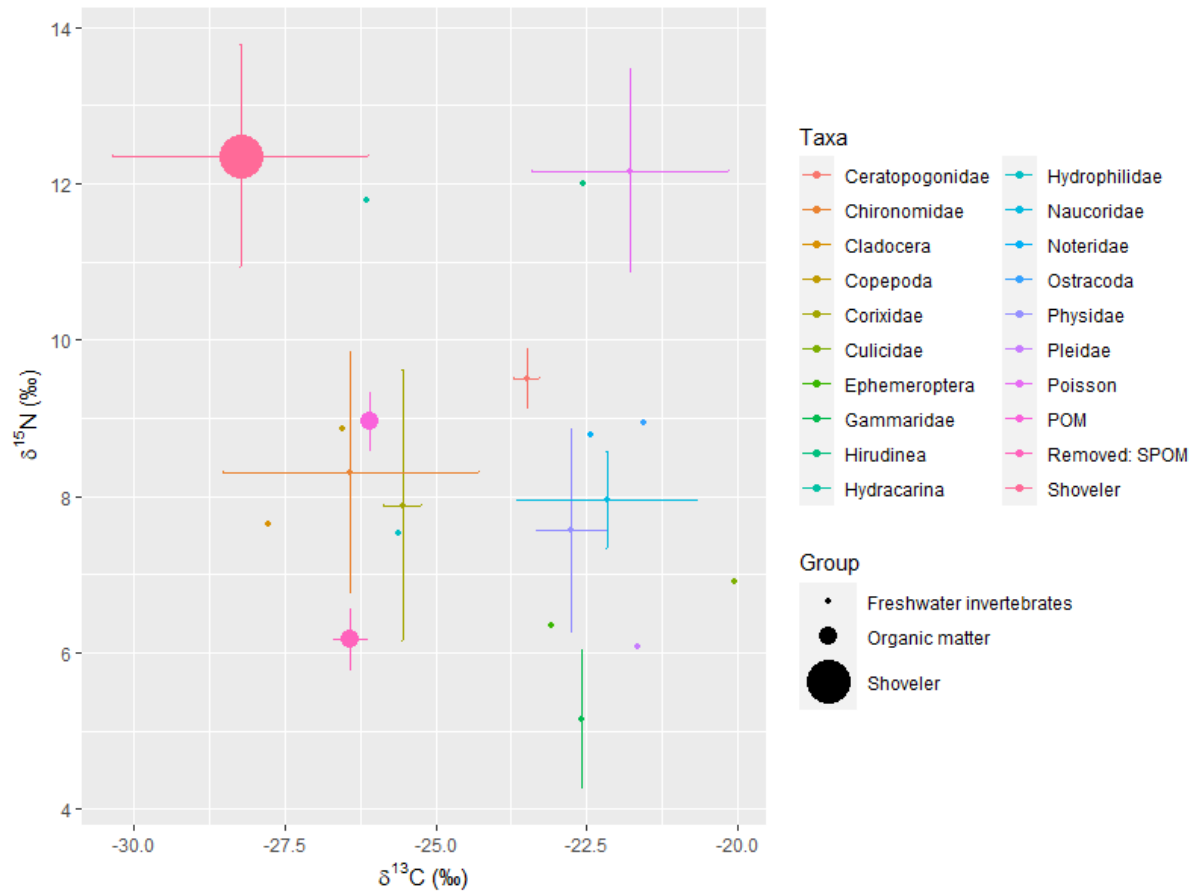


Figure 3. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (mean \pm SD) of shoveler and its potential prey from MB. The deleted SPOM have been included in this graph.

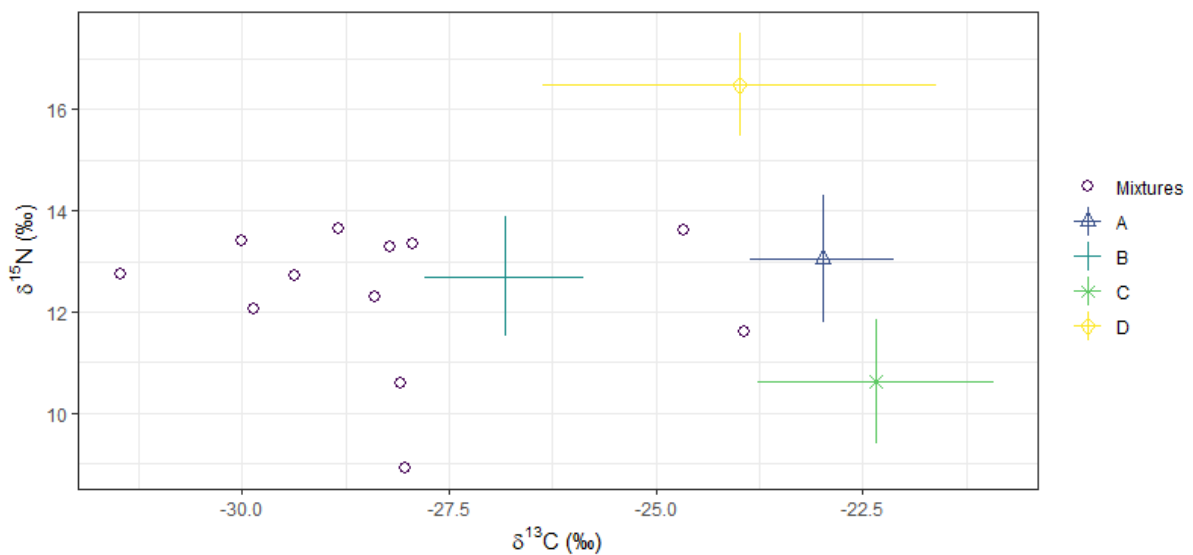


Figure 4. Stable carbon and nitrogen isotope values of food web components in MB. Symbols represent means \pm 1SE. For the trophic cluster composition, see Table 1. Mixtures = shoveler from MB.

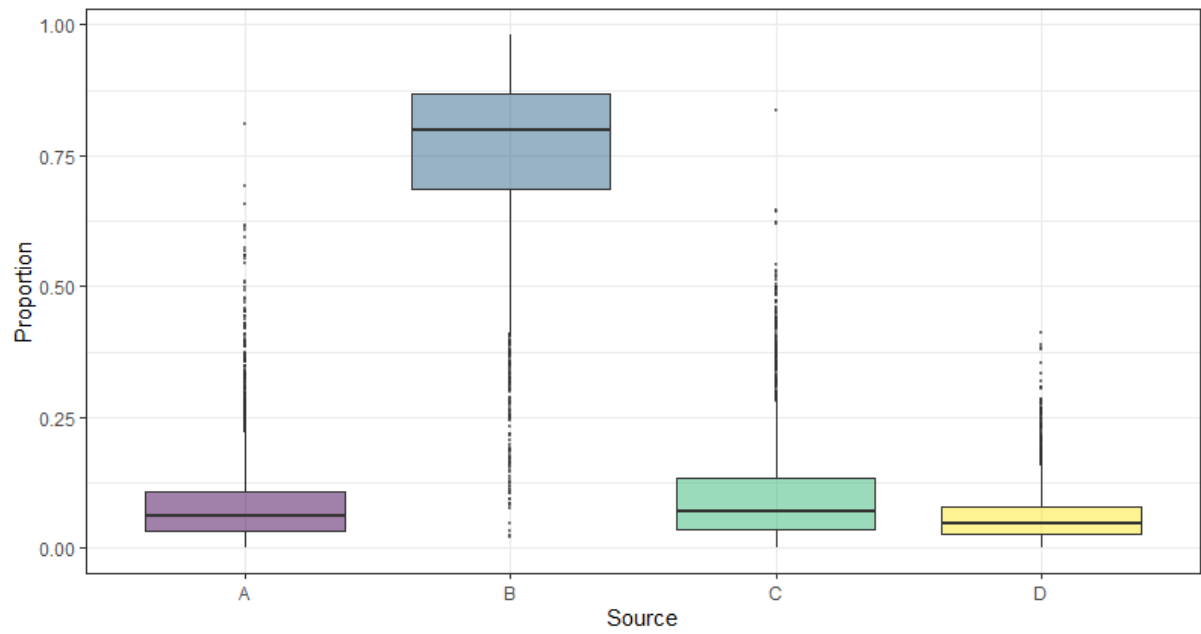


Figure 5. Contributions (% mean \pm 1 SE) of dietary sources to shoveler from MB based on a two-isotope ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) Bayesian mixing model. For the trophic cluster composition, see Table 1.