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Different levels of precision in studies on the alimentary tract content of omnivorous fish affect predictions of their food niche and competitive interactions

Małgorzata Adamczuk *, Tomasz Mieczan

Department of Hydrobiology, University of Life Sciences, B. Dobrzańskiego 37, 20-262 Lublin, Poland

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ABSTRACT

The food niche partitioning of omnivorous fish is commonly estimated on the basis of the alimentary tract content (ATC). However, since omnivorous fish utilise different ecological formations, data relating to ATC are very noisy, since an identified ATC comprises remains that can be determined according to the species level, determined only according to general food categories (i.e. higher taxonomic levels) as well as amounts of fragmented and digested remains that cannot be determined taxonomically. Thus, a variety of scales of precision can be applied during work on ATC. Up until now, there has been no evidence as to whether and how precision in ATC estimation can affect the results. This study aims at assessing how three different options of the same database influence the effectiveness and concurrency of indexes commonly used to describe the food niche of fish. The options include: (1) only general (higher than species level) food categories; (2) categories of different levels of generality; and (3) only detailed (species level) food categories. The study shows that the use of detailed (species level) food categories only, with the exclusion of general food categories, is the best method to recognise food niche partitioning and competitive interactions among fish. The food categories estimated in detail were cladocerans, and the possibility to use cladocerans as specific markers to find similarities in fish diets is discussed.

1. Introduction

Niche partitioning and intra- and interspecific competition between fish are topics of unswerving interest to researchers. This interest is enhanced by the increased spread of invasive fish, which are considered a serious threat to global biodiversity [1–4]. Food resources constitute a key component underlying competitive interactions [5] and are often the principal mechanism of niche segregation [6]. Thus, niche parameters can rapidly respond to changes in intra- and interspecific competition as well as to changes in food abundance. The competition within or between populations of fish caused by strong overlaps of feeding niches can result in utilising alternative and metabolically worse food resources [7], and can lead to the spatial segregation of species or of age groups of one species [8–11]. In order to find the best way to describe the food niches of fish, numerous methods and software applications have been created, yet quite simple indexes have been successfully applied in most studies. Almost all of these indexes have focused on fish alimentary tract contents (ATC). However, the problem of estimating the food niche overlapping with omnivorous fish on the basis of ATC arises from the fact that these fish utilise different ecological

* Corresponding author.
E-mail address: malgorzata.adamczuk@up.lublin.pl (M. Adamczuk).

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formations. Thus, at least several highly specialised taxonomists have to be involved in the arduous work on ATC. Additionally, data relating to ATC are very noisy because an identified ATC comprises remains that can be determined according to the species level, determined only according to general food categories (i.e. higher taxonomic levels) as well as amounts of fragmented and digested remains that cannot be determined taxonomically. Thus, a variety of scales of precision can be applied during work on the ATC. Up until now, there has been no evidence whether and how precision in ATC estimation can affect the results. This study aims at assessing how three different options of the same database influence the effectiveness and concurrency of indexes commonly used to describe the food niche of fish. The options include: (1) only general (higher than species level) food categories, (2) categories of different levels of generality, and (3) only detailed (species level) food categories. It can be suspected that choosing only general food categories could result in losing detailed information. A solution including categories of different levels of generality in the dataset could result in methodological errors; choosing only more detailed food categories could result in losing information on a large part of the ATC. The study was conducted by applying three commonly used indexes, including the index of relative importance (IRI) [12], Levins' index (niche breadth index) [13], and Shoener's similarity index [14]. The indexes were considered for the ATC of 4 species, including perch *Perca fluviatilis* L., roach *Rutilus rutilus* (L.), bleak *Alburnus alburnus* (L.), and catfish *Ictalurus nebulosus* Le Sueur, 1819. Perch and roach are widely distributed all over Europe. Roach is an omnivorous species that feeds on zooplankton, zoobenthos, detritus, epiphytes, phytoplankton and macrophytes [15,16]. At the juvenile stage, perch feeds on zooplankton, but as it increases in size, it switches to benthic macro-invertebrate food and later to a piscivorous diet [17,18]. Bleak is a cyprinid native to most of Europe that mainly inhabits lentic environments [19]. Bleak is an efficient zooplankton feeder, and its diet is also complemented by surface insects, blue-green algae and zoobenthos [20,21]. Roach, perch and bleak, while native to Polish lakes, are successful invaders and are regarded as a serious threat to native fauna in the regions of their invasion [22–24]. Catfish is native to the eastern regions of the United States of America. The fish was introduced in some European countries, including Poland, in the 1880s for aquaristic and farming purposes [25], and it is currently present in the freshwater bodies of almost all of Europe [26]. It eats a very wide range of food, including planktonic crustaceans, zoobenthos, epiphytes, filamentous algae, and fish [27–29], and is probably rarely preyed on by native piscivorous species. Their being opportunistic omnivores and lack of natural enemies make catfish considered to be competitors for native fish species.

The specific goal of the study was to compare the results of the indexes in order to assess: (1) whether results based on different options of the same database are similar, and (2) which of the options gives us the greatest opportunity to interpret the results. The food categories that were estimated in detail were cladocerans. This group was chosen because cladocerans are willingly eaten by omnivorous fish and are abundantly found in their ATC, and their chitinous carapaces are tough and small enough to not be crumpled and fragmented during ingestion.

2. Materials and methods

2.1. Fish sampling

Fish were caught in Lake Piaseczno (51°23′03″N, 23°01′46″E), which is situated in eastern Poland. The lake was selected for the studies because it has a meso-eutrophic status, thus suggesting limited food resources and resulting in strong feeding competition among fish. Additionally, Lake Piaseczno is without an outlet and is not stocked with fry, thus the structure of the relations among species and age classes of fish is not deranged. The lake area is 83.2 ha and its maximum depth reaches 38.8 m. The fish were collected by gillnets in the pelagic zone, nine times during the spring–summer–autumn seasons, including three times for each season. Every gillnet consisted of 14 panels with mesh sizes of 6.25, 8, 10, 12.5, 16.5, 22, 25, 30, 33, 38, 43, 50, 60, and 75 mm. The selection of fish species for further studies was based on the assumption that the number of individuals in each age group of distinct fish species was at least 20 for all catches. This assumption was fulfilled for four fish species, including bleak *A. alburnus*, roach *R. rutilus*, perch *P. fluviatilis*, and catfish I. *nebulosus*.

2.2. Laboratory analyses

Because age determines the biotic interactions of fish [30,31], diet analyses were conducted with regard to the age level. The age of the fish was determined on the basis of the yearly growth of scale radii, except for catfish, whose approximate age was determined on the basis of their total body length. The scales were measured with the aid of a microfiche projector. Annuli measurements were taken horizontally from the focus to the anterior-median edge. The length of each catfish individual was measured to the nearest millimetre. Two age groups were determined: $\leq$ 2+ with body length $<$ 130 mm, and $\geq$ 3+ with body length $\geq$ 130 mm [32–34]. The ATC of at least 20 random individuals for each age group within species was estimated for proportions of food items. Prey from the complete ATC, after identification, were counted and weighed (wet weight), with the exception of Cladocera and Copepoda, whose biomass was computed with the use of mathematical estimations [35].

2.3. Statistical analyses

The dataset of each ATC was estimated based on three options. Option A comprised only general (higher than species level) food categories, option B comprised categories of different levels of generality, and option C comprised only detailed (Cladocera species) food categories (Table 1). These options were applied to estimate the food niche partitioning of fish by using the index of relative importance (IRI) [12], Levins' index [13], and Shoener's similarity index [14].