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Assessing the importance of food for improving noble crayfish culture conditions

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ABSTRACT

Key-words: *species protection measures, feeding trials, food preference, crayfish culture, noble crayfish*

Captive breeding and crayfish culture are considered important measures in species protection activities. Thus, knowledge on optimal feeding of crayfish in captivity is needed in order to secure minimal mortality and prevent detrimental effects to health. To optimize conditions of crayfish prior to subsequent stocking, feeding trials were conducted with the aim of investigating the connection between food intake, food preference and temperature under near natural conditions. During a five-month period, noble crayfish were fed on fish, carrots, algae and chironomid-larvae according to a pre-defined rotation system, whereby the ambient water temperature ranged from 5 °C to 13 °C, following the natural temperature regime. The results of these feeding trials demonstrate a direct correlation between rising temperature and increasing food intake for water temperatures exceeding 8 °C. Food intake is further influenced by the variety of food items available at any one time. The results also confirm that *Astacus astacus* has a strong preference for fish and that alternation of food types has an impact on consumption. Our results prompt the following recommendations for optimized feeding conditions of crayfish in captivity prior to their release: (1) a balanced diet containing not only plant tissue but also a significant proportion of animal tissue and (2) the amount of available food must be adjusted according to the carapace length of the crayfish.

RÉSUMÉ

Évaluation de l'importance de la nourriture pour l'amélioration des conditions d'élevage d'écrevisses à pattes rouges

Mots-clés : *mesures de protection des espèces,*

L'élevage en captivité d'écrevisses est considéré comme une mesure importante dans les activités de protection des espèces. Ainsi, les connaissances sur l'alimentation optimale de l'écrevisse en captivité est nécessaire afin d'assurer un minimum de mortalité et prévenir les effets néfastes pour sa santé. Pour optimiser la condition de l'écrevisse avant le repeuplement ultérieur, des essais d'alimentation ont été menés dans le but d'étudier les liens entre la prise alimentaire, la préférence alimentaire et la température dans des conditions proches des conditions naturelles. Pendant une période de cinq mois, des écrevisses à pattes rouges

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essais d'alimentation, préférences alimentaires, élevage de l'écrevisse, écrevisse à pattes rouges

ont été nourries avec des poissons, des carottes, des algues et des larves de chironomes selon un système de rotation pré-définie, la température ambiante de l'eau variant de 5 °C à 13 °C, suivant le régime naturel de température. Les résultats de ces essais d'alimentation montrent une corrélation directe entre l'augmentation de la température et l'augmentation de la prise alimentaire pour les températures de l'eau supérieures à 8 °C. La prise alimentaire est en outre influencée par la variété des produits alimentaires disponibles à un moment donné. Les résultats confirment également que l'écrevisse à pattes rouges a une forte préférence pour le poisson et que l'alternance de types d'aliments a un impact sur la consommation. Nos résultats conduisent aux recommandations suivantes pour les conditions d'alimentation optimisées d'écrevisses en captivité avant le repeuplement : (1) une alimentation équilibrée contenant non seulement des tissus végétaux, mais aussi une proportion importante de tissus animaux et (2) la quantité de nourriture disponible doit être ajustée en fonction de la longueur de la carapace de l'écrevisse.

INTRODUCTION

The noble crayfish *Astacus astacus* (Crustacea, Decapoda, Astacidae) is one of only three indigenous crayfish species to be found in Austria (Füreder and Hanel, 2000). Due to crayfish plague and various other threats, the number of populations has declined in recent years, bringing noble crayfish to the brink of extinction (Bohman and Edsman, 2011). These factors have led to a classification as "vulnerable" in the IUCN red list (Edsman *et al*., 2010). Several strategies to counter the loss of this species have been discussed and approved. One of these strategies involves taking crayfish from stable populations for stocking purposes (Schulz *et al*., 2002) and creating "ark sites" which provide suitable habitats safe from any threat (Peay, 2009). Captive breeding and stocking of crayfish has been successfully carried out in several countries, including Austria (Füreder, 2009) and Great Britain (Whitehouse *et al*., 2009).

Stocking is performed either by breeding and raising crayfish from a limited number of individuals or berried females or by selecting young but sexually mature animals taken from the donor populations. There is a consensus amongst the scientific community that the age of the crayfish to be stocked is case-specific (Kozak *et al*., 2011). Therefore, no clear recommendations whether to stock juveniles or adult crayfish have been given (Kozak *et al*., 2011). As taking too many individuals from a donor population could be detrimental, especially to weak populations (Schulz *et al*., 2002), the survival of every single crayfish is important. While keeping crayfish prior to stocking, it must be ensured that their health state remains stable or actually improves. Since the crayfish are destined to be set free in nature, it is important to hold them under near natural temperatures. This, however, entails providing a holding location with a natural diurnal rhythm and water temperatures corresponding to the respective season as opposed to large indoor holding tanks. In order to optimise holding conditions, an in-depth knowledge of feeding choice of captive noble crayfish is imperative.

Crayfish were first described as "voracious and indiscriminate feeders" by Thomas Huxley, who stated that "the food of the crayfish is made up of very diverse substances, both animal and vegetable" (Huxley, 1895). Later studies observed a distinct preference for herbivorous food (Abrahamsson, 1966; Gaeveskaya, 1969). More recent publications, however, contradict the idea of crayfish being predominantly herbivorous, stating a distinct preference for animal protein (Momot, 1995; Guan and Wiles, 1998). Macroinvertebrates as well as fish, vegetal detritus and periphyton were all determined to be important components of a crayfish diet (Scalici and Gibertini, 2007).

The main objective of this study was to investigate the relationship between food preference, food consumption and natural ambient water temperature. The following research questions were addressed: (1) Is food intake influenced by temperature? (2) How selective are crayfish in their choice of food? (3) Is carapace length decisive for food demand? (4) Do crayfish prefer a varied diet? To this aim, we conducted feeding trials in which food items naturally available to crayfish in their habitat and food items used in commercial crayfish rearing were chosen. The experimental setup was designed to answer these questions. The outcome enabled us to identify some recommendations for optimized feeding conditions of captive noble crayfish.

MATERIALS AND METHODS

> *STUDY DESIGN*

Thirty-eight male and two female noble crayfish (*Astacus astacus*) with a carapace length of 43.3 mm (SD = 6.8) and weighing 19.1 g (wet weight) (SD = 6.5) were taken from two local populations and kept in a groundwater-fed holding tank of 9000 L volume. The tank was located outdoors with only a metal grid as cover, thus ensuring a natural light-dark cycle and temperature regime. Within this tank, crayfish were held in purpose-built containers of four individuals each, subdivided with opaque barriers to eliminate any interaction between individuals. In this way, a possible bias on food intake through competitive behaviour or mutual inclination could be avoided. Shelter possibilities in the form of terracotta flower pot halves with 13 cm collar-diameter were provided for every single individual. Throughout the entire experiment no crayfish went into moulting, therefore the size of each individual did not vary during the feeding trials.

Water temperature, oxygen saturation and pH level were recorded throughout the duration of the experiment. The data obtained during the feeding trials was used to answer the questions whether food intake is influenced by temperature, how selective crayfish are in their choice of food, if size is decisive and if crayfish prefer a varied diet.

During the course of the feeding trials, 36 crayfish were constantly fed to excess, while four individuals (box J) formed a control group and were starved throughout a period of five months.

With the exception of box J, the crayfish were provided every Monday and Wednesday with a fresh supply of water-saturated food. This was subsequently removed 48 h later for weighing. From Friday to Monday the crayfish remained undisturbed and with no food supply. This procedure was repeated for 20 consecutive weeks from January 21st, 2013 until June 14th, 2013. The days on which crayfish were offered food (Monday – Wednesday and Wednesday – Friday) are referred to in this paper as feeding periods. To supply or remove food, the boxes, which were otherwise kept at the bottom of the tank, were lifted just under the water surface so that the food items could be provided, replaced or removed.

To ensure that the weight difference was the actual weight loss through feeding and that water-logging had not added weight to the food item, the food items were saturated with water and then only drip-dried before weighing them prior to feeding. Accordingly, food items had to be dabbed with a dry paper towel for the same length of time after feeding as they had been beforehand. Saturation with water was achieved through keeping food items submerged in a glass or jar for 24 h before feeding.

The crayfish in the three boxes designated to the multiple-choice feeding trials were offered all four food-types simultaneously throughout the entire experiment. Crayfish used for the singular feeding experiment in the first six boxes (A to F) were given the food items in a different succession with boxes A/B, C/D and E/F as groups with three different successions respectively. These crayfish received only one type of food item at any given time (Figure 1). Determination of food preference of noble crayfish in captivity was accomplished using data from the multiple choice feeding group. Thus, influence stemming from different nurturing approaches used in the non-multiple choice groups was avoided.

The feeding rotation in boxes A and B was clockwise, in C and D anticlockwise and in boxes E and F the food items were rotated diagonally. These three groups are referred to within this study as feeding rotation 1 (boxes A and B), feeding rotation 2 (boxes C and D) and feeding rotation 3 (boxes E and F), respectively.

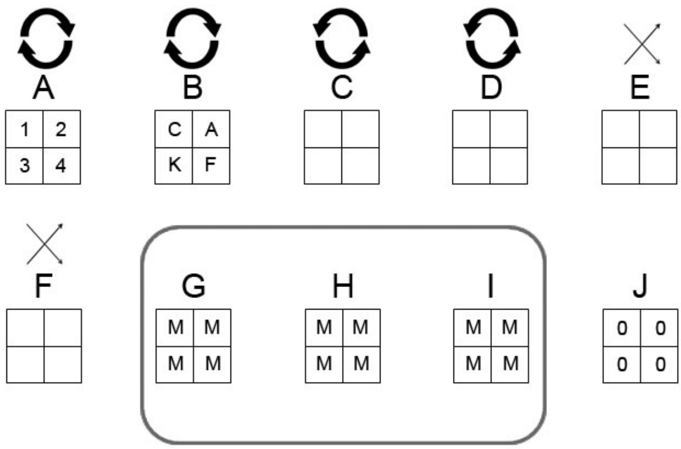

Figure 1
Schematic of feeding diagram. The letters A–J stand for the 10 boxes containing 4 crayfish each. The numbers 1–4 identify the crayfish and the figure above each box indicates the sequence of rotation. C, A, K and F are the abbreviations of the food types given (C = chironomids, A = algae, K = carrots, F = fish). The letter M in boxes G, H and I defines the 12 individuals of the multiple choice feeding groups and the zero in box J stands for the group which was starved throughout the experiment.

Table I
Mean percentage of dry weight of all food items calculated and mean percentage of carbon and nitrogen determined through elemental analysis in the laboratory.

Food type	Dry weight of water-saturated food in %	Mean % C	Mean % N
Carrots	12.36%	38.94%	0.96%
Chironomid-larvae	4.94%	46.25%	10.65%
Fish	32.7%	49.15%	13.68%
Algae	5.1%	41.44%	4.47%

> *FOOD ITEMS*

In order to test a broad spectrum of food items while maintaining a simple experimental design, two representatives of both tissue types were selected: Spirulina algae and carrots were used as plant tissue, brown trout and chironomid larvae represented animal tissue. More specifically, the food items used were brown trout, chironomid larvae enclosed in agarose gel, carrots and algae (*Arthrospira platensis*) held together by agarose. Elemental analysis for measuring carbon and nitrogen content of the food items was carried out using a Flash EA 1112 (NC Soils Konfiguration) Thermo Electron Corporation FlashEA® Organic Elemental Analyzer (Brechbühler AG, Schlieren, Switzerland).

The respective percentage of carbon, nitrogen and dry-weight of all food types is shown in Table I. The agar blocks were made using AGAR-AGAR, Danish powdered (Carl Roth GmbH + Co. KG, 76185 Karlsruhe, Germany; Article number: 4508) in a concentration of 25 g per litre of water. Dry-weight was determined for all food items for better comparability.

> *DATA ANALYSES AND STATISTICS*

All statistical analyses were conducted using RStudio (2012) (RStudio: Integrated development environment for R (Version 0.96.122) [Computer software]. Boston, MA. Retrieved January 2nd, 2014).

A statistical significance level was set to $p < 0.05$. The data generated in the feeding trials did not display a normal distribution and therefore non-parametrical tests (Kruskal-Wallis, Mann-Whitney-*U*) were applied. For the Mann-Whitney-*U* tests as post-hoc tests, the p level was adjusted using the Bonferroni correction.

While dividing the crayfish into their respective treatments, attention was paid to allotting an even distribution of animal sizes. Statistical analysis of the difference in carapace length between the non-multiple choice groups ($n = 24$) and the multiple choice group ($n = 12$) using a Mann-Whitney-*U* test yielded no significant difference. Comparison of all feeding rotations separately and also with the multiple choice group using a Kruskal-Wallis test detected no significant difference in carapace size distribution.

To determine any correlation between food consumption and temperature, the sum of food intake per feeding period of the multiple choice feeding group with respect to the ambient water temperature was analysed by applying Spearman's rank correlation. For a clearer representation, temperature data was also grouped in four bands of 2° centigrade increments. These were analysed with a Kruskal-Wallis and Mann-Whitney-*U* tests.

Establishing the existence of a food preference was achieved by calculating the mean food intake of each food item by each individual per feeding period and then subjecting it to a Kruskal-Wallis test. The preferred food item was identified through Mann-Whitney-*U* tests.

In order to investigate any correlation between the carapace length of crayfish and their food consumption, the mean food intake throughout the entire experiment was calculated for each individual. Spearman's rank correlation was used to detect any relationship between food-intake and carapace length.

For a comparison of both nurturing approaches (multiple choice and non-multiple choice), the sum of the food intake for each feeding period and box was calculated. This was necessary as each individual of the multiple choice group had every one of the four different food items at its disposal whereas the crayfish of the non-multiple choice group had access to only one of the four food types at any one time. Food intake was then examined using a Mann-Whitney-*U* test.

To uncover possible links between the food intake of crayfish and the previously ingested food type, the overall ingestion of each food type with respect to the previously offered item was assessed. Fish had been determined to be by far the most preferred food type – and such a significant preference suggests that crayfish would consume large amounts of fish regardless of their previously offered food item – which could bias the calculations. Therefore, the overall food intake with respect to the previous food type, disregarding the consumption of fish, was calculated and examined with a Kruskal-Wallis and Mann-Whitney-*U* tests.

RESULTS

> *THE EFFECTS OF WATER TEMPERATURE ON FOOD INTAKE*

Spearman's rank analysis yielded no significant correlation ($rs = -0.142$, $p = 0.12$, $n = 12$) between the sum of food intake per feeding period of the multiple choice feeding group and the ambient water temperature. However, when looking at sub-sets of temperatures (5 °C–7 °C [temp1], 7 °C–9 °C [temp2], 9 °C–11 °C [temp3] and >11 °C [temp4]) we found a significant difference between temperature and food intake (Kruskal-Wallis $p < 0.001$, $n = 12$). Subsequent Mann-Whitney-*U* tests revealed these differences to occur between all temperature groups with the exception of between temp1 and temp4 ($p = 0.83$, $U = 487$) as well as between temp2 and temp3 ($p = 0.6$, $U = 314$). The results yielded the following values: [temp1] – [temp2] $p < 0.0125$, $U = 826$; [temp1] – [temp3] $p < 0.0125$, $U = 835$; [temp2] – [temp4] $p < 0.0125$, $U = 139$; [temp3] - [temp4] $p < 0.0125$, $U = 125$. This data indicates a decline in food consumption rates from very low to medium temperatures but a positive correlation between food intake and rising water temperature above 7 °C (Figure 2).

> *FOOD PREFERENCES*

A Kruskal-Wallis test detected a significant difference ($p < 0.001$, $H = 1165.339$, $n = 12$) between the rate of consumption of the respective food items while comparing the mean

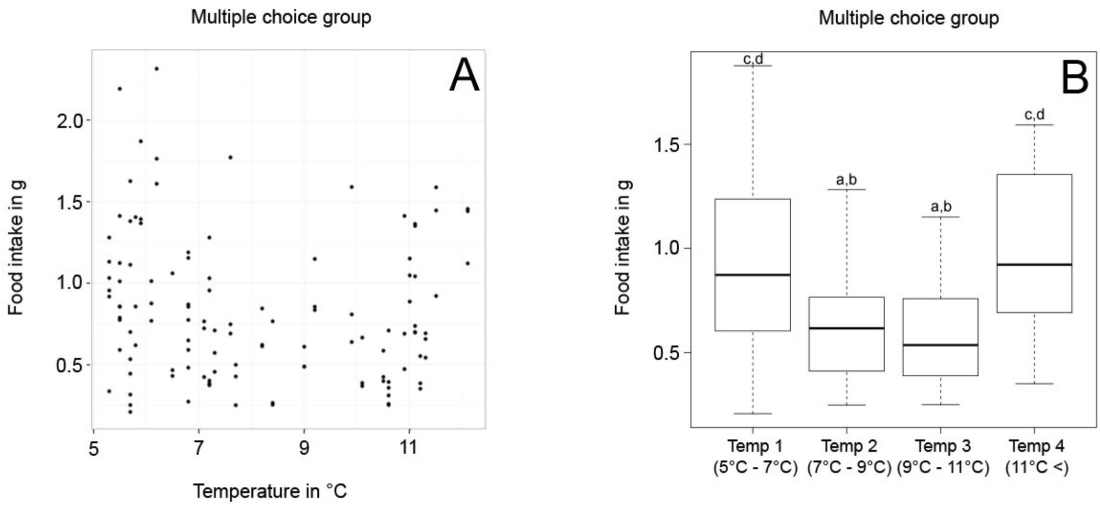

Figure 2

(A) Sum of food intake of the multiple choice group per feeding period and the respective mean-temperature measured during that period displayed as a scatterplot. Spearman's rank correlation between the sum of food intake and the respective mean-temperature revealed a non-significant weak negative correlation (rs = −0.142, p = 0.12) (n = 12). (B) Boxplot of food intake at four different temperature ranges. A Kruskal-Wallis test calculating the difference in quantity of ingested food of the multiple choice group at four different temperature-classifications detected a significant difference in food intake ($p < 0.001$) (n = 12). a – food intake was significantly lower than at temp1; b – food intake was significantly lower than at temp4; c – food intake was significantly higher than at temp2; d – food intake was significantly higher than at temp3. Horizontal lines touching the vertical lines above and below the boxes represent 1.5× interquartile range; outliers are not shown.

food intake of each food item by each individual of the multiple choice group per feeding period. Ensuing Mann-Whitney-*U* tests determined significant differences ($p < 0.001$) in the consumption not only between fish and the other three food types but indeed between every single food type offered (algae-fish: $p < 0.001$, $U = 3694$; chironomids-carrots: $p < 0.001$, $U = 160420.5$; carrots-fish: $p < 0.001$, $U = 4938$; algae-chironomids: $p < 0.001$, $U = 51350.5$; algae-carrots: $p < 0.001$, $U = 98580.5$ and chironomids-fish: $p < 0.001$, $U = 9219$) (Figure 3). When both tissue types (fish and chironomids as animal tissue, carrots and algae as plant tissue) are compared, a distinctive preference for animal tissue (Mann-Whitney-*U* $p < 0.001$, $U = 785878$, $n = 12$) is evident.

> *FOOD DEMAND BASED ON CARAPACE LENGTH*

Spearman's rank analysis yielded a significant positive correlation between the carapace length of crayfish and their food consumption. These significant correlations were observed both in the multiple choice group ($rs = 0.867$, $p < 0.05$, $n = 12$) and in the non-multiple choice group ($rs = 0.624$, $p < 0.05$, $n = 24$), demonstrating that larger crayfish have a higher food intake than their smaller counterparts (Figure 4).

> *THE INFLUENCE OF A VARIED DIET*

The comparison of the overall food intake for each feeding period and box of both nurturing approaches using a Mann-Whitney-*U* test revealed significantly higher food consumption ($p < 0.001$, $U = 354215$, $n = 36$) in the multiple choice group (Figure 5).
The overall food intake with respect to the previous food type, disregarding the consumption of fish, was calculated and subsequent examination with a Kruskal-Wallis test revealed a

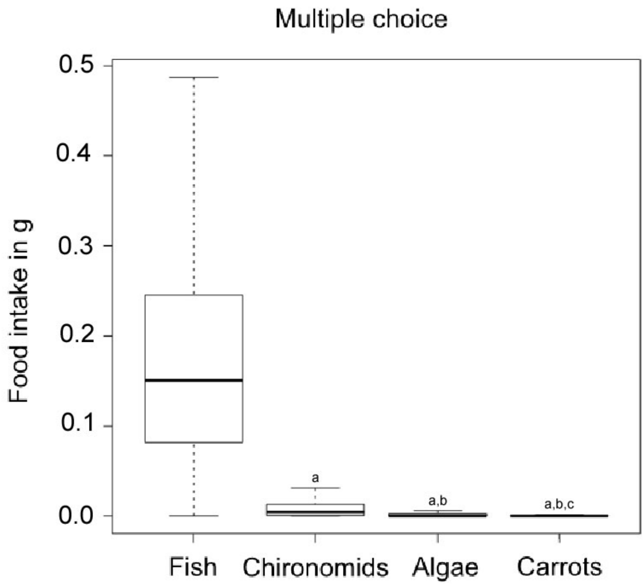

Figure 3
Amount of ingested food per feeding period classified as the four food types (algae, chironomids, fish and carrots). a – significantly lower consumption than fish; b – significantly lower consumption than chironomids; c – significantly lower consumption than carrots. Horizontal lines touching the vertical lines above and below the boxes represent 1.5× interquartile range; outliers are not shown.

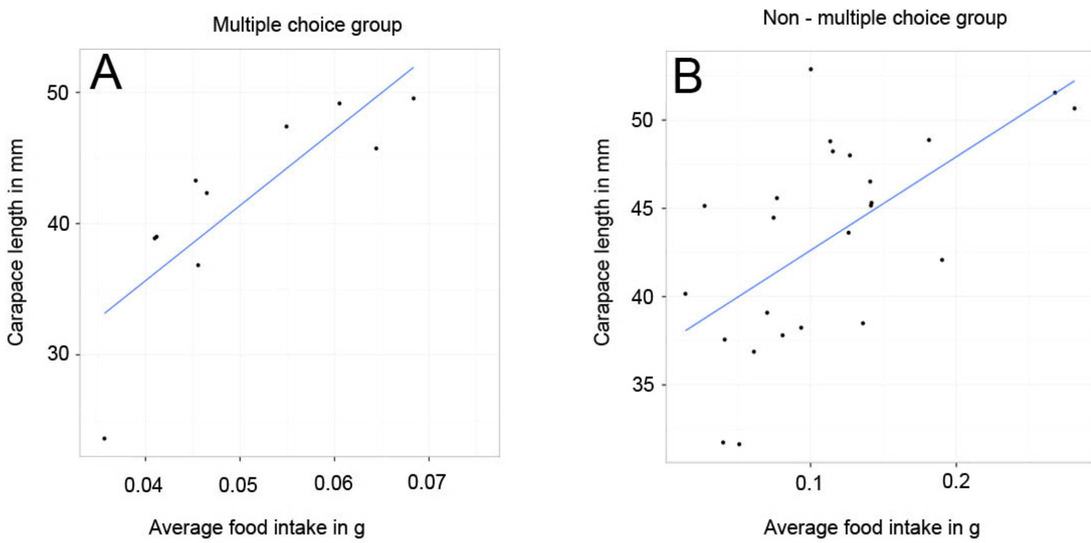

Figure 4
Mean food consumption per individual of the multiple choice group (rs = 0.867), (p-value = 0.0012) (n = 12) (A) and the non-multiple choice group (rs = 0.624) (p-value = 0.001) (n = 24) (B). The trend lines were determined using linear regression.

significant difference in food consumption ($p < 0.001$, $H = 279.935$, $n = 24$). Following Mann-Whitney-*U* tests ($n = 16$) determined these differences to occur between all food types (algae-fish: $p < 0.001$, $U = 11522$; chironomids-carrots: $p < 0.001$, $U = 2129$; carrots-fish: $p < 0.001$, $U = 11827$; algae-chironomids: $p < 0.01$, $U = 8032.5$) apart from between algae-carrots ($p > 0.0125$, $U = 3616.5$) and chironomids-fish ($p > 0.0125$, $U = 7553$) (Figure 6).

All crayfish of the control-group which had been starved throughout the experiment (box J) survived this prolonged period without nourishment.

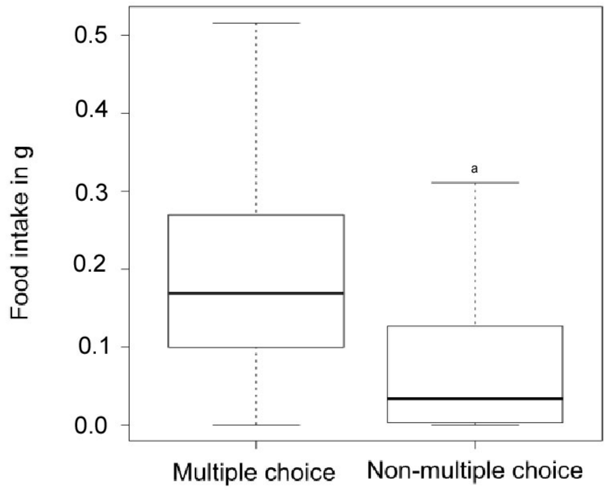

Figure 5
*Comparison of food intake of the multiple choice group with that of the non-multiple choice group for each feeding period and box. Mann-Whitney-U test: (p-value = 2.7*e* $^{-62}$*) (n = 36). a – significantly lower food intake. Horizontal lines touching the vertical lines above and below the boxes represent 1.5*× *interquartile range; outliers are not shown.*

DISCUSSION

Captive breeding and crayfish culture is a task in which more than just one single factor is important. Therefore, to improve or even optimise crayfish culture conditions, several aspects were researched in one single experiment. After investigating the connection between food intake, food preference and temperature, we were able to demonstrate a significant correlation between increased food intake and increasing water temperatures above 8 degrees.

Food consumption of crayfish in these feeding trials was expected to correlate positively with rising temperature (Mundahl, 1990; Croll and Watts, 2004). This was based on research verifying the assumption of a direct correlation between temperature increase and food intake (Jones and Momot, 1983, Söderbäck *et al*., 1987). Our findings support the assumption of a direct correlation between food intake and increasing temperature for a water temperature exceeding 8 °C, but not for temperatures between 5 °C–8 °C.

The increased food consumption at peak temperatures coincides with the approaching moulting-season. Previous research suggests the highest food intake for crayfish to occur at temperatures near maximum temperature tolerance (Mundahl, 1990). However, the experiments referred to had been carried out under laboratory conditions at constant temperature.

The design of our outdoor-experiment with near-natural temperature regime involved disturbing crayfish during their natural resting phase, in which otherwise little or no activity may have taken place (Huxley, 1895). This might have influenced the intake of food. This assumption is supported by the survival of all individuals of box J which had been starved but also left undisturbed throughout the experiment. Their survival is possibly due to reduced nutritional demands arising from reduced metabolic rate and activity.

Results from previous field observations (Holdich *et al*., 2006) indicate that adult crayfish consume substantially more plant tissue than we observed in the feeding trials. A possible explanation therefore is our experimental setup under controlled conditions in which crayfish were not required to forage for food actively. All food types were equally readily available at any given time. It may be further assumed that catching fish or finding fish-carrion is generally more difficult than feeding off plant-detritus and or macrophytes. Therefore plant-tissue can be considered a more likely source of nutrition in the natural habitat than during these feeding trials, especially for older specimens (Abrahamsson, 1966).

The comparison of calorific value and protein-content may yield a further explanation for the preference for fish. A calorific value of 148 kcal (=619.646 kJ) per 100 g for raw "mixed

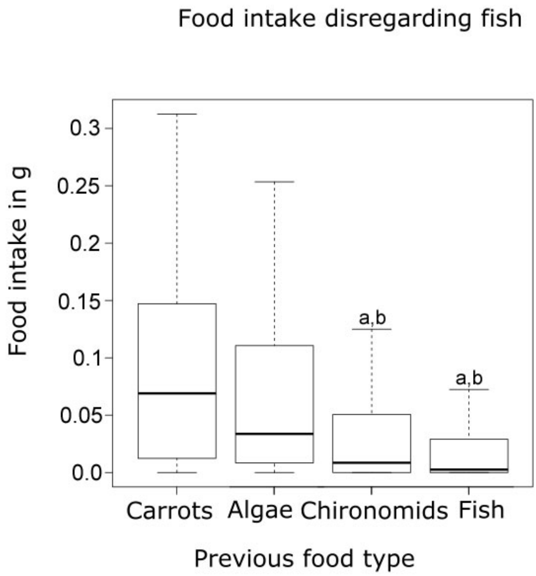

Figure 6
Food intake per week disregarding fish-consumption with respect to the food consumed the previous week of the non- multiple choice group. The previously fed food types are represented on the x-axis (carrots, algae, chironomids and fish). A higher food consumption after plant tissue (algae and carrots) than after animal tissue (chironomids and fish) can be observed. a – significantly lower consumption than after carrots; b – significantly lower intake than after algae. Horizontal lines touching the vertical lines above and below the boxes represent 1.5x interquartile range; outliers are not shown.

species" trout compared to 41 kcal (=171.659 kJ) per 100 g of raw carrots (USDA, 2014) makes fish a more desirable food item from an energy-technical point of view.

Additionally, the protein percentage in fish is 22 times higher than in carrots and the proportion of total lipids is 27 times higher. Our analysis of elemental composition of food items shows a 13-fold higher value of nitrogen in fish than in carrots. This indicates why fish tissue has been described as beneficial to the growth of crayfish (Ahvenharju and Ruohonen, 2005). It also indicates why crayfish displayed a significant preference for fish in our feeding trials.

Captive breeding entails not only selecting suitable nourishment but it also raises the question of how much food is required.

The nutritional demands for aquatic animals are usually stated in percentage of body weight (Jussila and Evans, 1996). Our experimental design allowed us to establish a correlation between carapace length and food intake. We observed in all crayfish groups, regardless of their nurturing type, a food intake analogous to the length of the carapace. Gross efficiency of food conversion verifiably decreases with the increasing size of crayfish (Guan and Wiles, 1998). This, in turn, leads to higher food consumption in larger individuals in order to maintain a positive energy balance.

Other factors, however, also influence the food intake of crayfish in captivity. The significantly higher food consumption by crayfish of the multiple choice group compared to that by the non-multiple choice group concurs with previous research. Earlier studies demonstrated that crayfish with access to a broader diet variety display higher growth rates than crayfish with a less attractive diet (McClain and Romaire, 2009). Aquatic animals are attracted to food through a plurality of substances rather than through one sole stimulant (Brönmark and Hanson, 2000). Therefore, offering a diversity of food items may have made the food more attractive than when the food items were offered separately.

All animals need a minimum amount of nutrition to maintain their metabolism (Bennett, 1990). It seems that if crayfish were fed on an inappropriate diet and subsequently offered a more suitable food type, the food consumption would increase. Previous studies have shown the phenomenon of energy compensation among crayfish (Stumpf *et al*., 2011) and other crustaceans alike (Wu *et al*., 2000). This was also observed in our experiments where crayfish consumed more food in general after having consumed plant tissue which has a lower energetic value.

Crayfish have been described as omnivores (Huxley, 1895), sometimes as predominantly herbivorous (Gaeveskaya, 1969; Scalici and Gibertini, 2007) or with a distinct preference for animal protein (Momot, 1995) or even shifting preferences depending on the age (Reynolds, 1998; Guan and Wiles, 1998). Our findings illustrate the heterogenic nature of crayfish diet with a clear preference for animal tissue. They reinforce the suggestion of plant tissue ideally being supplemented with animal tissue when rearing crayfish (Oliveira and Fabião, 1998) or other crustaceans (Syslo and Hughes, 1981).

It seems, however, plant tissue is more frequently and widely used as supplementary food in crayfish farms than animal tissue in addition to the natural flora and fauna (Ackefors, 2000). On a practical level, plant matter is cheaper and more convenient. Besides, the problems of decomposing excess food are not as severe as with animal tissue where heterotrophic microorganisms account for rapid degradation of water quality (Moriarty, 1997).

Crayfish farmers and captive breeders alike are confronted with finding the ideal balance between labour-saving measures, cost intensive feeding and also meeting the nutritional demands of crayfish.

If crayfish are kept in temporary storage, their growth-performance may be enhanced by ensuring that the amount of available food is more than adequate for the individual crayfish, taking its size into consideration. Furthermore, food put at the disposal of the crayfish should be diverse enough for the individual to make a selection. The diet should be balanced, containing not only plant tissue but also a significant proportion of animal tissue.

Future research with similar feeding trials could also be of interest in the case of higher holding densities instead of solitary confinement. These would have the aim of establishing the conditions under which crayfish resort to cannibalism, despite having an adequate and suitable diet.

Further research could also aim at clarifying the correlation between food consumption and temperature where feeding trials span the period of a whole year and where the crayfish are not disturbed during their natural resting cycle.

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