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Short communication

Influence of net cage farming on the diet of associated wild fish in a Neotropical reservoir

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ABSTRACT

Aquaculture in net cages is a well recognized strategy to meet the growing demand for food by the world's population. This type of fish production is increasing in freshwater, especially in large Neotropical reservoirs. However, it may lead to several impacts on freshwater assemblages. Thus, we aimed to determine if the artificial feed may indirectly (the load of nutrients may artificially increase production in the region and fish take advantage of this production) or directly (consumption by wild fish) alter the diet of the fish species living near the cages. We also determined if the intensity of food intake (measured by relative stomach weight) was altered by the inclusion of artificial feed. We gave special attention to the protein levels of the pellets used during the study (32% protein in the first 30 days; 28% protein after), distance from the cages (0 m, 100 m, and 400 m), and strata in the water column (surface and bottom), and to better evaluate the effect of the cage, we sampled before its installation. Overall, the dominant species changed their intake pattern of feeding, and also intensified the consumption of artificial feed. The load of organic matter (feed not consumed by caged fish) led to proliferation of microcrustaceans (which was readily consumed by some fish species), and to abrupt oscillation in the composition of food items of several species. The indirect effects were more conspicuous when the food pellet used presented higher protein level (32%), and directly when protein level was lower. The nature and intensity of the impact of food losses from aquaculture in the aquatic environment and their incorporation into the food chain still require more detailed investigation, at the individual (physiology) and population (autoecology) level, as well as higher levels of organization (communities and ecosystems).

1. Introduction

The increase in production of fish in net cages worldwide is helping to meet the growing demand for food by the world's population. Coastal areas, lakes and reservoirs are the most promising environments for this expansion in production. The main advantages of this culture system are the use of readily available water sources, greater management efficiency and easy harvesting, as well as high stocking rates and continuous water flow, which theoretically improve the water quality inside the cages (Cyrino and Kubitza, 1996; Furlaneto et al., 2006). Borghetti and Silva (2008) estimated that the operational costs per ton of fish are 30% to 40% of those of traditional systems. The expansion of this aquaculture system is being incorporated into government policies for the sector, receiving strong support from official agencies for implementation in public waters.

Nevertheless, there are a number of socio-environmental problems associated with this system that have been overlooked, usually linked to the intensive rearing methods that involve high stocking rates and the use of high-protein content feeds, as well as non-native fish scapes (Agostinho et al., 2007). Several studies have shown that net cage cultures affect the presence and abundance of wild fish and other organisms in their surroundings. Most of these studies, however, were carried out in coastal environments and few of them evaluated the impacts of these changes on assemblages (Boyra et al., 2004; Degefu et al., 2011; Dempster et al., 2002; Tuya et al., 2006; Valle et al., 2007). In the Neotropical zone, various studies have evaluated the socio-environmental problems associated with aquaculture in reservoirs, including eutrophication (Carvalho and Ramos, 2010), the attraction and aggregation of fish in the vicinity of net cages (Ramos et al., 2008), changes in fish diets associated with the culture environment (Strictar-Pereira et al., 2010), changes in the benthic community (Menezes and Beyruth, 2003) and the dispersal of non-native species (Agostinho et al., 2007). Future efforts towards developing net cage fish culture must consider its environmental sustainability because

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some of the above-mentioned problems may affect its viability as a productive activity (Andrade and Yasui, 2003).

With regard to changes in the diets of wild fish, studies performed to date reveal that following the start of net cage aquaculture, some species begin feeding predominantly on the artificial feed (pellets) that is offered to the cultivated fish but not ingested by them (Ramos et al., 2008), while other species alter their diets in response to the high availability of other organisms or detritus resulting from the culture (Ramos et al., 2008; Strictar-Pereira et al., 2010).

This study aimed to evaluate the direct and indirect effects of food losses (not consumed by caged fish) in cultivation of tilapia in net cages on the diets of wild ichthyofauna, seeking to identify the effects of artificial feeds with two different levels of protein, based on samples obtained prior to cultivation and in two subsequent periods established according to feed protein level. Moreover, variations in artificial feed intake were evaluated, based on the dominant species (>90% of the total abundance). More specifically, we aimed to answer the following questions: (i) how much did the addition of artificial feed alter the composition of the diet of the fish assemblage associated with net cage cultivation? (ii) Is the direct ingestion of the artificial food by wild species the only relevant change in the dietary composition of the assemblage? (iii) Is the intensity of food intake (measured by relative stomach weight) altered by the inclusion of artificial feed? To better achieve our goals, we considered in our design the protein level of the feed (32% and 28%), distance from the cages (0 m, 100 m and 400 m) and the strata of the water column (surface and near the bottom).

2. Materials and methods

2.1. Study area

This study was developed concomitantly with another designed to evaluate the productive and economic performance of Nile tilapia *Oreochromis niloticus* in net cages, carried out in the Corvo River (22° 39′ 34.93″ S and 52°46′42.86″ W), in the stretch dammed by the Rosana reservoir (Alexandre Filho, 2008) — Fig. 1. This reservoir, the last of a series of eight along the Paranapanema River, had its dam closed in 1986, and its water retention time is 18.6 days (CESP, 1996). The surface area of the reservoir is 22,000 ha, and its total length is 116 km. Due to its position in the series of reservoirs, Rosana has a high Secchi depth and low total phosphorus and nitrogen concentrations, and can be classified as oligotrophic (Nogueira et al., 2002; Pagioro et al., 2005).

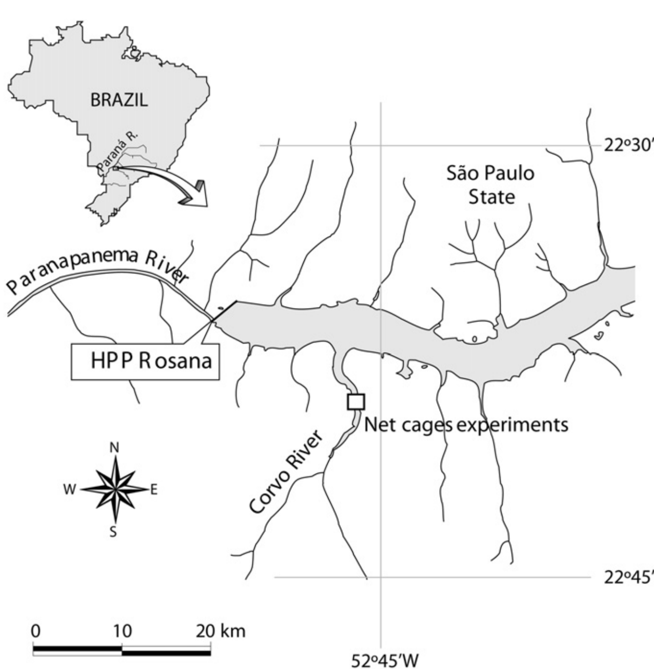

Fig. 1. Map of the Rosana reservoir showing the location of the study area.

Although the experiment was conducted in the lacustrine area of the reservoir, and therefore the most oligotrophic, the backwater of the Corvo River receives effluent that is discharged upstream by the starch industry after primary treatment. During the study period, there were no restrictions on water quality that were prohibitive to the presence of fish. Water temperature ranged between 19.4 and 29.1 °C (average 23 °C), which was normal for the time of year (winter). Dissolved oxygen concentrations oscillated between 6.0 and 8.7 mg L^{-1}, pH from 6.2 to 8.1, Secchi depth between 1.3 to 3.8 m and specific conductance (at 25 °C) between 32 and 56 μS cm^{-2}. The depth in the net cage area varied between 5 and 8 m.

2.2. Sampling procedures

Experimental cultivation in the net cages was carried out during autumn and winter, for 140 days (April 17 to September 3, 2006), using nine cages, each measuring 2.0 × 2.0 × 1.7 m, in which we applied three treatments (densities of 100, 150 and 200 tilapia m^{-3} in triplicate). Juveniles subjected to sex reversal had an initial average weight of 99 g, and were fed during the first 30 days on extruded feed of 5 mm in diameter containing 32% crude protein (CP), and later on 8-mm diameter feed containing 28% CP. Food was supplied three times a day, with the amounts determined according to biomass at the time and water temperature, adjusted for *ad libitum* conditions (Alexandre Filho, 2008).

Sampling of wild fish associated with cultivation was carried out monthly from April to September, using 10 sets of gillnets (2.4 to 16 cm mesh between opposite knots) set at two strata (near the bottom and at the water surface) in the area around the net cages (0 m, 100 m and 400 m from the cages). The nets were set at dawn and checked for caught fish at 4 p.m., 10 p.m. and 8 a.m. the following day. Captured individuals were anaesthetized (clove oil) and taken to a nearby laboratory, where they were identified, measured (total and standard length, in mm) and weighed (in grams). The fish were then dissected, and their stomachs weighed and fixed in 4% formalin for later analysis.

The contents of 647 stomachs belonging to 35 species were analysed under an optical microscope, stereoscope or by the naked eye, as appropriate, and items were identified to the lowest possible taxonomic level. The volume and frequency of occurrence of each item were recorded. Volume was determined by (i) measuring the displacement produced in a water column inside a graduated cylinder when greater than 0.1 ml, or (ii) by using millimetre slides, and recording the result in mm^3, later converting the value into millilitres when the volume was lower than 0.1 ml (Hellawell and Abel, 1971). Occurrence described the proportion of stomachs in the sample in which a given item occurred.

2.3. Data analysis

To evaluate the changes in the dietary composition of the assemblage before and after cultivation, the samples were grouped as follows: PRE — prior to the onset of cultivation (140 stomach contents); Phase 1 — use of fingerling feed containing 32% CP in the first 30 days (232 stomach contents); and Phase 2 — use of adult feed containing 28% CP for the remaining 110 days of cultivation (275 stomach contents). Variation in the diet was analysed for all stomachs by calculating the frequency of species that ingested each item, and by applying the Feeding Index (FI), which combines the occurrence and volume methods as shown in the equation (Kawakami and Vazzoler, 1980): $FI = (Fi*Vi)/[\sum(Fi*Vi)]$, in which Fi = % of frequency of occurrence of the item, Vi = % of item volume; i = food item from 1 to n.

The possible changes in each type of resource were inferred based on the variations in the proportion of their volume and occurrence in each phase of cultivation. To evaluate specific changes in intake pattern, with the aim of detecting species that were indirectly affected by ingesting artificial feed, the diet was evaluated only by the variation in volume of the items that each species ingested during the different cultivation phases.

To determine the influence of the distance from culture cages (0 m, 100 m and 400 m) and cultivation phases (PRE, Phase 1 and Phase 2) on the intensity of feeding activity, the means of the relative stomach weight index (IR) were calculated based on the percentage of the total weight represented by stomach weight. The significance levels of the differences among the means of this variable for the factors (distance and phase) and their interaction were evaluated using analysis of variance (two-way ANOVA). Prior to this, the homogeneity of the variances was tested by applying the Levène test. The data series for two of the species (*A. osteomystax* and *S. pappaterra*) showed heterogeneous variance even after transformation. Nevertheless, data analysis was carried out because (i) in one of the species, the nature of the novel ingested items differed from the previously ingested items (from insects to plankton), which suggests that the heterogeneity in variances is an expected characteristic of the experiment; and (ii) ANOVA is robust for heterogeneities in variance (Dempster et al., 2009; Underwood, 1997). All analyses were carried out using Statistica v.7.0 software.

3. Results

3.1. Variations in dietary composition according to cultivation phase

The resources most frequently ingested by the wild fish assemblage in the period prior to cultivation (PRE) were microcrustaceans (46%), aquatic insects (17%), algae (12%) and detritus-sediment (11%). Following installation of the cultivated fish (Phase 1), at which point the feed had the highest protein content, the importance of microcrustaceans in the fish diets increased, accounting for 80% of the Feeding Index, with a drastic reduction in the other items (Fig. 2A). During this phase, artificial feed not ingested by tilapia was the second most important resource (8%), followed by aquatic insects (7%).

In Phase 2, when the feed used contained less protein, there was a marked reduction in the consumption of microcrustaceans (10%). Aquatic insects (40%) were the most frequently ingested resource, followed by detritus-sediment and artificial feed, both in similar percentages (±18%) (Fig. 2A). It should be noted that detritus-sediment may contain relevant quantities of feed, which, being partially digested in the stomach, could not be isolated and thus remained unquantified. Of the 35 species recorded, more than half consumed aquatic insects; during the final cultivation phase this value reached 81% (Fig. 2B). Microcrustaceans and algae were ingested by the greatest number of species during Phase 1 of cultivation, involving 29% and 47% of the total number of species, respectively. Direct intake of pellet feed was observed in 18% of species during the first Phase and 38% in the second Phase.

Simultaneous analysis of the volume and occurrence of food items during the different cultivation phases (Fig. 3) demonstrated that the most important variations were shown by microcrustaceans, particularly with regard to volume. Their contribution increased drastically in the first month of cultivation (from 35% to 67% of the ingested total), with no significant change in occurrence (from 35% to 38% of stomachs). This contribution to volume decreased abruptly after changes in the protein level in the feed (from 67% to 12%), and occurrence also fell during Phase 2 (from 38% to 16% of analysed stomachs). With the exception of pellet feed and detritus-sediment, all other items occurred in fewer stomachs after the onset of cultivation. With regard to the contribution to the total volume ingested by the assemblage, pellet feed and detritus-sediment, in addition to fish and aquatic insects, reached higher percentages in Phase 2, and only microcustaceans showed their highest level of contribution in Phase 1. Algae and terrestrial insect intake decreased during cultivation, both in volume and occurrence, showing the opposite trend to feed intake.

3.2. Specific responses to the introduction of artificial feed

Among the captured fish species we selected eight dominant species that accounted for more than 90% of the total abundance of the assemblage. Different patterns of abundance were observed over space and time (Table 1). With regard to the water column stratum, most species were captured near the bottom, although *Auchenipterus osteomystax* was recorded mainly near the surface and *Metynnis maculatus* in both strata.

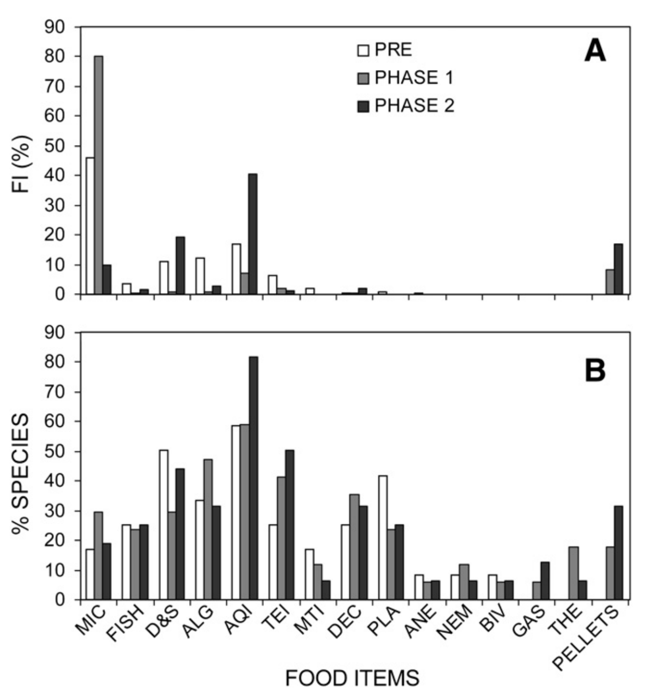

Fig. 2. Temporal variations in Feeding Index (A; FI) values and percentages of species that ingested the different food resources (B) in the vicinity of the area of tilapia cultivation in net cages (MIC = microcrustaceans, FISH = fish, D&S = detritus and sediment, ALG = algae, IQI = aquatic insects, TEI = terrestrial insects, MTI = mites, DEC = decapods, PLA = plants, ANE = annelids, NEM = nematodes, BIV = bivalves, GAS = gastropods, THE = thecamoebae, PELLETS = artificial feeding).

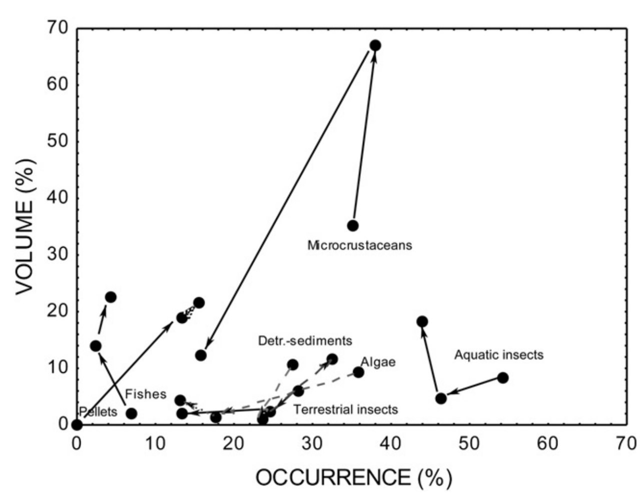

Fig. 3. Temporal variation in volume and occurrence of the main items ingested by the fish assemblage in the area of cultivation in net cages (arrows indicate the temporal sequence of the PRE Phase, and Phase 1 and 2 of cultivation).

Table 1
Location of the maximum and minimum values of abundance for the main species in the areas of cultivation in net cages in the Rosana reservoir.

Species	Water column stratum[a]	Maximum abundances		Minimum abundances	
		Distance from cages	Cultivation phases	Distance from tanks	Cultivation phases
A. osteomystax	Surface	400 m	1	0 m	2
S. brevipinna	Bottom	0 m	PRE	400 m	1
I. labrosus	Bottom	0 m	1	400 m	2
L. platymetopon	Bottom	0 m	PRE	400 m	2
P. squamosissimus	Bottom	400 m	PRE	0 m	2
P. maculatus	Bottom	0 m	1	400 m	PRE
M. maculatus	Surface	100 m	2	100 m	Pre/Bottom
S. pappaterra	Bottom	400 m	1	100 m	2

[a] Considering only the depth of highest occurrence, except for *M. maculatus*, which was similarly abundant at the bottom and on the surface.

Four species showed greater abundance in the vicinity of the net cages (0 m) and lower abundance at greater distances (400 m), all of them near the bottom (*S. brevipinna, L. platymetopon, I. labrosus* and *P. maculatus*). However, two of these species (the first two, both detritivores) were more abundant in the PRE Phase, and were therefore distributed independently from cultivation phase. Three species were more abundant at 400 m from the net cages (*A. osteomystax, P. squamosissimus, S. pappaterra*) with lower abundance in the vicinity of the cages. Of these, only *P. squamosissimus* was more abundant prior to cultivation. The abundance of *M. maculatus* was more variable at intermediate distances (100 m), where the lowest value was recorded in the PRE Phase and the highest in Phase 2.

We recorded direct pellet feed intake in at least half of the dominant species in the fish assemblage in the area sampled near the net cages (Fig. 4). It should be emphasized that typically detritivorous species, such as *S. brevipinna* and *L. platymetopon*, both with considerable abundance in the area sampled, may have ingested large quantities of feed, but that this could not be quantified due to the difficulty in separating decomposing feed from other residues. The species with the highest feed intake was the omnivore *P. maculatus,* with feed accounting for 98% of its diet in Phase 1 and 50% in Phase 2, followed by the invertivores *I. labrosus* (32% and 15%) and *S. pappaterra* (29% in Phase 2) (Fig. 4). The herbivore *M. maculatus*, which featured a markedly algivorous diet in the PRE Phase, ingested feed in the first (17%)

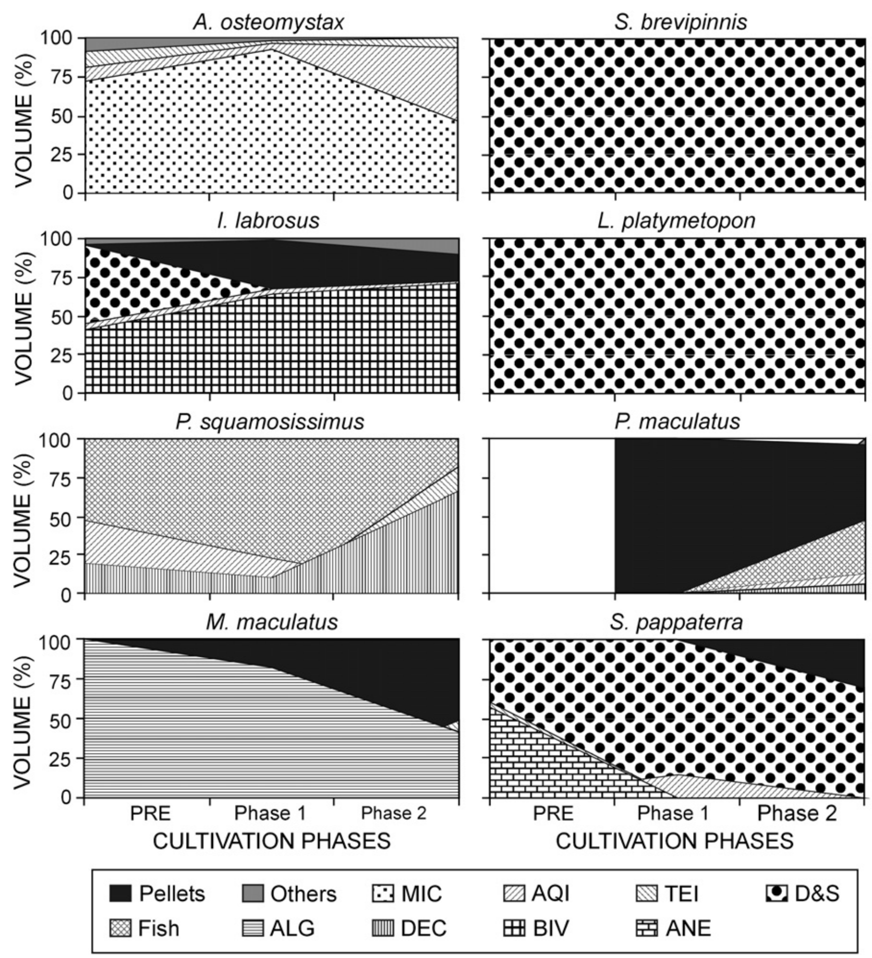

Fig. 4. Dietary composition of the dominant species in the fish assemblage associated with cultivation in net cages in the Rosana Reservoir, Paranapanema River, during different phases (PRE = prior to cultivation; Phase 1 = feed containing 32% protein; Phase 2 = feed containing 28% protein) (MIC = microcrustaceans, FISH = fish, D&S = detritus and sediment, ALG = algae, AQI = aquatic insects, TEI = terrestrial insects, ACA = mites, DEC = decapods, PLA = plants, ANE = annelids, NEM = nematodes, BIV = bivalves, GAS = gastropods, THE = thecamoebae).

and second phases (52%) (Fig. 4). In addition to the species considered herein, two others with low abundance ingested considerable quantities of feed (*Pimelodella gracilis* and *Parauchenipterus galeatus*). *Auchenipterus osteomystax*, with a predominantly zooplanktivorous diet in the PRE Phase, became essentially zooplanktivorous (98%) in Phase 1 (feed containing the highest protein level). In Phase 2 (feed containing lower protein levels), the diet of *A. osteomystax* consisted of insects and zooplankton in similar proportions (48%) (Fig. 4).

3.3. Changes in intensity of feeding activity

Significant differences were found between the means of the relative stomach weight for six of the eight most abundant species, with the exception of *S. brevipinna* and *S. pappaterra* (Table 2). No significant differences in feeding activity were recorded in relation to distance; *I. labrosus* was the only species in which the differences between cultivation phases were affected by distance (significant interaction; Table 2) (Fig. 5).

Higher feeding activity, inferred by relative stomach weight, was observed in three of the eight most abundant species in the assemblage (*A. osteomystax*, *I. labrosus* and *P. maculatus*) during the first month of cultivation (Phase 1), when the feed containing the highest protein level was ingested in the vicinity of the cages (Fig. 5).

Four other species showed a trend for increased relative stomach weight in the vicinity of the cages, but none showed significant differences (*L. platymetopon, M. maculatus, S. brevipinna* and *S. pappaterra*). Likewise, *P. squamosissimus* showed a trend for reduced stomach weight at different distances from the culture cage area, but this was not significant (Table 2) (Fig. 5).

4. Discussion

The proportion of species with stomachs containing undigested artificial feed was low (28% of the analysed total) compared to marine environments (Fernandez-Jover et al., 2008). However, it was consistent with the proportion observed in reservoir environments (Nunes, 2008; Ramos et al., 2008). The estimated direct intake of artificial feed – between 8% and 18% of the total – can also be considered low, but we did not quantify it for detritivorous species. For the same reason, the percentage of species involved in direct intake (17% and 38% in the different phases) should be considered an underestimation.

Dempster et al. (2010) examined five dominant fish species near marine fish farms, all included artificial feed in their diets, and reported that between 66% and 89% of stomachs analysed contained feed pellets. These authors estimated that about 10% of the feed used in the culture was consumed directly by wild fish. In our study, only four of the eight dominant species ingested feed pellets, and this food item was found undigested in only 9.4% of stomachs. It is possible that the inert and initially buoyant nature of this type of food may restrict its use to a small number of species in reservoirs. In addition to its nature, the manner in which it enters the standing water may also limit its use by species whose evolutionary history took place in fluvial environments.

The impact of adding artificial feed into the trophic chain is still not well understood. Dempster and Taquet (2004) suggested that the persistent supply and resulting aggregation of wild fish near fish farms could be beneficial to the stock if combined with measures prohibiting any type of fishing in the vicinity, effectively turning the zone into a protected area such as a marine reserve. They also stated that the excess feed from cultivation would improve fish growth, and that protection would assure the increase in spawning stocks and resulting larval recruitment.

On one hand, the intake of excess feed by fish could reduce the amount that reaches the bottom by up to 80% (Felsing et al., 2005), reducing its negative effects on benthonic communities (Katz et al., 2002; Menezes and Beyruth, 2003). On the other hand, the intake of rations containing terrestrial plant products (e.g. soybeans, corn) leads to changes in condition, fat levels in the liver, and fatty acid composition (e.g. ω3 and ω6 ratios; oleic and linoleic acids), making the body composition of wild fish similar to that of cultured species (Dempster et al., 2009; Fernandez-Jover et al., 2007). Although the increase in condition may improve reproductive capacity (Izquierdo et al., 2001), low ω3 levels have a negative relationship with egg quality and larval survival (Fernández-Palacios et al., 2007). Attention must be given to the possible intake of drugs and hormones along with the feed given to fish cultures (Dempster et al., 2009).

The species with the lowest amount of pellets in their diet following the start of cultivation had previously consumed various different items, making it impossible to identify a clear feeding pattern. These included the herbivore/algivore *M. maculatus* (Resende et al., 1998), the benthivores *S. pappaterra* and *I. labrosus* (Abes et al., 2001; Hahn and Cunha, 2005), and the omnivore *P. maculatus* (Hahn and Fugi, 2007). These species also showed differences in feed intake among the phases, with *P. maculatus* and *I. labrosus* featuring higher intake during the first Phase (higher protein level) and the others in the second Phase. However, the periods of higher feed intake also resulted in greater relative stomach weight. The behavior of *Iheringichthys labrosus*, a species with considerable feed intake and aggregation in the vicinity of the cages in this study, differed from that observed in Machadinho reservoir, where it did not ingest feed in the vicinity of the culture cages (Rech, 2008). It should also be mentioned that the two species with the highest relative feed intake (*P. maculatus* and *M. maculatus*) were the same as those recorded in a similar culture system at the Nova Avanhandava (Ramos et al., 2008) and Chavantes reservoirs (Ramos et al., 2008). Equally relevant is the fact that studies on the diet of the piscivore *P. squamosissimus* at Nova Avanhandava, similar to this study, found no evidence of pellets feed, and the most important modification, like here, was the increase in the consumption of decapods.

As mentioned, changes in diet between the cultivation phases were also observed in species that did not ingest feed directly. Concomitant

Table 2
Analysis of variance applied to the relative stomach weight of each species considering cultivation phases (PRE phase — before installation of net cages; Phase 1 = feed containing 32% protein; Phase 2 = feed containing 28% protein) and distance from cages (0 m, 100 m and 400 m), as well as their interactions. (Numbers in bold = significant at $p<0.01$) (D.F.: degrees of freedom; S.S.: mean sum of squares).

	D.F.	S.S.	F	D.F.	S.S.	F
	A. osteomystax			*S. brevipinna*		
Phase	2	412,467	**6.25**	2	5432	1.15
Distance	2	96,927	1.47	2	6906	1.48
Phase*Distance	4	19,213	0.29	4	6175	1.32
Residuals	887	65,933		236	4870	
Homogeneity of variance	9.23 (p<0.01)			0.27 (p=0.99)		
	I. labrosus			*L. platymetopon*		
Phase	**2**	19,420	**6.33**	2	28,293	**13.37**
Distance	2	3065	0.99	2	2217	1.05
Phase*Distance	4	8755	**2.85**	4	815	0.38
Residuals	191	3067		168	2116	
Homogeneity of variance	1.61 (p=0.71)			1.06 (p=0.39)		
	P. squamosissimus			*P. maculatus*		
Phase	2	4088	**3.7**	2	6923	**7.17**
Distance	2	171	0.15	2	2630	2.72
Phase*Distance	4	1043	0.95	4	417	0.43
Residuals	108	1103		104	965	
Homogeneity of variance	0.33 (p=0.95)			0.21 (p=0.91)		
	M. maculatus			*S. pappaterra*		
Phase	**2**	6924	**7.17**	2	213	0.38
Distance	2	2631	2.72	2	968	1.72
Phase*Distance	4	418	0.43	4	683	1.21
Residuals	104	966		72	562	
Homogeneity of variance	2.60 (p=0.92)			4.64 (p<0.01)		

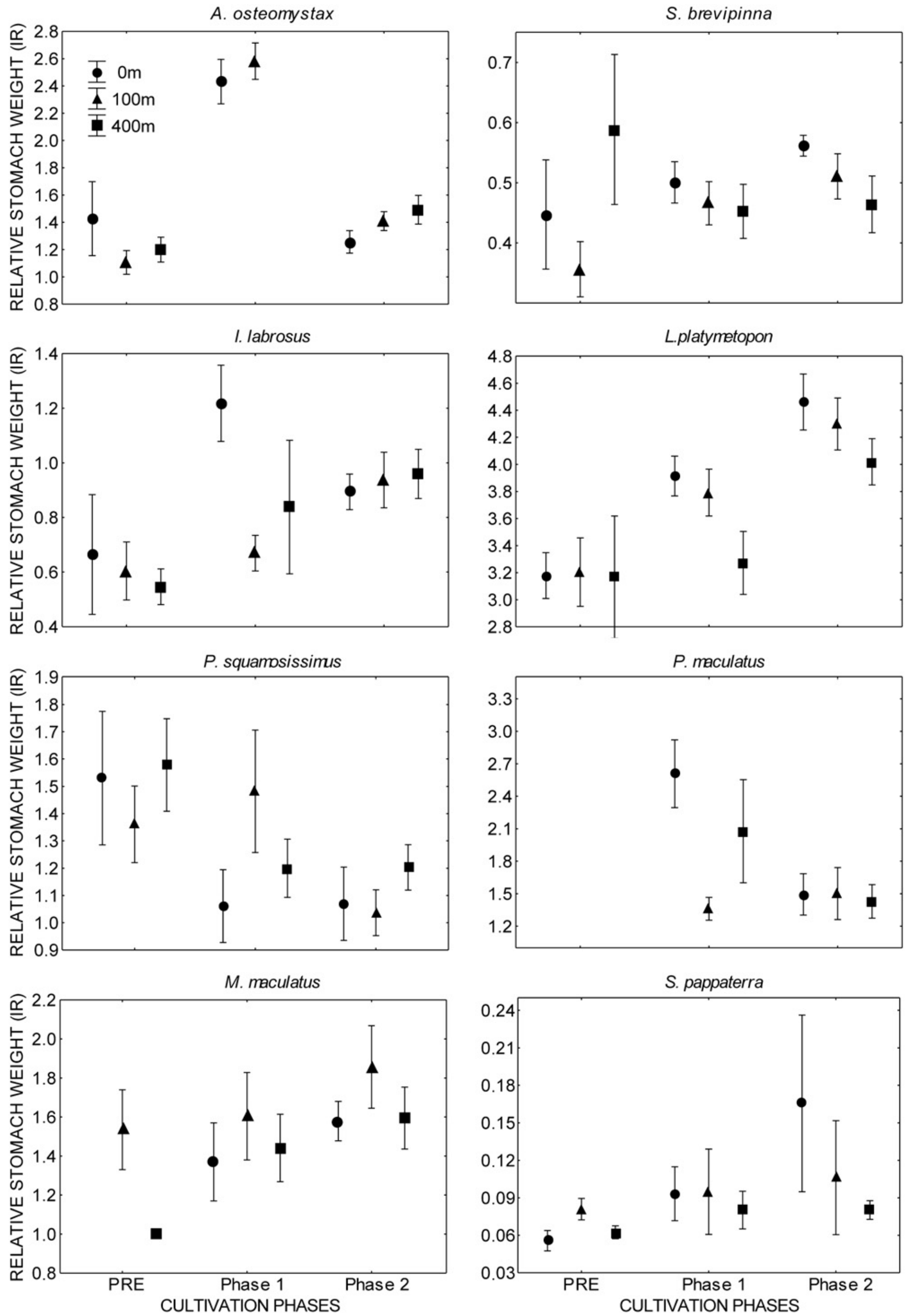

Fig. 5. Variations in the relative stomach weight of the dominant fish species in the assemblage associated with tilapia cultivation in the Rosana Reservoir, Paranapanema River, during different phases (PRE = prior to cultivation; Phase 1 = feed containing 32% protein; Phase 2 = feed containing 28% protein) (Vertical bars: standard errors).

studies performed in the cultivation area revealed that these changes impacted on isotopic composition at different points of the trophic chain, indicating changes in the energy source and trophic position of the organisms (Figueroa and Benedito, 2008). For example, although it did not ingest the artificial feed, *A. osteomystax* showed a trend in isotopic variation similar to that of the culture species (Eche, 2008). In that sense, it is relevant that zooplankton density increased substantially after cultivation began (Borges et al., 2010; Dias et al., 2011). In our study, *A. osteomystax* had a zooplanktivorous diet in the PRE Phase, but in Phase 1 it fed essentially on zooplankton. This suggests that nutrients contained within the feed reached *A. osteomystax* via zooplankton as a direct or indirect intermediary (via phytoplankton). The predominance of zooplankton-eating species in the vicinity of culture cages has been reported in marine (Fernandez-Jover et al., 2008) and freshwater environments (Nunes, 2008). In a study concomitant to ours, Strictar-Pereira et al. (2010) reported that the intense feeding activity observed in the first month of cultivation – when zooplankton density was high – was not reflected by the nutritional condition (relative weight). The highest feeding activity values coincided with the lowest average condition. Strictar-Pereira et al. (2010) associated the low condition of *A. osteomystax* after cultivation began with the lower nutritional value of zooplankton compared to aquatic insects. The diet of *A. osteomystax* also showed significant variation, as discussed by Strictar-Pereira et al. (op. cit.).

The results presented herein indicate that the food that is not consumed by tilapia in net cages promotes significant changes in the diet of associated species, which begin to directly ingest the excess feed pellets from cultured fish or indirectly consume resources that become abundant as the result of the addition of organic matter and nutrients. The nature and intensity of the impact of food losses from aquaculture in the aquatic environment and their incorporation into the food chain still require more detailed investigation, at the individual (physiology) and population (autoecology) level, as well as higher levels of organization (communities and ecosystems).

It is imperative that the efforts applied by support agencies to expand this modality of cultivation in public waters in Brazil be shared with the research and management sectors. However, it is known that, in addition to other impacts not discussed herein (see Agostinho et al., 2007 for details), the attraction exerted on fish by the food supplied but not consumed by cultured individuals and the physical structure of the nets may result in large aggregations vulnerable to overfishing and predation. This makes it essential that actions – such as fishing bans – be taken to protect wild stocks in the spatial regulation of this activity. Furthermore, as emphasized by Fernandez-Jover et al. (2008), the specific variations in fish response to food losses from cultures and the different compositions of ichthyofauna between environments mean that monitoring of the wild fauna associated with this type of aquaculture should be conducted whenever a new fish farm is to be installed. Faced with the potential impact of these cultures on the biota and water quality, their environmental sustainability remains to be confirmed, at least in large-scale projects.

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