

Feeding of *Cichla monoculus* Spix, 1829 (Teleostei: Cichlidae) during and after reservoir formation in the Tocantins River, Central Brazil.

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ABSTRACT: Feeding of *Cichla monoculus* Spix, 1829 (Teleostei: Cichlidae) during and after reservoir formation in the Tocantins River, Central Brazil. We examined *Cichla monoculus* feeding in a stretch of the upper Tocantins River during construction of the Serra da Mesa power plant. Fishes were sampled bimonthly during two periods: reservoir filling (Dec/96 to Apr/98) and operation (Jun/98 to Feb/00). Stomach contents analysis confirmed the piscivorous habit of the species but also revealed differences in diet composition between filling and operation phases. Tetragonopterin fishes were the main prey during the filling phase, and cichlids were dominant prey during the operation phase. Reduced feeding was observed in reproductive individuals. Juveniles had a more diversified diet than strongly piscivorous adults. The predator-prey size relationship was weak in both the phases ($r^2 < 0.43$) and positive only during the operation phase. We recorded cannibalism on juveniles throughout whole period of study. Feeding plasticity and availability of cichlid prey are probably important factors that explain persistence of *C. monoculus* in reservoirs.

Key-words: *Cichla monoculus*, feeding, reservoir, Serra da Mesa.

RESUMO: Alimentação de *Cichla monoculus* Spix, 1829 (Teleostei: Cichlidae) durante e após a formação de um reservatório no Rio Tocantins, Brasil Central. Neste trabalho caracterizamos a alimentação de *Cichla monoculus* em um trecho do alto rio Tocantins durante a instalação da usina hidrelétrica Serra da Mesa. Os peixes foram capturados bimestralmente em dois períodos: fase de enchimento do reservatório (dez/96 a abr/98) e fase de operação da usina hidrelétrica (jun/98 a fev/00). As análises do conteúdo estomacal confirmaram o hábito piscívoro da espécie, porém revelaram diferenças na composição da dieta entre a fase de enchimento e a fase de operação. Caracídeos tetragonopteríneos foram as principais presas na fase de enchimento e ciclídeos foram dominantes na fase de operação. Foi observada redução da atividade alimentar em indivíduos reprodutivos. Juvenis apresentaram dietas diversificadas quando comparadas à forte piscivoria dos adultos. A relação predador-presa foi fraca em ambas as fases ($r^2 < 0.43$) e positiva apenas na fase de operação. Canibalismo foi registrado ao longo de todo o período de estudo. A plasticidade alimentar e disponibilidade de ciclídeos como presas são, provavelmente, fatores que explicam a persistência de *C. monoculus* em reservatórios.

Palavras-chave: *Cichla monoculus*, alimentação, reservatório, Serra da Mesa.

Introduction

The family Cichlidae occurs in Africa, Asia, South and Central America. In South America, the family is represented by 50 genera and nearly 450 species (Kullander, 1998). Most Brazilian species occur in Amazonian rivers (Lowe McConnell, 1999). The species of the genus *Cichla* are called "tucunaré" in Brazil (referenced in other countries

as "pavón" or "peacock cichlid"). *Cichla* are diurnal piscivorous common in lentic habitats. Because they are important sportfish, tucunarés were introduced into lakes of tropical and subtropical areas, including Southern Brazil, Panama, Puerto Rico, Hawaii and Florida (Zaret & Paine, 1973; Jepsen et al., 1997).

The upper Tocantins River, Central Brazil, was dammed in October 1996 by the Serra da Mesa hydroelectric power plant. Regulated flow and non-cyclic disturbances caused by dam operation decrease biotic diversity (Agostinho et al., 1999). *Cichla monoculus* Spix, 1829 was a rare species in the region before the damming of the Tocantins River, but became abundant and widespread in the reservoir after its formation (unpublished). Rapid colonization by *Cichla* species was reported after damming of the Jamari River (Santos, 1995), Uatumã River (Santos & Oliveira Jr., 1999), Caroní and Paragua rivers (Williams et al., 1998), and when the species was introduced in reservoirs in southern Brazil (Arcifa & Meschiatti, 1993; Magalhães et al., 1996 and Santos et al., 2001).

The study of feeding relationships increases understanding of the ecology of species and communities. Transformation from lotic to lentic conditions in dammed rivers is accompanied by changes in food-resource availability, which in turn influences biotic interactions. Fish species respond differently to a new lentic environment (Hahn et al., 1997a). Few studies have examined the trophic structure of fish communities in reservoirs (Barbieri et al., 1982; Arcifa et al., 1988; Braga, 1990; Arcifa & Meschiatti, 1993; Loureiro & Hahn, 1996; Hahn et al., 1997a; Hahn, et al., 1997b; Hahn et al., 1998; Oliveira Jr., 1998, Abujanra et al., 1999 and Albrecht et al., in press), and hydroelectric plant construction in Brazil is continuing, and more studies are needed.

Herein, we present results from a study of the feeding ecology of *Cichla monoculus* during and after construction of Serra da Mesa dam.

Materials and methods

Study site: The study site, located between 49°30'W and 48°00'W and 13°00'S and 15°00'S in the upper Tocantins River, is a part of the Tocantins-Araguaia Basin in Brazil. This basin extends 2,500 km within a drainage area of ca. 767,000 km² that receives a mean annual discharge of ca. 10,000 m³s⁻¹. The Tocantins River begins at the Brazilian Shield, a high plateau of Central Brazil and empties into the Amazon River estuary. The study area is located in the "cerrado" region of the Brazilian Shield, a landscape of gently rolling hills and open woodlands. Before impoundment, the main channel of the Tocantins River was 40 - 100 m wide with depths up to 90 m. The river bed was rocky, the flow fast; the banks were high (ca. 20 m) with little floodplain development, and water level changed rapidly in response to upstream discharge and local runoff. The region has one dry (April to September) and one rainy season (October to March). In October of 1996 the Tocantins River was dammed to create the Serra da Mesa Reservoir. Initially the waters arose quickly, with filling completed in April of 1998 yielding a flooded area of 1,784 Km² with a volume of 54,400 x 10⁶ m³. According to the classification proposed by Straskraba & Tundisi (1999), Serra da Mesa is considered a reservoir of a large tonnage. During the filling phase, an estimated 32.2 tons of vegetation was flooded by hectare, which was followed by a period of water hypoxia. After several months, water in the top 10 m regained oxygen (De Fillipo et al., 1999). At the beginning of hydroelectric plant operation, the water level of the reservoir dropped ca. 10 m and exposed margins lacking vegetation cover.

Field procedures: Field sampling was conducted with 650 m² gill nets area (meshes 15, 20, 25, 30, 35, 40, 45, 60, 80, 110 e 150 mm adjacent knot) bimonthly from December 1996 to February 2000 at 13 sampling stations. The total study period includes the filling phase (Dec/96 to Apr/98) and the operation phase (Jun/98 to Feb/00). To study spatial variation, we considered nine reservoir locations. To study temporal variation, we compared data during the filling and operation phases. Fish specimens were measured for standard length (SL) to the nearest millimeter and weight (Wt) to the nearest gram. Based on dissection, the gonadal development was identified according to vascular irrigation and relative occupation in the abdominal cavity, for both sexes; for females, size and color of oocytes was registered. According of these characteristics the following classification was considered: females - immature, initial maturation, advanced maturation, mature,

spawning, recovering and recovered; and males: immature, maturation, mature, expelling, recovering and recovered. Gonad maturity stages subsequently were aggregated into the reproductive categories (advanced maturation, mature, spawning and, for males, expelling) and non-reproductive (initial maturation, recovering, recovered). Relative frequency of reproductive and non-reproductive individuals with full stomach and empty stomach was registered. Stomach contents of 176 *C. monoculus* specimens (4.8 - 33.6 cm SL) were preserved in 5% formalin and analyzed in the laboratory. Prey were identified, counted and weighed. Mutilated or partially digested food items were not measured. Food items were grouped according to family and/or order (fishes) or broader taxonomic categories (vegetation, insects). Frequency of occurrence and gravimetric methods (e.g. Hyslop, 1980) were used to analyze diet. Results were expressed by the Kawakami & Vazzoler (1980) alimentary index modified by Hahn et al. (1997a).

$$IA_i = (F_i \times V_i / \sum (F_i \times V_i)) \times 100$$

Where: IA_i = alimentary index; i = food items 1, 2, ... n ; F_i = frequency of occurrence (%); V_i = wet weight (%).

The Chi-square test (χ^2) ($p < 0.05$) was used to verify differences in feeding between phases (Zar, 1996).

The abundance values of *C. monoculus* and its main preys were estimated and expressed by capture per unit of effort (CPUE) in number of individuals:

$$CPUE_n = N / (m^2 \times h)$$

where: CPUE_n = capture per unit of effort in number of individuals; N = number of individuals captured; m^2 = gill nets area; h = gill nets exposition time.

In order to verify differences in the mean values of capture between filling phase and operation phase, the t test ($p < 0.05$) (Zar, 1996) was used.

The stomach fullness index (e.g. Zavala-Camin, 1996) was used to verify differences on alimentary activity between filling phase and operation phase.

$$FI = (W_s / W_t) \times 100$$

where: FI = stomach fullness index; W_s = weight of stomach content; W_t = total fish weight.

Mann-Whitney Test ($p < 0.05$) (Zar, 1996) was used to verify differences in the mean values of stomach fullness index between the two phases.

Frequencies of occurrence of food items by standard length classes (2 cm intervals) were used to document diet changes during growth.

Regression analysis was used to examine the relationship between prey size and predator size during the filling and operation phases.

Results

A total of 1,041 specimens was captured, 656 in filling phase (CPUE_n = 6.3934) and 385 in operation phase (CPUE_n = 3.4586).

We identified 26 prey items for *C. monoculus*, with a greater proportion of stomachs during the filling phase (22 items in 81 stomachs) than the operation phase (14 items in 95 stomachs). During the filling phase the alimentary index identified four main items (95% of the total), with tetragonopterin characid fishes being the most abundant (Fig. 1). During the filling phase, the diversity of tetragonopterin genera (e.g., *Astyanax*, *Ctenobrycon*, *Knodus*) in the diet was fairly even. Three prey categories were dominant (85% of the total) during the operation phase, with cichlid fishes most common. During the operation phase, *Bryconops* species were the main tetragonopterins consumed (90%), and species of other genera were rare or absent in stomach contents samples. *Anchoviella* sp. was recorded in diet only during the operation phase. Insects, which had minor importance during the filling phase, disappeared from the diet after lake formation.

Chi-square test indicated significant difference on feeding between phases ($\chi^2 = 103.4642$; $p < 0.05$).

The values of the Tetragonopterinae CPUE_n were higher in filling phase ($t = 2.319$; $p = 0.0323$). The Cichlidae CPUE_n values (Tab. I) were not different ($t = 1.877$; $p = 0.0769$).

The values of the stomach fullness index (1.1535 in filling phase and 0.9807 in operation phase) were not different between the phases ($U = 4324.0$; $p = 0.3597$), indicating similar feeding activity.

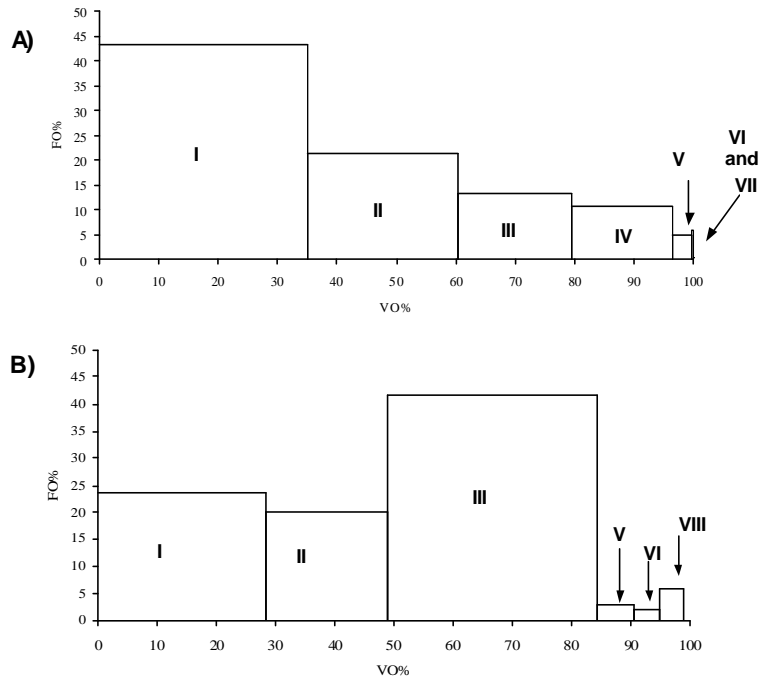


Figure 1: Percent weight and percent frequency of occurrence of the main items consumed by *Cichla monoculus* in the upper Tocantins River. A) filling phase (December 1996 – February 1998); B) operation phase (April 1998 – February 2000). I – Tetragonopterinae, II – Unidentified Fishes, III – Cichlidae, IV – Other Characiformes, V – Sciaenidae, VI – Plants, VII – Insects, and VIII – *Anchoviella* sp.

Table I: Abundance (N) and CPUEn of Tetragonopterinae and Cichlidae captured in the upper Tocantins River from December 1996 to February 2000.

	N		CPUEn	
	Filling phase	Operation phase	Filling phase	Operation phase
Tetragonopterinae*	3707	88	36.1284	0.7905
Cichlidae ^{ns}	1157	3060	11.2761	27.4891

* Significant difference $p < 0.05$; ns – no significant

Only 15% of the reproductive individuals had stomach contents, and 46% of non-reproductive individuals had stomachs containing prey (Fig. 2). No difference in percentages of stomachs with prey was found between filling and operation phases.

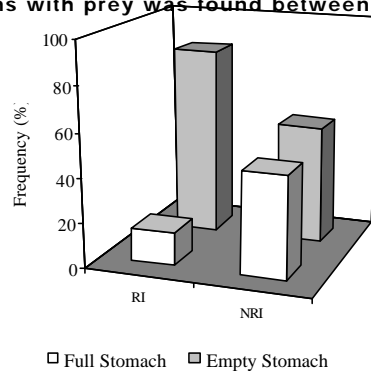


Figure 2: Percentage of full and empty stomach in reproductive (RI) and non-reproductive (NRI) individuals of *Cichla monoculus* captured in the upper Tocantins River from December 1996 to February 2000.

The adult (>16.5 cm SL) diet was strongly dominated by fishes, with insects and vegetation being rare. The smallest length class (4.5-6.5 cm SL) consumed only microcrustaceans. Fishes and insects were the main prey for individuals 6.5-16.6 cm SL (Fig. 3). The same result was obtained in both phases.

The relationship between predator and prey size was weak during both the filling and operation phases (Fig. 4).

Cannibalism was recorded for 8% of *C. monoculus* stomachs examined (14 of 176), with a slightly higher frequency during the operation phase. *Satanoperca* aff. *jurupari* was the most common cichlid in the diet, with young *C. monoculus* ranking second.

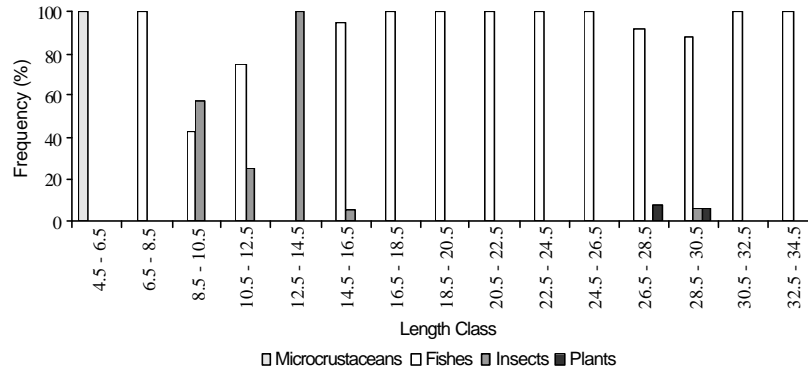


Figure 3: Percentage of the food items by length class of *Cichla monoculus* captured in the upper Tocantins River from December 1996 to February 2000.

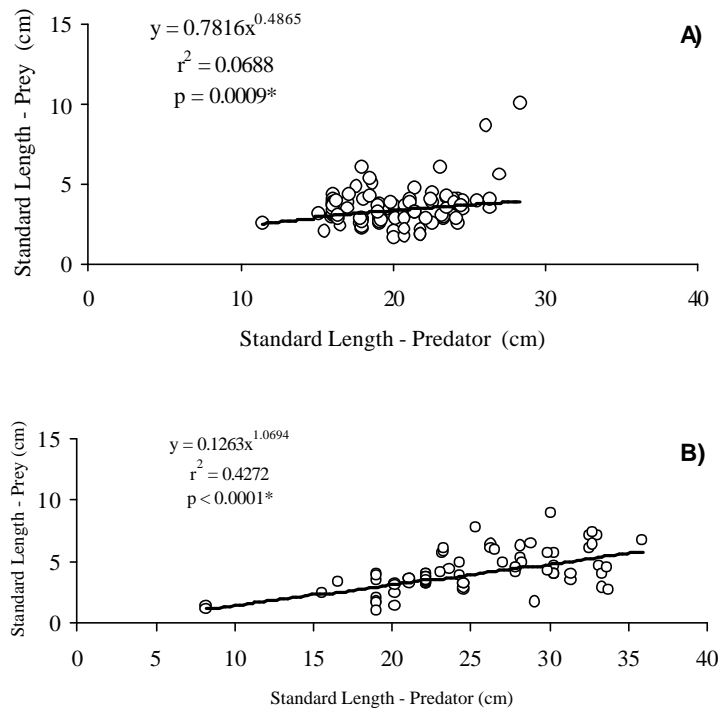


Figure 4: Relation between standard length of *Cichla monoculus* (predator) and the prey ingested in the upper Tocantins River. A) filling phase (December 1996 - February 1998); B) operation phase (April 1998 - February/2000). * significantive.

Discussion

The high degree of piscivory exhibited by *C. monoculus* in Serra da Mesa Reservoir is similar to findings reported for *Cichla* species from other drainages (Lowe-McConnell, 1969; Arcifa & Meschiatti, 1983; Braga, 1990; Jepsen et al., 1997; Winemiller et al., 1997; Oliveira Jr., 1998; Williams et al., 1998; Lipparelli, 1999; Reis & Caramaschi, 1999 and Santos et al., 2001).

The feeding varied significantly between phases. During reservoir filling, tetragonopterin characids ("lambaris") were the principal prey of *C. monoculus*, constituting 52% of the diet according to the AI. In contrast, cichlids only represented c.a. 5% of the diet during reservoir filling. When the reservoir had been filled and the hydroelectric plant began to operate, the main prey (40% according to AI) of *C. monoculus* were cichlids, and occurrence of Tetragonopterinae was reduced to 23% (and 96% in the reservoir). Similar result was found for *Hoplias malabaricus* in the Segredo Reservoir during its formation, when *Astyanax* (Tetragonopterinae) was the main prey (Loureiro & Hahn, 1996). Reservoir dynamics may partially explain these results. During the period of reservoir filling, marginal vegetation was submerged, providing productive littoral habitat for several species of Tetragonopterinae as reported for other reservoirs (Agostinho et al., 1999). During the operation phase, the water level of the reservoir decreased approximately 10 m, which reduced the amount of aquatic vegetation available for refuge, spawning and feeding. Abundance and diversity of tetragonopterin species in the diet was reduced after several months of plant operation. In contrast, cichlids (e.g., *Satanoperca* aff. *jurupari*, *Geophagus* cf. *surinamensis* and *Crenicichla* spp.) increased in the diet of *C. monoculus*. Cichlids and tetragonopterins have different life history strategies (Winemiller, 1989a), with cichlids being generally better adapted to lentic environments (Lowe-McConnell, 1999). The feeding plasticity of *C. monoculus* shown in this study, may explain the success of its colonization in Serra da Mesa Reservoir. Feeding plasticity has been identified as an important factor for the success of native river fishes in reservoirs (Loureiro & Hahn 1996; Hahn et al.; 1997a; 1997b; 1998; Agostinho et al. 1999; Gama, 2000; Albrecht & Caramaschi 2003 and Albrecht et al., in press.).

Cichla in reproductive condition reduced feeding activity. Alterations in feeding activity during the reproductive period can be caused by an increase in gonadal volume and a concomitant decrease in abdominal cavity space (Nikolsky, 1963). Thus, a large gonadal volume (40% of body cavity in females and 25% in males, unpublished) may inhibit ingestion of large prey. Spawning site selection and courtship by male *Cichla* and brood defense by both sexes are probably associated with decreased feeding activity (Jepsen et al., 1997).

Ontogenetic changes in fish diets are common (Nikolsky, 1963; Wootton, 1990). The juveniles of nine piscivorous fishes in the Venezuela llanos consumed more microcrustaceans and aquatic insects than fishes (Winemiller, 1989b). In Serra da Mesa reservoir, adult *C. monoculus* fed mostly on fishes, whereas juveniles ingested microcrustaceans and insects in addition to fishes. Presence of insects and plants in the stomachs of adults could be remains from the stomachs of ingested prey or material ingested incidentally during prey capture. *Cichla ocellaris* (= *C. monoculus*) smaller than 8.2 cm SL from a Ribeirão Preto River Reservoir consumed mostly aquatic insects (Arcifa & Meschiatti, 1983). Similar patterns have been reported for other piscivorous fish species in Brazilian reservoirs (Arcifa et al., 1988; Hahn et al., 1997a; Almeida et al., 1997; Hahn et al., 1998).

Piscivorous fishes, such as *Hoplias malabaricus* and *Plagioscion squamosissimus*, feed on larger prey as they grow (Loureiro & Hahn, 1996; Hahn et al., 1997b). Strong and positive correlations of predator and prey length were reported for four piscivorous species in a Venezuela reservoir that included *C. temensis* and *C. orinocensis* (Williams et al., 1998). A relationship between predator length and prey length was not evident for *C. monoculus* during the filling phase of Serra da Mesa Reservoir. During the operation phase, this relationship was positive but weak. In the filling phase the medium-size of *C. monoculus*

was lower than the next phase. The weak relationship between predator and prey size probably reflects an interaction between prey size, abundance, habitat use and profitability, the latter being a function of nutritional value relative to capture and handling costs. During the operation phase, large *C. monoculus* specimens fed on large *Satanoperca* aff. *jurupari* and *Geophagus* cf. *surinamensis*, but also consumed small (3-4 cm SL) specimens of *Anchoviella* sp.

Cannibalism is common in piscivorous fishes and provides a strong mechanism of density dependent population regulation (Nikolsky, 1963; Wootton, 1990). *Cichla ocellaris* in Panama were reported to lack evidence of cannibalism suggesting the coloration pattern of young *Cichla* serves as a species recognition signal for adults (Zaret, 1977). The same phenomenon was reported for *C. ocellaris* in Guyanan rivers and Hawaiian reservoirs (Lowe-McConnell, 1969; Devick cited in Zaret, 1977) and to *C. monoculus* in an Amazonian reservoir (Oliveira Jr., 1998). Conversely, young of *C. ocellaris* (= *C. monoculus*) were reported in the stomach contents of adult conspecifics in the Pantanal Matogrossense and in a southern Brazilian reservoir (Lipparelli, 1999; Santos et al., 2001). In Pantanal Matogrossense, cannibalism was more intense during the rainy season, and Lipparelli (1999) suggested that higher turbidity during this period might confound *Cichla* attacking heterospecific prey. In Lajes Reservoir, abundance of juveniles of *C. monoculus* in adult diet's was similar throughout the year, and Santos et al. (2001) suggested cannibalism could result from overpopulation and low prey availability. Mixed shoals of small cichlid fishes, including young *Cichla monoculus* (5-10 cm SL), were observed in the littoral area of Serra da Mesa Reservoir. Juvenile conspecifics might have been ingested following *Cichla* attacks that were initially directed at heterospecific cichlids. The muddy water hypothesis of Lipparelli (1999) is not viable for Serra da Mesa Reservoir because its waters are highly transparent.

As piscivorous, *C. monoculus* could affect the community structure of the reservoir. Yet, the species also is affected by resource dynamics at the base of the food web. The filling of Serra da Mesa Reservoir increased allochthonous resources that likely increased in aquatic invertebrate abundance. The operation phase was accompanied by a reduction of water level and resources in the littoral area. From April 1998 until February 2000, the reservoir was characterized by: 1) a dry climatic period; 2) exposed lake margins, and 3) oscillations of the level of the reservoir potentially affecting spawning areas and feeding by nearshore prey. High prey availability probably influenced the expansion of the *C. monoculus* population during the period of reservoir formation, and reduction in prey abundance probably will limit its population in the future.

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