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Fish community structure in Sermo Reservoir, Yogyakarta, Indonesia: Initial study on invasive fish species

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Fish community structure in Sermo Reservoir, Yogyakarta, Indonesia: Initial study on invasive fish species

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Abstract. Invasive species are becoming issues in freshwater ecosystems throughout the world including Indonesia. Sermo Reservoir is located in Yogyakarta, Centra Java, was indicated to have invasive species identified as Cichlidae family. The study aimed to assess fish communities' structure and identified invasive fish in Sermo Reservoir. The research was conducted in Sermo Reservoirs, Yogyakarta, Indonesia on March-October 2019. In total, about 3,084 individuals of 10 fish species belonging to 3 families and 8 genera were captured using a experimental gillnets (mesh size 0.75; 1; 1.5; 2; 2.5; 3 inch) at five stations. The fish community in Sermo Reservoir was dominated by Cichlid fish (98.66%). Red devil (*Amphilophus labiatus*) and Midas cichlid (*A. citrinellus*) were dominant species founded in Sermo Reservoir (58.82% and 37.00%, respectively). Another species of cichlid that caught consist of nile tilapia (*Oreochromis niloticus*), mozambique tilapia (*O. mossambicus*), and jaguar cichlid (*Parachromis managuensis*). The study showed that *Amphilophus* spp. have high dispersal (One-way ANOSIM revealed *Amphilophus* spp. was not significantly different for spatio-temporal ($p>0.05$)). SIMPER analysis ($p <0.05$) showed that *A. citrinellus* and *A. labiatus* had spread throughout the waters and were concentrated in Tegiri station which had more littoral zones.

Keywords: *Amphilophus*; invasive; midas cichlid; red devil; Sermo Reservoir

1. Introduction

Reservoirs 'the man-made lakes' are constructed with the primary aim of the generation of electricity and water storage for purposes of irrigation as well as the water supply for humans. Moreover, reservoirs have an integral role in the fisheries and livelihood security of the local community. Sermo Reservoir, the only reservoir was built in Yogyakarta Special Region, an area of about 157 ha and volume capacity of about 25 million m^3. The Sermo Reservoir was constructed in 1996, with the aim of water storage for irrigation and water drinking supply. Furthermore, Sermo Reservoir also provides benefits for the fisheries sector especially capture fisheries. The Sermo Reservoir has an important role in providing animal protein and generating employment for the surrounding community [1].

Small scale fisheries in Sermo Reservoir used to be very beneficial for the local people, however, the fisheries yield was reported to be declined due to the emergence of invasive species known as a red devil (*Amphilophus* spp.). Red devil fish was unintentionally introduced to Sermo Reservoir around 1995, through fishes restocking program in Sermo Reservoir [2]. The Red Devilfish in Sermo Reservoir currently has dominated in fishermen catch. Currently, that red devil dominated almost >70% of the catches [2-4]. In term of consumption, the red devil and midas cichlid has no economic value, and need more process to produce a useful product such as poultry feed [2].

The fishes found in the early inundation of Sermo Reservoir were silver barb (*Barbonymus gonionotus*), carp (*Cyprinus carpio*), spotted barb (*Barbodes binotatus*), Yellow rasbora (*Rasbora lateristriata*), Barred loach (*Nemacheilus fasciatus*), catfish (*Clarias batrachus)*, nile tilapia (*Oreochromis niloticus*), Mozambique tilapia (*Oreochromis mossambicus*) and Guppy (*Poeciliata reticulata*) [5]. The fishes in Sermo were native species from the river and introduced species from the stocking program. Since early inundation until the 2000s, several government agencies have stocked some species in Sermo Reservoir to increase fishermen catch and production, such as nile tilapia and common carp. The red devil species is thought to have entered Sermo Reservoir through the stoking of tilapia since the red devil seed looks similar to the tilapia seed. The fish turned out to have a very high rate proliferation in Sermo Reservoir and dominate the fishermen catch [5, 6].

The stocking of fish into inland water in Indonesia is mostly implemented in the lentic ecosystem (lake, reservoir, swamp, and other types of puddle) aimed to increase the production of fish biomass. The stocking of fish into inland water should be conducted with a precautionary approach to prevent changes in ecosystem balance. Introduced new species of fish into inland water can cause a negative impact if the species turn invasive and detrimental both ecologically and economically [2, 7]. The presence of invasive alien species can threaten native species in the ecosystem, and contribute to the extinction of native fish up to 30% [8].

This study aimed to assess the fish community and identify invasive species in Sermo Reservoir. This information is expected to be used as basic information to determine policy in controlling or eliminating invasive species in Sermo Reservoir.

2. Material and methods

2.1. Study area

The study was conducted in Sermo Reservoir, Kulon Progo District, Yogyakarta Special Region, Indonesia (figure 1). Sermo Reservoir has the main water input from Ngrancah River. Sampling sites determined using stratified random method [9], five sampling sites that represented all characteristic of the overall reservoir, namely (1) Sidowayah, (2) Tegalrejo, (3) Tegiri, (4) Klepu, and (5) DAM.

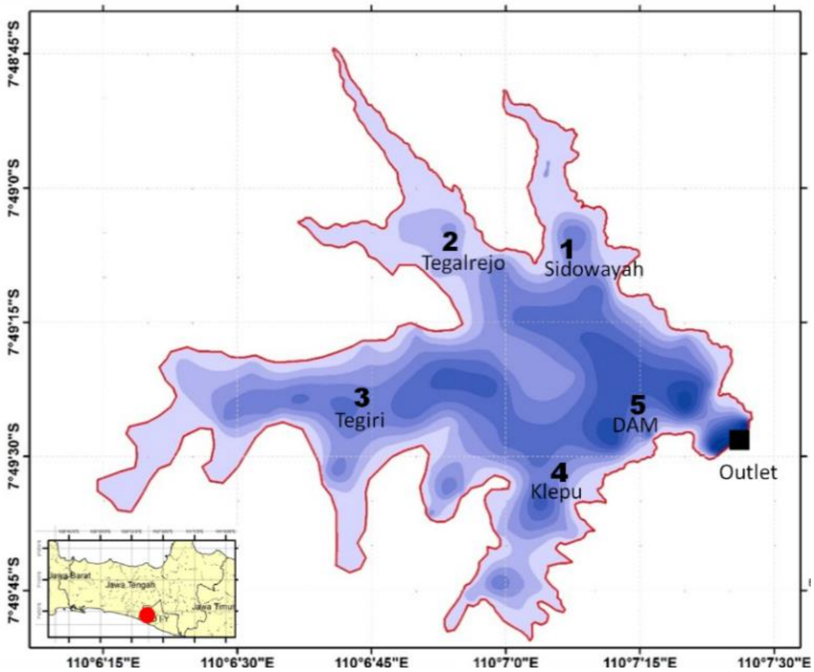

Figure 1. Sampling stations in Sermo Reservoir shows five sampling point used during the study (1: Sidowayah, 2: Tegalrejo, 3: Tegiri, 4: Klepu, and 5: DAM) Map source: BP2KSI [10].

2.2. Fish sampling
Sampling was undertaken from March-October 2019 in five sites, namely (1) Sidowayah, (2) Tegalrejo, (3) Tegiri, (4) Klepu, and (5) DAM. Fishes were captures using experimental gillnet that were installed parallel to the coastline of the reservoir from morning to evening (7 am-3 pm) and from evening until morning (5 pm-7 am). The gillnets were made of monofilament with multi mesh size [11], that were 0.75-1.00-1.50-2.00-2.50-3.00 inch (twine = 0.20 mm). The dimension of the gillnet was a mesh length ranging from 73.2-91.4 m and mesh depth ranging from 1.9-6.0 m.

The fishes were caught then measured using a ruler with a precision of 1 mm for its total length and height, furthermore weighed using a digital scale with a precision of 0.01 grams. Identification of fish species refers to Barlow and Munsey [12], Kottelat *et al*. [13], Loiselle [14], and fishbase site [15]. Fish samples that required further identification were preserved using 10% formalin solution and put in the coded plastic sample.

2.3. Data analysis
Fish community was analyzed using an index of relative importance (IRI) that were combined abundance (N), biomass (W), and occurrence of catch (F) with formula IRI = [(%Wi+%Ni)Fi/ Σ[(%Wi+%Ni)Fi]*100 [16-17]. IRI of the fish community was calculated based on total catch spatial and temporal. Diversity index of Shannon or entropy (H'), equitability Pielou's index (J'), and Simpson index of dominance (D) were assessed for relative abundance from each fish species with bootstrap (center type; n=9,99) to get interval limits of 95% [18]. One-way Analysis of Similarity Test (ANOSIM) was used to assess spatial and temporal differences in abundance and biomass of fish communities. The similarity matrix used in the ANOSIM test was calculated based on Bray-Curtis [18]. SIMPER analysis (Similarity Percentage) was used for ANOSIM calculation which was significantly different ($P<0.05$) in spasio-temporal fish communities [19]. All the calculation process was done using PAST 3.26 [19].

3. Results and discussion

3.1. Species composition
In total, the fishes were caught by approximately 2,089 individuals consisted of 10 fish species belonging to 8 genera and 3 families (table 1). The dominant family was Cichlidae that consisted of 5 species, midas cichlid (*Amphilophus citrinellus*), red devil (*Amphilophus labiatus*), mozambique tilapia (*Oreochromis mossambicus*), nile tilapia (*Oreochromis niloticus*), and jaguar guapote (*Parachromis managuensis*). All the species of Cichlidae family in Sermo were identified as non-native species. The most abundance of cichlid species was *Amphilopus labiatus*, followed by another cichlid, *Amphilophus citrinellus.* Based on the index of relative importance (IRI), Red devil and Midas had higher value than other species, mewhich ans both of species dominated catches during the survey. Cichlid fishes were more abundant compared to native species (98.66%).

The Midas cichlid complex (*A. citrinellus, A. amarillo,* and *A. labiatus*) existence in Indonesia was still being debated especially for their species identity. Several publications referred to the “red devil” fish, the local name of *Amphilophus* spp. used in Sermo Reservoir, as *A. citrinellus* [20]. Nevertheless, other publications refer to *A. labiatus* [3, 4] and *A. amarillo* [21]. An effort to investigate the red devil fish through a molecular approach by using a partial control region of mitochondrial DNA. It was concluded by the author that the red devil fish was identified as *A. amarillo* [21]. Nevertheless, the study provides weak evidence and shows no distinct clade was successfully constructed from the bootstrapped phylogenetic analysis. The uses of mitochondrial regions were also proved to be unsuitable for Midas cichlid complex identification in their original location (Lake Nicaragua) [22]. Until now, the only powerful approach to distinguish the Midas cichlid was based on their phenotypic or morphological information [23]. It was identified that A. amarillo has a specialized phenotypic characteristic by looking at the orange coloration of the throat area [24]. Thus, the closest species existing in Indonesia were either *A. citrinellus* or *A. labiatus*. Our previous investigation has successfully identified through Generalized Proscrusted Analysis (GPA) morphological, the differentiation between *A. citrinellus* and *A. labiatus* existed in Sermo Reservoir (figure 2). This finding was also confirmable as their similar morphology differences from A. *citrinellus* and *A. labiatus* from Nicaragua (figure 3). The existence of these two species is similar to Kedungombo Reservoir [25].

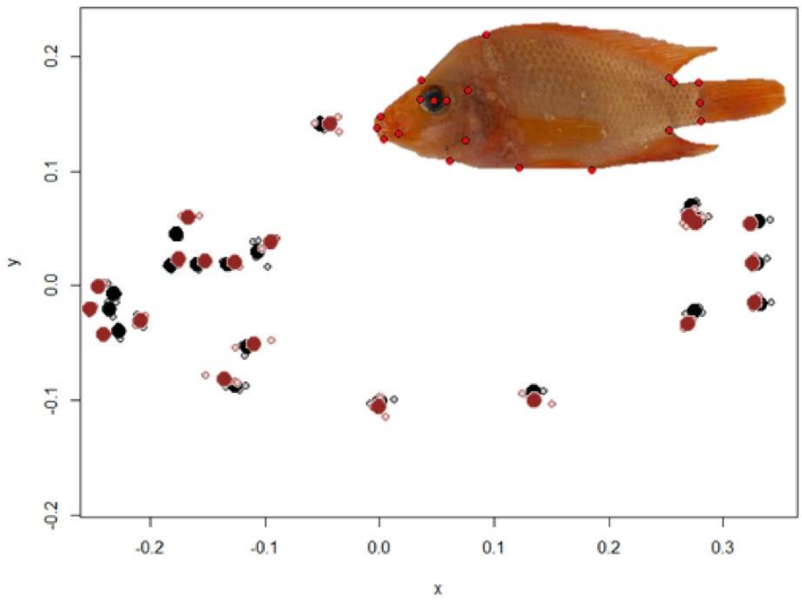

Figure 2. *Generalized proscrusted analysis* (GPA) using 20 landmarks showed morphological differentiation between *A. citrinellus* and *A. labiatus* . The lips morphology landmark (red circle) was noticed as the most distinguishable part among all the assessed landmarks [26, 27].

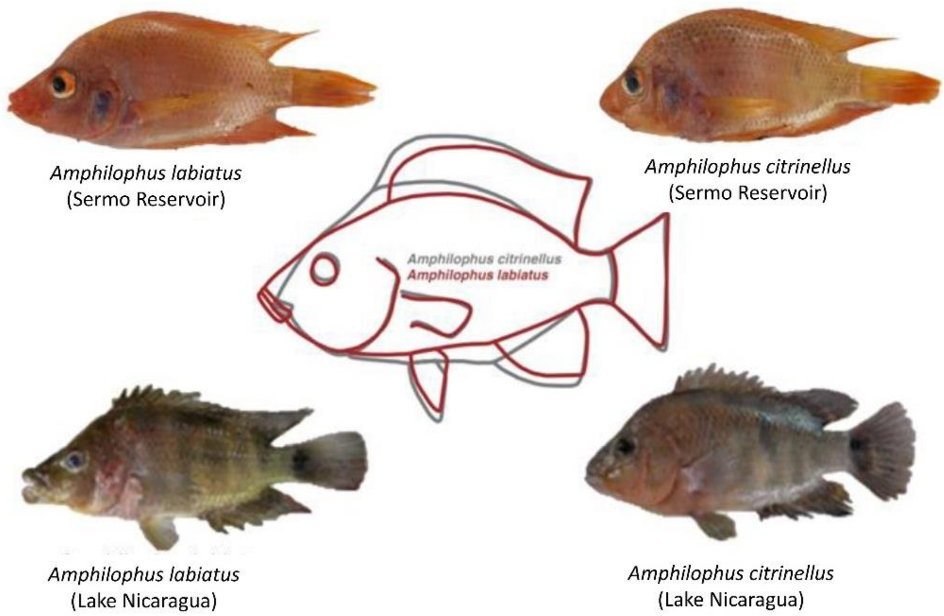

Figure 3. Morphological appearance of red devil fish from Sermo Reservoir (Upper figure) [26] and their origin location, Nicaragua Lake (bottom figure) [23].

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Native species of fishes in Sermo were spotted barb (*Barbodes binotatus*), silver barb (*Barbonymus gonionotus*), bonylip barb (*Osteochilus vittatus*), and yellow rasbora (*Rasbora lateristriata*) while other fishes were introduced species. All the native species in Sermo belong to Cyprinidae and the introduced species are Cichlidae and Eleotridae. IRI values that were presented in table 1 show that Cichlidae species which were *Amphilophus labiatus* and *Amphilophus citrinellus* more abundant than other species in Sermo Reservoir. All the native species of fishes (Cyprinidae) in Sermo were found in smaller abundance compared to Cichlidae species that were non-native species. Based on the IRI value (table 1), silver barb (*Barbonymus gonionotus*) was the species that has the smallest IRI value. This is because the species was just re-stocking along with bony lipbar (*Osteochilus vittatus*) in June 2020 by the Fish Quarantine and Inspection Agency of Yogyakarta (Ministry of Marine Affairs and Fisheries). Based on the analysis, Cichlidae species, especially *Amphilophus labiatus* and *Amphilophus citrinellus* were being invasive species that dominated in fish community structure.

The invasive of Cichlidae in the freshwater ecosystem not only occurred in Sermo Reservoir, it was reported that a similar case also occurred in another freshwater ecosystem in Indonesia. The Cichlidae fish that enter inland water and become invasive in Indonesia, mostly because of unintentional introduction, such as occurred in Ir. H. Djuanda reservoir [28], Cirata reservoir [29], Jati Gede reservoir [30], Kedungombo reservoir [25], Lake Matano [31, 32], Beratan Lake [33] and Sentani Lake [34, 35]. A similar condition also occurred in Sermo Reservoir whereas the Cichlidae species have high proliferation and become dominant in the community.

Table 1. IRI of fish community structure in Sermo Reservoir.

No.	Common Names	Family	Species	W	N	F	IRI (%)
1	Midas cichlid*	Cichlidae	*Amphilophus citrinellus*	15,676.5	1167	25	37.00
2	Red devil*	Cichlidae	*Amphilophus labiatus*	27,271.24	1706	25	58.82
3	Mozambique tilapia*	Cichlidae	*Oreochromis mossambicus*	506.17	13	6	0.19
4	Nile tilapia*	Cichlidae	*Oreochromis niloticus*	3,107.41	55	15	2.59
5	Jaguar guapote*	Cichlidae	*Parachromis managuensis*	438.08	5	3	0.07
6	Spotted barb	Cyprinidae	*Barbodes binotatus*	298.61	38	9	0.35
7	Silver barb	Cyprinidae	*Barbonymus gonionotus*	4.09	4	2	0.01
8	Bonylip barb	Cyprinidae	*Osteochilus vittatus*	902.56	79	9	0.84
9	Yellow rasbora	Cyprinidae	*Rasbora lateristriata*	36.75	5	4	0.02
10	Marble goby*	Eleotridae	*Oxyeleotris marmorata*	295.54	12	6	0.13

Remarks: *non-native; W = biomass (gram); N = abundance (number of fish); F = occurence of catch

Table 2. IRI of fish community structure in Sermo Reservoir based on spatial.

Species	Family	IRI (%)				
		DAM	Klepu	Sidowayah	Tegalrejo	Tegiri
Amphilophus citrinellus	Cichlidae	52.9	32.1	34.1	35.2	33.0
Amphilophus labiatus	Cichlidae	44.0	60.2	58.2	56.3	65.3
Oreochromis mossambicus	Cichlidae	2.4	0.4	0.4	0.1	0.1
Oreochromis niloticus	Cichlidae	-	5.1	4.0	5.2	1.5
Parachromis managuensis	Cichlidae	0.4	-	0.1	0.2	-
Barbodes binotatus	Cyprinidae	-	0.1	1.6	1.5	-
Barbonymus gonionotus	Cyprinidae	-	0.4	0.02	-	-
Osteochilus vittatus	Cyprinidae	-	1.5	1.3	1.5	0.02
Rasbora lateristriata	Cyprinidae	0.1	0.1	-	-	0.1
Oxyeleotris marmorata	Eleotridae	0.1	0.2	0.3	0.1	0.02
Total		100.0	100.0	100.0	100.0	100.0

3.2. Spatially and temporally fish composition

Observation of the fish community in Sermo Reservoir spatially showed that *Amphilophus labiatus* and *Amphilophus citrinelus* were found in high abundance across all the sites compare to other species. IRI value of fish community structure spatially in Sermo Reservoir in table 2 shown that *Amphilophus labiatus* were recorded found abundant in all site, and *Amphilophus citrinelus,* though distributed across the sites, it found most abundant in DAM site. It seems that *Amphilophus labiatus* has invaded almost all part of the reservoir so that *Amphilophus citrinelus* were concentrated in the DAM area (table 2). This rapid expansion of red devil cichlids can be explained by the morphology of cichlids. The Cichids have a highly integrated pharyngeal jaw apparatus, which supports them during the invasion and colonization of new lacustrine environments [36]. The invading cichlids can successfully occupy a range of adaptive zones and to specialize progressively into diversified subzones, which may help to explain why cichlid fishes have successfully invaded new ecosystems in many different parts of the world [37].

Table 3. ANOSIM analysis (R-value) of fish community structure spatially.

Spatial Variable	Sidowayah	Tegalrejo	Tegiri	Klepu	DAM
Sidowayah		0.0240	0.0245	-0.1573	-0.1458
Tegalrejo			0.4129*)	0.072	0.0182
Tegiri				-0.0028	0.1169
Klepu					-0.3636
DAM					

Remarks: *) significant different ($p<0.05$)

Table 4. ANOSIM analysis (R-value) of fish community structure temporally.

Temporal Variable	Mar	Apr	Jun	Jul	Aug	Sep	Oct	Nov
Mar								
Apr	-0.1273							
Jun	-0.0438	0.0714						
Jul	-0.2182	0.0000	-0.1071					
Aug	0.1375	-0.1071	0.4063	0.4643				
Sep	-0.1636	0.2500	0.0000	-0.5000	0.6429			
Oct	-0.0364	0.0000	0.0000	-0.5000	0.3929	-0.5000		
Nov	-0.1250	-0.0357	-0.1719	-0.3214	0.2813	-0.1429	-0.1429	

The ecological indices consist of diversity index (H'), equitability Pielou's index (J'), and Simpson index of dominance (D) of fish community structure spatially and temporally in Sermo is presented in figure 4. The diversity index spatially and temporally was categorized as low-medium, while the dominance index and equitability were medium (figure 4). This indicated that one species tend to be dominant in the community with the result that diversity species becomes low and dominance rise. In Tegiri site, the diversity index was categorized as low and dominance index was high. This indicated that the *Amphilophus* spp. was abundant in Tegiri. The diversity index value that was assessed temporally showed that the ecological index tends to improve in June when the silver-barb restocking was implemented. *Amphilophus* spp. has dominated the fish community structure in Sermo Reservoir and affected the fish community ecologically.

Oneway ANOSIM revealed fish community abundance was not significantly different for spatial ($R=0.0417$, $p>0.05$) and temporal ($R=0.0285$, $p>0.05$) as presented in tables 3 and 4. This is because *Amphilophus* spp. has dominated completely with the high abundance in all part of Sermo Reservoir. The ANOSIM analysis showed that Tegalrejo and Tegiri site was significantly different ($R=0.4129$, $p<0.05$). This indicates that the two locations are different dominant for *Amphilophus* spp.. Tegiri station has litoral area become the location that was dominated by *Amphilophus* spp.. The littoral characteristics of the habitat (Tegiri) are thought to be very favorable to *Amphilophus* spp.. Based on SIMPER analysis in table 5, *Amphilophus* spp. have higher contributed than other species, with a cumulative contribution of almost 90% in fish community structure. Tegiri station has litoral area become the location that was dominated by *Amphilophus* spp..

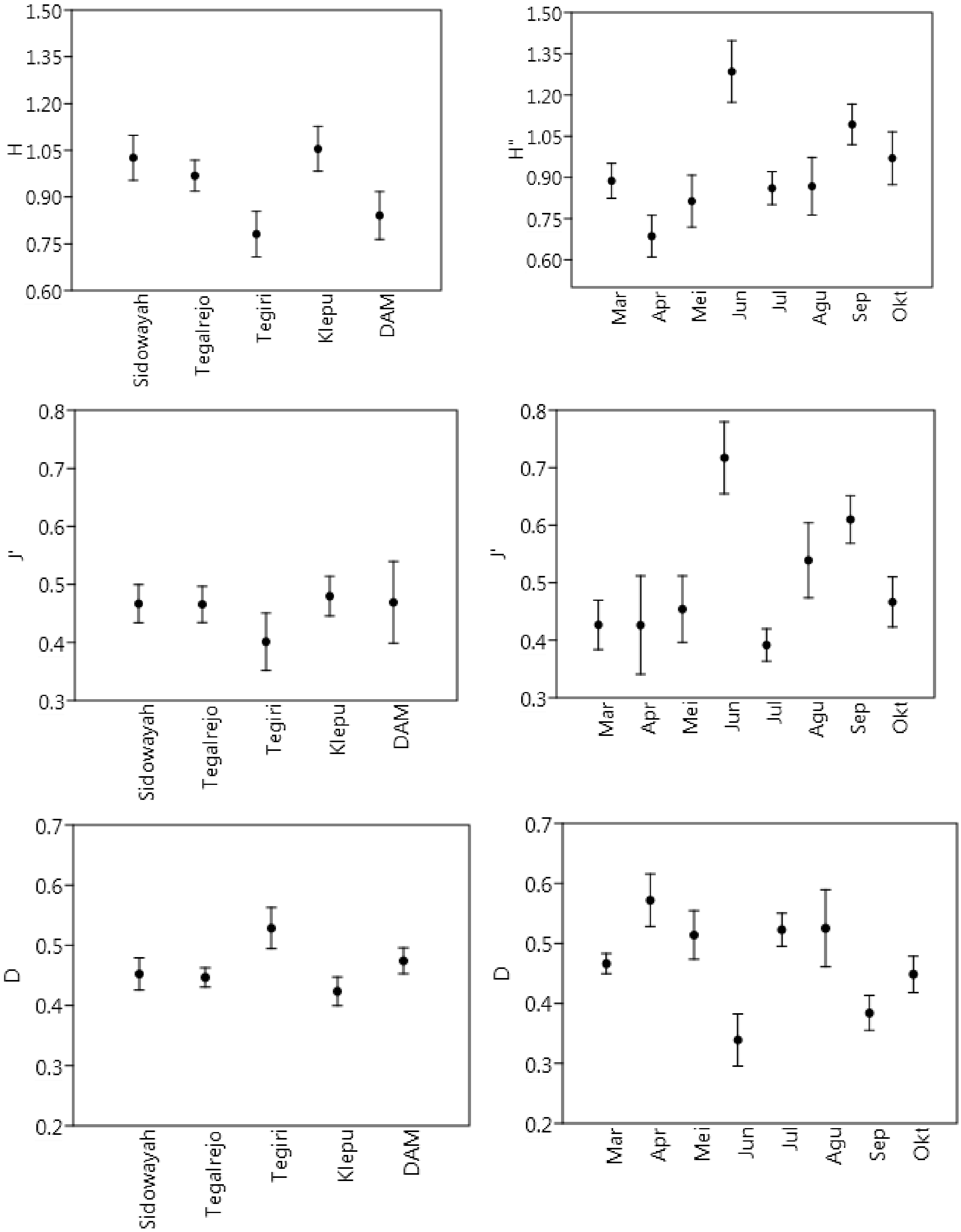

Figure 4. Ecological indices of fish community structure in Sermo Reservoir based on spatio-temporally.

Table 5. SIMPER analysis of the fish community in Sermo Reservoir.

Species	Average Dissimilarity	Contribution %	Cumulative %
Amphilophus labiatus	27.67	52.97	52.97
A. citrinellus	18.59	35.58	88.55
Osteochilus vittatus	2.02	3.86	92.41
Oreochromis niloticus	1.65	3.16	95.57
Barbodes binotatus	1.04	1.99	97.56
Oxyeleotris marmorata	0.39	0.75	98.31
O. mossambicus	0.35	0.66	98.98
Barbonymus gonionotus	0.26	0.50	99.48
Rasbora lateristriata	0.16	0.31	99.79
Parachromis managuensis	0.11	0.21	100.00

Based on bray-curtis analysis (50% of similarity) there was six groups of the fish community (figure 5). Group 1 consists of spotted barb, nile tilapia, and bonylip barb. Group 2 only has silver bar, while group 3 consists of mozambique tilapia and marble goby. Group 4 and 5 consists of yellow rasbora and jaguar guapote, respectively. The las group, consists of red devil and midas cichlid. Red Devil and midas cichlid share 79.08%, which means that the dispersals of both species are the same.

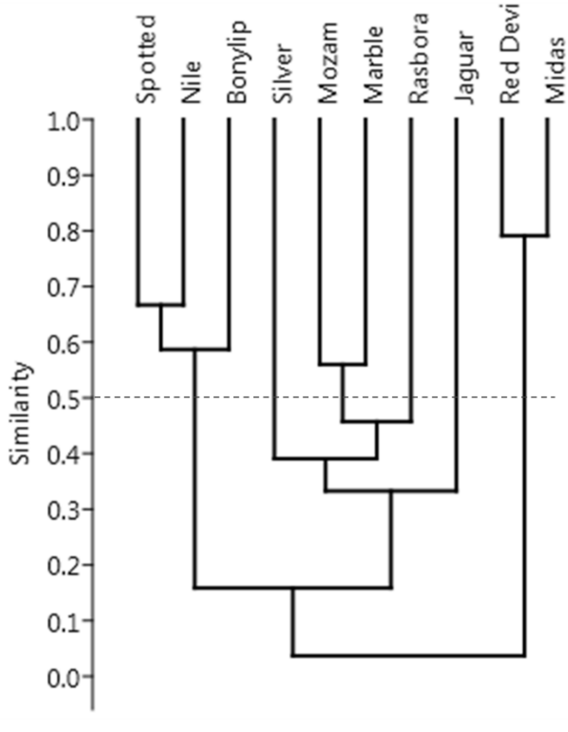

Figure 5. Bray-curtis similarity dendrogram of fish community in Sermo Reservoir (remarks: Midas = midas cichlid; Jaguar = jaguar guapote; Rasbora = yellow rasbora; Marble = marble goby; Mozam = mozambique tilapia; Silver = silver barb; Bonylip = bonylip barb; Nile = nile tilapia; Spotted = spotted barb).

4. Conclusion

Amphilophus citrinellus and *A. labiatus* has dominated Sermo Reservoir spatially and temporally, therefore their existence in Sermo has altered the structure of the fish community. *A. citrinellus* and *A. labiatus* have the same dispersal pattern in Sermo, especially in the littoral zone.

Acknowledgments

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