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Aquatic invasive species distribution within Wallace region: a preliminary review

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Abstract. The introduction of many aquatic species into new habitats have been recorded to be invasive and later threatened the native species present in that habitat. The unique biogeography of the Wallace region, particularly Sulawesi Island characterized by having high endemic fauna. Several lakes in Sulawesi have experienced the population reduction of endemic species due to introduced species that become invasive. This paper intended to review the aquatic invasive species and their distribution in the Wallace region. The literature review revealed the number of invasive species introduced in the Wallace region varies from 1 species to 12 species, the highest found in Lake Tondano. This preliminary review record that Malili lakes are most researched, both for endemic species and invasive species, based on the number of publications found through an internet search, with publications on endemic species, are more than invasive species. Among 13 lakes in Sulawesi, 4 lakes, namely Lake Moat, Sidendreg, Wawanloa, and Masapi, have no record on aquatic invasive species. A similar situation also happens in Maluku. The information on the mode and reason for fish introduction into Appo Swamp in West Sulawesi and watershed in Manggarai Regency, East Nusa Tenggara, is still lacking. All in all, the conclusive cause and effect of introduced species that become invasive on the endemic species in the region is need to be prove or unproven based on scientific data. At this time, the literature review has not been able to find documentation on marine invasive species in the Wallace region. As for invasive species management, prevention is better than eradication.

1. Introduction

⁶IUCN define invasive species as “an alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity” (IUCN, 1999), introduced deliberately or unintentionally outside their natural geographic range into an area ¹⁰where they are not naturally present [1]. CBD News (2001) added that invasive alien species (IAS) have the ability to establish themselves, in ¹⁶the, out-compete natives, and take over the new environments. In 2008, CBD redefined IAS as those non-⁵native species that threaten ecosystems, habitats, or species [2], and according to Vitousek (1977), are key drivers of ¹¹man-caused global environmental change. Therefore, the term invasive refers to species that have a negative impact on the environment, economy, and human health up ⁵their introduction [3]. Pejchar and Moone (2009) more sum up, that after habitat destruction, IAS as the second greatest agent of species endangerment and extinction, particularly on islands; inflicting serious impacts on the ecos-⁸tem processes which are fundamental to human well-being and at end altering the good and services [4].



Indonesia is regarded as the world's second most diverse freshwater fishes with 1300 fish species after Brazil with 3000 species [5]. Unfortunately, major threats to the extinction of freshwater fishes, particularly lake communities, are habitat degradation/changes (35%), introductions of exotic species, or alien non-native species (30%), followed by pollution, eutrophication, and changes in water level [5,6]. Aquaculture is a major source of invasive aquatic species because species diversification has become important and as a result, species which are known for higher growth rate and increased production were introduced all over the world, although cultured organisms often have low genetic diversity and tend to be maladapted to survive in wild. As a result of this, alien species are recognized as one of the most significant threat to the aquatic biodiversity. Only recently, invasive species is stated as major caused for biodiversity loss and changes the ecosystem function leading to the domination of a species in an ecosystem by replacing the native species. In Indonesia, local/native fishes are threatened by the increasing number of alien species introduced, mostly for aquaculture and aquarium purposes. Ministry of Environment and Forestry documented 1800 alien invasive flora and fauna introduced to Indonesia, of which family Poeciliidae and Cichlidae dominate as exotics fishes. Two families are considered tolerant to wide temperature ranges. However, some non-native species such as common carp, Nile tilapia, catfish, and Siamese gourami have long been cultured and accepted.

The unique biogeography of the Wallace region, particularly Sulawesi Island, was characterized by having high fauna endemic [7]. However, Dudgeon (2006) cited that the rate of aquatic biodiversity has declined much higher than those of terrestrial and marine ecosystems. Management effort and conservation on endemic species, which are now threatened by invasive species, require information on their diversity, distribution, and habitat [8].

The records on aquatic invasive species in Sulawesi are found in quite a number of publications, more on Pisces. However, information on aquatic invasive species of the Wallace region is not yet available. Therefore, the objective of this paper is to review the aquatic invasive species and their distribution in the Wallace region. The information on the present spatial distribution of aquatic invasive species is needed to take management actions accordingly in order to protect the endemic species of the Wallace region.

2. Methods

As many as possible, the literature on invasive species has been searched for the review. The main sources come from conference proceedings, publications in books and journals, as well as from the internet. The review described literature findings briefly and listed the families, species, and recorded location of invasive species in the Wallace region, focusing on the freshwater of Sulawesi, Nusa Tenggara, and Moluccas provinces. The distributions were then tabled and mapped spatially in order to find the information gap within the region. A review of the management status of invasive species is also described to have a better understanding of the situation.

3. Results and discussion

3.1. Literature review

Inland waters in the Wallace region are dominated by lakes in Sulawesi and retention basin, locally known as "embung", in Nusa Tenggara. The three biggest lakes, Matano, Mahalona, and Towuti, are connected to each other by means of rivers, hence known also as Malili Lakes. Aside from the three lakes, two smaller lakes, Wawontoa and Masapi, are integrated into Malili Lakes as well. Malili lakes are famous for having unique fish resources. Other lakes, Tempe, Sidendreg, and Limboto, are considered as inundated lakes ("Danau banjiran") with high productivity (eutrophic).

In general, freshwater fish species in the Wallace region, particularly in Sulawesi and Nusa Tenggara, are much less compared to those in Western Indonesia. Out of 1300 freshwater fish species discovered in Indonesia, 70 species are found in Sulawesi [5], and the number of fish species found in inland waters in this region is not more than 50 species, of which almost all are not acknowledged as native freshwater species [9]. Furthermore, Schuster also cited that in lesser Sunda Island groups

(Nusa Tenggara and Maluku), the inland water fauna is extremely limited, such as inventories on komodo found only 14 species of freshwater fish.

However, because of its unique biogeography, the fauna endemic is high. Out of 70 freshwater fishes found in Sulawesi, 52 species are endemic [10]. Sulawesi has a total of 13 lakes, of which ancient Malili lakes are most famous. In regards of Sulawesi lakes' endemic species, Kottelat, et. al., (1996) cited that: 1) Malili lakes are home for two endemic fish genera, 26 endemic fish species (including 15 of the 17 known species of *Telmatherinidae*), one endemic snake (*Enhydris matanensis*), three crabs, around 10 shrimps and 60 mollusks, one macrophyte and possibly sponges and water mites as well; 2) Poso Lake has one endemic fish genus, seven endemic fish species, and numerous endemic invertebrates; 3) Lindu Lake has only one fish species, and 4) Tondano with one endemic fish genus. The majority of these endemic species are now either protected or threatened [5].

Examples of several introduced species that become invasive were documented. Kottelat, et. al., (1996) mentioned that the introduction of tilapia (*O.mossambicus*) into lake Lindu in 1987 has resulted in the extinction of its endemic mollusk and virtually extinct of its endemic fish, *Xenopoecilus sarasinorum* [5]. Additionally, the introduction of unknown fishes and their parasites into Lake Poso triggered the extinction of its endemic fishes, the *Adrianchthys kruyti* and *Weberogobius Amadi*, and seriously threatened *X.poptae* and *Oryzias orthognathus*. Earlier, in 1990, Kottelat observed that *W.amadi* was the base of subsistence fishery in Poso but now is collapsed. As early as 2005, louhan fish, also known as flower horn, *Melanochromis auratus*, of which some considered of no economic value, but known as aquarium fish when small, become invasive species in Matano Lake (Figure 1.) [5]. However, Hadiaty and Wirjoatmodjo (2002), record several endemic fish species of the lake, *Telmatherina antoniae*, *T. prognatha*, and *T. opudi* were already fallen into threatened species [11]. By 2008, Tantu and Nilawati (2008) mentioned that of 20 fish species found living in Matano Lake, 16 of them were introduced through local Fisheries Agency (Dinas Perikanan), the illegal introduction is done by local community unintentionally released from the fish pond, and through fish aquarium trader [12]. Furthermore, in 2012, Herder et al. (2012) reported that between years 2000-2010, Lake Matano was reported to have 14 invasive fish species [13].



Figure 1. Louhan, the invasive fish species in Lake Matano (source of picture: <http://www.mongabay.co.id>).

Historically, the introduction of fish has been practiced since Indonesian colonial times, in the 19 century [14], including introduction into inland waters [15]. The number of fish species introduced to Indonesian inland waters was not less than 17 species, mostly as cultured species [15,16], and 16 fish species have been introduced into Sulawesi inland waters. *Channa striata*, locally known as ikan gabus, was stated as the first introduced species into Indonesian inland waters in 1915, followed by *Cyprinus carpio* (locally named ikan mas), from China and Japan, in 1920. The introduction of *Barbonymus gonionotus* (local name tawes) and *Trichogaster pectoralis* (local name, ikan sepat) in 1937 [24] Tempe Lake, have successfully increase fish production of the lake, and even considered to reach the highest fish catch in the world, producing 980 kg/ha/year [16].

The objectives of fish introduction are mostly aiming at increasing fishery productivity of an area, developing consumable and recreational fishes or intended to fill the niche, or as pest control (biologically). Table 1 summarized invasive species documented in the Wallace region up to present (summarizing report of [17–19]).

Table 1. Distribution of aquatic invasive species in Wallace waters.

Province	Family	Species	Province	Location	Family	Species
North Sulawesi	Anabantidae	<i>Anabas testudineus</i>	South Sulawesi	Lake Matano (recorded 14 introduced species)	Anabantidae	<i>Anabas testudineus</i>
	Belontiidae	<i>Trichogaster trichopterus</i>			Belontiidae	<i>Trichogaster petoralis</i> <i>Oreochromis mossambicus</i> , <i>oreochromis niloticus</i>
	Cichlidae	<i>Oreochromis niloticus</i>			Cichlidae	<i>Channa striata</i> *
	Channidae	<i>Channa melasoma</i>			Channidae	<i>Clarias batrachus</i> , <i>Clarias gariepinus</i>
	Channidae	<i>Channa striata</i>			Claridae	<i>Cyprinus carpio</i> *
	Claridae	<i>Clarias batrachus</i>			Cyprinidae	<i>Amphilophus sp</i> **
	Cyprinidae	<i>Barbodes gonionotus</i>			Cyprinidae	<i>Colossoma macropomium</i>
	Cyprinidae	<i>Cyprinus carpio</i>			Cyprinidae	<i>Hypostomus plecostomus</i>
	Cyprinidae	<i>Osteochilus hasselti</i>			Cyprinidae	<i>Trichogaster trichopterus</i>
	Cyprinidae	<i>Ctenopharyngodon idellus</i>			Gorontalo	Lake Towuti
Eleotrididae	<i>Ophiocara porocephala</i>	Channidae	<i>Cyprinus carpio</i> **			
Osphronemidae	<i>Osphronemus goramy</i>	Cyprinidae	<i>Amphilophus sp</i> **			
Anabantidae	<i>Anabas testudineus</i>	Belontiidae	<i>Trichogaster petoralis</i>			
Belontiidae	<i>Trichogaster petoralis</i>	Belontiidae	<i>Trichogaster trichopterus</i> <i>Oreochromis mossambicus</i>			
Cichlidae	<i>Oreochromis mossambicus</i>	Cichlidae	<i>Channa striata</i> *			
Cichlidae	<i>Oreochromis niloticus</i>	Channidae	<i>Clarias striata</i>			
Channidae	<i>Channa striata</i> *	Claridae				
Cyprinidae	<i>Barbodes gonionotus</i>	Cyprinidae				
Cyprinidae	<i>Cyprinus carpio</i>					
Cyprinidae	<i>Osteochilus hasselti</i>					
Cyprinidae	<i>Ctenopharyngodon idellus</i>					
	(Aquatic plant)		Lake Sidenreng			

		<i>Cichlidae</i>	<i>Oreochromis mossambicus</i>		Lake Masapi		
Central Sulawesi	Lake Poso	<i>Cichlidae</i>	<i>Melanochromis auratus</i>			<i>Anabantidae</i>	<i>Anabas testudineus</i>
		<i>Channidae</i>	<i>Channa striata*</i>			<i>Belontiidae</i>	<i>Trichogaster trichopterus</i>
	Lake Lindu	<i>Cichlidae</i>	<i>Oreochromis mossambicus</i>			<i>Cichlidae</i>	<i>Oreochromis mossambicus</i>
	Lake Tempe	<i>Anabantidae</i>	<i>Anabas testudineus</i>	South East Sulawesi	Rawa Aopa Swamp	<i>Channidae</i>	<i>Channa striata*</i>
		<i>Belontiidae</i>	<i>Trichogaster petoralis</i>			<i>Claridae</i>	<i>Clarias batrachus</i>
		<i>Cichlidae</i>	<i>Oreochromis niloticus</i>			<i>Cyprinidae</i>	<i>Barbodes gonionotus</i>
		<i>Channidae</i>	<i>Channa striata*</i>			<i>Cyprinidae</i>	<i>Cyprinus carpio**</i>
		<i>Claridae</i>	<i>Clarias batrachus</i>			<i>Helostomatidae</i>	<i>Helostoma temmincki</i>
		<i>Cyprinidae</i>	<i>Barbodes gonionotus</i>			<i>Anabantidae</i>	<i>Anabas testudineus</i>
South Sulawesi	Lake Buaya	<i>Cyprinidae</i>	<i>Cyprinus carpio**</i>	west Sulawesi	Lampuko mampie (Salt marsh)	<i>Belontiidae</i>	<i>Trichogaster leeni</i>
		<i>Helostomatidae</i>	<i>Helostoma temmincki</i>			<i>Channidae</i>	<i>Channa striata*</i>
		<i>Anabantidae</i>	<i>Anabas testudineus</i>			<i>Claridae</i>	<i>Clarias batrachus</i>
		<i>Belontiidae</i>	<i>Trichogaster petoralis</i>	Central Sulawesi	CA Morowali	<i>Channidae</i>	<i>Channa striata*</i>
		<i>Cichlidae</i>	<i>Oreochromis niloticus</i>			<i>Cyprinidae</i>	<i>Osteochilus hasselti</i>
		<i>Channidae</i>	<i>Channa striata*</i>	Nusa Tenggara Timur (Manggarai, West Flores)	Lake Ranainete		<i>Cyprinus carpio; oreochromis mossambica</i>
		<i>Claridae</i>	<i>Clarias batrachus</i>		Lake Ranapoja		<i>Cyprinus carpio; oreochromis mossambica</i>
		<i>Cyprinidae</i>	<i>Barbodes gonionotus</i>		Lake Ranasiap		<i>Cyprinus carpio; oreochromis mossambica</i>
		<i>Cyprinidae</i>	<i>Cyprinus carpio**</i>	NTB			<i>Oreochromis SP (?)</i>
		<i>Helostomatidae</i>	<i>Helostoma temmincki</i>	Maluku			

Surprisingly, Table 1 pointed out that among 13 lakes in Sulawesi, Lake Tondano is having the highest number of invasive fish species (12 species). It could be because there are 35 rivers entering the lake, or the invasive species is indeed originated in the lake. A question needs to be answered and

clarified. The next highest is Lake Limboto with 9 invasive fish species and 1 invasive aquatic plant, the water hyacinth. The water hyacinth was, for some time, become a nuisance to fishery activity in Limboto. Although Matano, Mahalona, and Towuti lakes are interconnected, the number of invasive species found differs. Matano has 9 species; Mahalona has 7 species and Towuti 4 species. While Tantu and Nilawati (2008) reported 16 fish species introduced in Lake Matano [12], Herder et al. (2012) reported 14 species [13]; Kartamihardja (2014) only listed 4 species on his finding [17]. This difference will need to be clarified further for a better understanding of invasive species status in that particular lake. One recent publication is found to discuss Louhan or flower horn, the latest new invasive species in Matano Lake. Sentosa and Hediando (2019) stated that the Louhan had spread throughout Matano waters [18]. They also cited, the previous finding was done by Herder et al., (2012) where within 2 years (from 2010 to 2012), the fish has rapidly distributed, from southern part of the lake, particularly Soroako to all littoral area of the lake and beginning to threaten the endemic species. They also found that the distribution of the fish abundance is fluctuated and related to plankton distribution and abundances as the fish food [13]. So far, this review found that Malili lakes are most researched, both for endemic species and invasive species, according to the number of publications found through an internet search, although publications on endemic species are more than invasive species.

Unlike the Malili lakes, Lake Tempe, which also connected with Lake Buaya is having the same number (8) of invasive species. The geographical features of Tempe and Buaya lakes as inundated lakes might explain the similarity of species number between the two lakes due to the high range or mobility of species, especially during the rainy season, though data is still needed to prove or unproven it. Since 1993, Lake Tempe faces a major problem of sedimentation, detected 15-20 cm yearly.

Another interesting finding is that Rawa Appo or Appo swamp hosted 8 invasive species. The mode of introduction is interesting to know to be a swamp area. Morowali forest protected area, unexpectedly listed for having 2 invasive fish species. Again, the mode of and reason for introduction in this area will be of interest. In Southeast Sulawesi, this preliminary review found a report of alien invasive species, unknown but described as soft moss-like floating in Hakatutobu waters.

Aside from the list of 79 Pisces species potential as alien invasive species in Indonesia, of which 17 species are detected already enter in Indonesia inland waters [20]. Asian Clearing House Mechanism (CHM) released a list of 140 records of species that are invasive in Indonesia. On that list, invasive species of flora fauna in Indonesia fresh and marine waters are added, for instance, the *Alternanthera philoxeroides* (alligator weed, pigweed), water hyacinth, *Salvinia molesta* (aquarium water moss); *Acanthaster planci* (coral-eating starfish), *Acanthophora spicifera* (red alga, spiny seaweed), *Artemia* (brine shrimp), *Litopenaeus vannamei* (decapod crustacean), *Gracilaria salicornia* (red alga), *Kappaphycus* spp (red alga), *Tubastraea coccinea* (Colonial cup coral, orange cup coral, orange tube coral) [1]. However, the list not yet specified the location of invasive species cited. Whether or not those marine invasive species present in Wallace marine waters are something needed to be alarmed since the marine realm of the region is also rich in biodiversity.

3.2. Spatial distribution map

The spatial distribution map on aquatic ²²invasive species in Wallace waters is presented in Figure 2 to provide a more comprehensive view of aquatic invasive species.

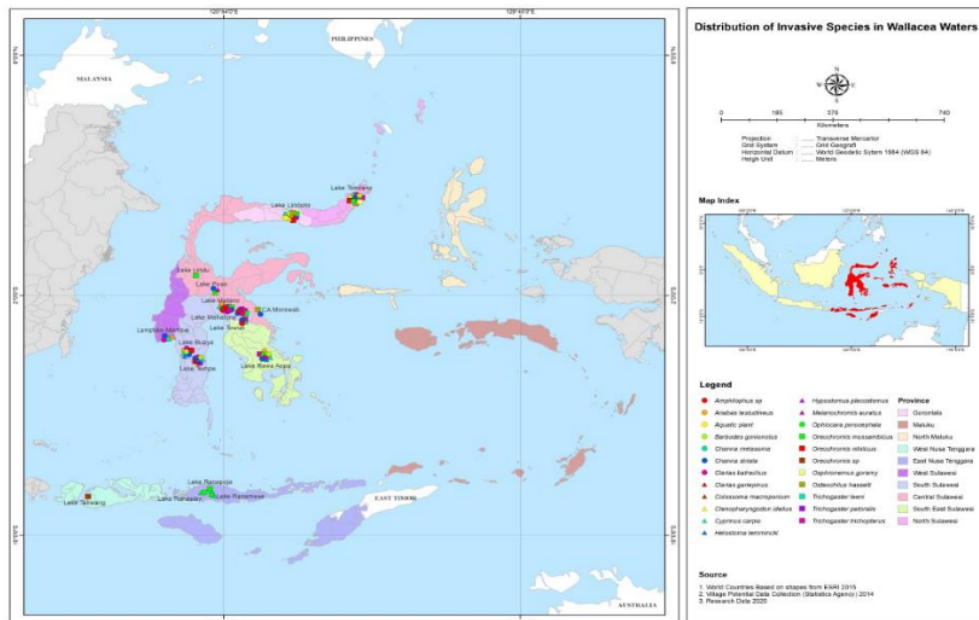


Figure 2. Aquatic invasive species distribution map within the Wallace region.

The map shows that Lake Matano joins with Mahalona through the Petea river. Mahalona joins with Towuti by Tominanga river, and last through the Larona river, the outlet of these Malili lakes end up in Bone Bay. This interconnection of the three lakes may explain, in part, the number of invasive species recorded a decrease from Matano with 9 species, Mahalona with 7 species and Towuti with 4 species. Other than that, the establishment of conservation zones of endemic species in Lake Towuti [21] might have been effective in controlling the introduction of invasive species into the lake.

The map also revealed that 4 other lakes in Sulawesi, Lake Moat, Sidendreg, Wawanloa, and Masapi have no record on aquatic invasive species. There is no data on invasive species that could mean really no invasive species, or no research has been done in those lakes yet.

As for invasive species in Nusa Tenggara, the geographical position of the locations were not available, so it is presented as around the area, similar to Morowali Protected Forest. In the future, sampling site coordinates (geographic position) is necessary for better information.

3.3. Management status

Three government agencies of ministry levels ¹⁸ responsible for dealing with Invasive Alien Species (IAS): Ministry of Environment and Forestry, Ministry of Marine and Fisheries Affairs (MMAF), and Ministry of Agriculture. Ministry of Environment and Forestry has the responsibility of controlling the IAS in the National Park and forest area, including the wetland. MMAF responsible for the inventory of invasive species invaded marine and coastal areas. Ministry of Agriculture is responsible for providing the threat of the IAS port.

In terms of regulation, through law No.16/1992, animal, fish ²⁰ and plant quarantine is established under Agriculture Quarantine Agency, Ministry of Agriculture. In 2009, the Ministry of Marine and Fisheries declared regulation No. 17/2009 (Permen 17 KKP/2009) prohibit the entering of "hazardous" fish's species in the Country. In 2014, the Ministry of Marine and Fisheries Affairs through Ministerial regulation "Permen KP No. 41/PER/2014" imposed regulation to control the 152

aquatic invasive and dangerous species, in which 79 Pisces species potential to be invasive in Indonesia [20].

Based on the responsibilities of each ministerial level in regard to IAS, MMAF is recommended to involve more in inland water fisheries management. Fisheries management in Indonesia favors more marine and coastal fisheries than inland water. Hence data on fish production from inland waters are mostly not available.

Up to the present, the introduction of IAS is controlled by quarantine system, in which invasive organism is categorized as pests. The acceptance or non-acceptance of alien/non-native/exotic need more based on Convention on Biological Diversity in such a way the risk and benefit of acceptance are perceived as a precautionary approach in fisheries management as a whole. The establishment of Environmental Impact Assessment upon introducing a species should be imposed more since it is better and much easier to prevent than to eradicate the non-indigenous that become invasive species.

The establishment of Endemic Conservation Zonation in Lake Towuti in 2014 [21] should provide conclusive cause and effect of invasive louchan fish to endemic species of Towuti lake.

4. Conclusions

Introduction of non-native, alien, exotic species in the Wallace Region has been done both intentionally and unintentionally, most of which are for aquaculture and aquarium species. Some introduced species have positive and negative impact ecologically and economically. Cases of Lake Tempe record the two non-native species introduced in 1937 give a positive impact on the fish production of the lake. In contrast (unintentional) introduction of flower horn to Lake Matano has an adverse effect on endemic fish diversity.

The literature review revealed the numbers of invasive species introduced in the Wallace region vary from 1 species to 12 species, the highest found in Lake Tondano. This preliminary review record that Malili lakes are most researched, both for endemic species and invasive species, based on the number of publications found through an internet search, with publications on endemic species, are more than invasive species. Among 13 lakes in Sulawesi, 4 lakes, namely Lake Moat, Sidendreng, Wawanloa, and Masapi, have no record on aquatic invasive species. There is no data on invasive species could really mean no invasive species, or no research has been done in those lakes yet. A similar situation also occurs in Maluku. The information on the mode and reason for fish introduction into Appo Swamp in Southeast Sulawesi and watershed in Manggarai Regency, East Nusa Tenggara, is still lacking.

All in all, the conclusive cause and effect of introduced species that become invasive on the endemic species in the region is need to be prove or unproven based on scientific data.

At this time, the literature review has not been able to find documentation on marine invasive species in the Wallace region. Whether or not those marine invasive species present in Wallace marine waters are something needed to be studied since the marine realm of the region is also rich in biodiversity.

As for invasive species management, prevention is better than eradication.

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