Preliminary survey of marine water striders (Hemiptera: Gerromorpha) in the southern part of the Miura Peninsula, Kanagawa

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INTRODUCTION

Although insects surpass all other organisms on the earth in terms of species numbers, there are relatively few found in the marine environment. Among more than one million species of insects, only a few thousand are considered to be marine (Cheng 2009; Cheng & Frank 1993). Water striders and their allies (Heteroptera: Gerromorpha) have probably been the most successful in colonizing the marine environment among the insects (Andersen 1999). More than 150 species of marine water striders, representing five families, seven subfamilies, and 25 genera, live mostly in estuaries, mangroves, intertidal coral reefs, and rocky coasts (Andersen & Polhemus 1976; Andersen 1982, 1999). Of these, only five species of oceanic *Halobates* have colonized in the high seas (Cheng 1985; Andersen & Cheng 2004; Ikawa et al. 2012b) and off the Japanese coast, three of these species are found (Miyamoto & Senta 1960; Ikawa et al. 2004). Along the Japanese coast, six species of marine water striders are known to live, all of which are designated as threatened or nearly threatened by the Japanese government or local governments because of population decrease (Association of Wildlife Research & EnVision 2012). Our knowledge about the biology and ecology of these marine water striders is still very limited although it is vital for developing conservation measures for them.

Two marine water striders, *Halobates japonicus* Esaki and *Halovelia septentrionalis* Esaki (Fig. 1), have been recorded at Misaki in the southern part of the Miura Peninsula, Kanagawa by Esaki (1924a, 1924b, 1926). Since then, however, there has been no collection record for *H. japonicus,* not only on the Miura Peninsula but also in the whole Kanto region. *H. japonicus* has now been designated as Threatened I by Nagasaki and Hiroshima Prefectures and as Data Deficient by Mie Prefecture (Association of Wildlife Research & EnVision 2012). On the other hand, *H. septentrionalis* is still found along the coast of the Miura Peninsula (Asano et al. 2012) but has now been designated as Threatened II by Chiba and Hiroshima Prefectures, as Nearly Threatened by Yamaguchi and Nagasaki Prefectures, and as Data Deficient by Kanagawa and Mie Prefectures (Association of Wildlife Research & EnVision 2012).

The author has been studying three endangered species of Japanese marine water striders, *Halobates japonicus, Halobates matsumurai,* and *Asclepios shiranui* (e.g., Ikawa et al, 2012b) and has also made observations of *Halovelia septentrionalis* on many occasions. All of these species are found on coasts without pollution or coastal

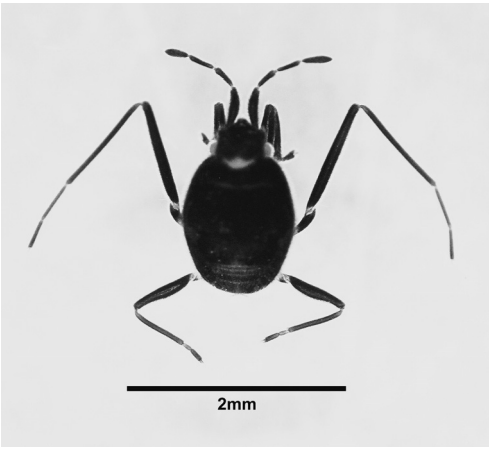

Fig. 1. Adult male *H. septentrionalis*.

development. Compared to the known habitats of these species, the Miura Peninsula was found to be much more populated and urbanized. The aim of this study is to search for *H. japonicus* and *H. septentrionalis* on the southern part of the Miura Peninsula and to examine this urbanized area as the habitat for these endangered marine water striders.

MATERIALS AND METHODS

1. *Halobates japonicus* Esaki and *Halovelia septentrionalis* Esaki

H. japonicus was described by Professor Teiso Esaki (1924a) and the type specimens were collected in Aburatsubo Bay at Misaki on the Miura Peninsula. Esaki (1924a) observed *H. japonicus* rapidly striding on the sea surface along the shore near the mouth of Aburatsubo Bay. The body length of *H. japonicus* is 5.0 mm (male)〜5.2 mm (female) (Andersen and Cheng 2004). It is a large species among the genus *Halobates*. *Halobates,* and also *Halovelia,* are wingless all throughout their life stages and live on the sea surface.

Esaki (1924b) first identified *H. septentrionalis* as *H. maritima* Bergroth. However, after having examined types of *H. maritima,* he found them to be a different species and described it as *H. septentrionalis* (Esaki 1926). Esaki (1924b) made field and laboratory observations on this species at Misaki Marine Biological Station, Tokyo Imperial University (currently, Misaki Marine Biological Station, School of Science, The University of Tokyo, hereafter, MMBS) which is located on the northern shore of Aburatsubo Bay. Esaki (1926) mentioned that this species was very common in Misaki. Andersen (1989b) suggested a trivial name, coral bug, for the *Halovelia*-species because most species are associated with coral reefs, although some species are found in coasts without them. In fact, *H. septentrionalis* is found among rocks along the shore (Esaki 1924b). Coral bugs are much smaller compared to *Halobates*. The body length of *H. septentrionalis* is 1.55〜1.70 mm (male) and 2.10〜2.28 mm (female) (Andersen 1989a).

This species is often found in the habitats of the sea skaters *H. japonicus, H. matsumurai,* and *A. shiranui* (Hayashi & Miyamoto 2003; Ikawa, personal observation). *H. septentrionalis* was seen to be slowly sliding near the rocky shore while *H. japonicus* was skating much faster over a wider range of the sea surface.

2. Sites surveyed

The Miura Peninsula is more urbanized compared to other known habitats of coastal *Halobates and Halovelia*. Therefore, if any other coast where they still live exists, one would expect it to be in areas least affected by human activities. Taking this into consideration, the present survey mainly concentrated on two sites: Aburatsubo Bay and Koajiro Bay (B) at Misaki on the Miura Peninsula (Fig. 2). Aburatsubo Bay was chosen because this is the place where Professor Esaki collected *H. japonicus* (1924a) and also *H. septentrionalis* (1924b), thus it is highly probable that these species can be collected if they have not gone extinct. Also, Aburatsubo is a deep inner bay fringed with vegetation and its geographical features are strikingly similar to those in the Kujukushima area of Nagasaki, the habitat of three marine water striders: *H. matsumurai, A. shiranui,* and *H. septentrionalis* (Kawachino 2001; Hayashi & Miyamoto 2003; Ikawa et al. 2012a). As for Koajiro Bay (B), it is nestled in the wooded hills called Koajiro-no-mori, and this whole area, including the bay, have now been preserved by the government and citizen groups. Obviously, it would seem that Koajiro Bay (B) is much less affected by human activities compared to the other shores and coves on the Miura Peninsula and thus might provide a suitable habitat for marine water striders.

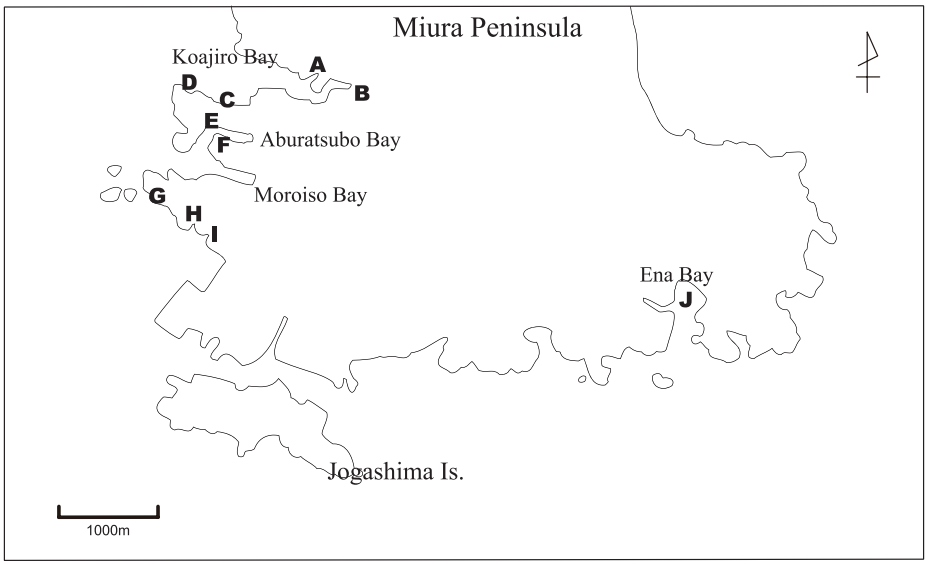

Fig. 2.　Map of sites surveyed. **A**: Koajiro Bay (A). **B**: Koajiro Bay (B). **C**: Koajiro Bay (C). **D**: Koajiro Bay (D). **E**: Northern shore of Aburatsubo Bay. **F**: Southern shore of Aburatsubo Bay. **G**: Moroiso (G). **H**: Moroiso (H). **I**: Moroiso (I). **J**: Ena Bay.

Some other sites were also surveyed whenever possible (Fig. 2). Six sites near these two bays, Koajiro Bay (A), (C), and (D), and Moroiso (G), (H), and (I) were chosen because coastal revetment appeared to be less than other shores and coves, although there seemed to be no areas free of piers, revetments, and/or waste pipes for human drainage. Ena Bay, the only site outside of the Misaki area, was surveyed because the western half of this bay had no bank revetment and a large tidal flat was exposed during the ebb tide, which could be suitable for marine water striders.

3. Survey of marine water striders

Surveys were conducted on July 12-13, 2011, July 9-11, 2013, September 18-20, 2013, and November 6, 2013. These dates correspond mostly to the spring tides according to the tide table for Aburatsubo, Misaki (35° 10′ N 139° 37′ E) provided by Japan Meteorological Agency (2013).

The date, time, and water level of each survey is listed in Table 1. Surveys were made mostly during the ebb tides when the rocks along the coasts became most exposed and the shorelines became accessible by land, except for some areas of Aburatsubo Bay. Around the middle of the northern and southern shores of Aburatsubo Bay, there were a few areas impossible to access from land even during the ebb tides. Most parts of the southern shore were quite inaccessible by land due to poor road connections. In addition, the innermost part of Aburatsubo Bay was off limits due to its use as a marina where numerous pleasure boats were anchored. Therefore, the survey for the entire Aburatsubo Bay, with one exception, could be conducted only once by a boat owned by MMBS on September 19, 2013.

Samplings were made by the use of insect nets with an opening of 25 cm in diameter either from a boat or from the shore. Specimens were stored in 99% ethanol for further use in laboratory studies.

RESULTS AND DISCUSSION

1. *H. japonicus*

No *H. japonicus* was found at any site surveyed in spite of intensive search in different seasons and years. Coastal *Halobates*-species appear to prefer inner bays and coves (Ikawa, 2010; Ikawa et al. 2012b). Therefore, Koajiro Bay (C) and (D), and Moroiso (G) appear to be too exposed to the open sea for the survival of *H. japonicus* (Fig. 2). As for the inner bays, Aburatsubo Bay, Koajiro Bay (A) and (B), and Moroiso (H) and (I), and Ena Bay the shores were partly embanked with concrete or piers, reducing tide flats or natural shorelines of fringed vegetation. Fishery or pleasure boats were also anchored or sailing around the bays. As a result, the space necessary for *H. japonicus* to complete its life cycle might have been highly reduced and fragmented. In addition, the seawater in the sites surveyed appeared to be heavily polluted by human drainage and garbage. Most known habitats of this species are in areas preserved by the government as National Parks, Quasi-national Parks, etc. where seawater pollution and coastal developments are kept to a minimum (Ikawa et al. 2012b). Obviously,

Table 1. Results of survey of *H. septentrionalis* in the southern part of the Miura Peninsula

Year/Month/Day	Site surveyed*	*H. septentrionalis* **	Water level (cm) and time during the survey	Lowest water level (cm) and time during the day	Highest water level (cm) and time during the day
2011/7/12	Koajiro Bay (B)	+	24~34 cm at 8:00~10:50	23 cm at 8:29	134 cm at 16:04
	Aburatsubo Bay (E)	+	52~117 cm at 11:00~14:00		
2011/7/13	Aburatsubo Bay (E)	+	30~52 cm at 11:30 ~12:30	14 cm at 9:22	142 cm at 16:46
2013/7/9	Moroiso (G)	–	32 cm at 13:00~13:20	13 cm at 11:24	145 cm at 18:14
	Aburatsubo Bay (E)	+	57 cm at 13:40~14:00		
2013/7/10	Aburatsubo Bay (E)	+	22~16 cm at 11:00~12:40	16 cm at 11:55	146 cm at 18:46
	Koajiro Bay (B)	+	45 cm at 14:00~14:15		
	Koajiro Bay (A)	–	45 cm at 14:15~14:45		
	Aburatsubo Bay (E), (F)	+	74~143 cm at 15:00~18:30		
2013/7/11	Ena Bay (J)	–	22~23 cm at 12:00~13:00	20 cm at 12:27	146 cm at 19:08
	Aburatsubo Bay (F)	+	23~37 cm at 13:30~14:30		
2013/9/18	Koajro Bay (C), (D)	–	33 cm at 09:40~10:00	33 cm at 9:49	154 cm at 16:15
	Koajiro Bay (A)	–	33 cm at 10:20~10:50		
	Koajiro Bay (B)	+	42 cm at 10:50~11:20		
2013/9/19	Moroiso (I)	–	51 cm at 09:15~09:30	37 cm at 10:26	157 cm at 16:41
	Moroiso (H)	–	51 cm at 09:40~09:50		
	Aburatsubo Bay (E), (F)	+	38 cm at 10:00~11:50		
2013/9/20	Koajro Bay (B)	+	52~100 cm at 11:50~14:00	44 cm at 10:59	159 cm at 17:06
2013/11/6	Aburatsubo Bay (E)	–	113 cm at 10:00~10:30	89 cm at 12:09	161 cm at 17:34
	Koajiro Bay (B)	+	90~107 cm at 11:40~14:30		

*: Letters in the parentheses indicate the sites shown in the map in Fig. 2.
**: [+] indicates *H. septentrionalis* was found and [–] where it was not found.

habitat alterations in the sites surveyed have quite affected the survival of this species. In conclusion, this species may very well be extinct in this area. Even if the species still exists, the population densities would be very low.

2. *H. septentrionalis*

This species was found in two sites, Koajiro Bay (B) in July 2011 and 2013, and in September and November 2013 and also in Aburatsubo Bay except for in November 2013 (Table 1). In the early days, *H. septentrionalis* was found abundantly in Misaki from June to September (Esaki 1924b). In fact, in July 2011 and 2013, and in September 2013, the abundance of *H. septentrionalis* appeared high in Abutatsubo Bay and Koajiro Bay (B) although the abundance was confined to the middle area of the bays. No *H. septentrionalis* was found in the other sites although surveys were conducted in July and/or September when they should be most abundant. The population densities of this species would have been too low to be found or they might already be extinct there.

3. *H. septentrionalis* in Aburatsubo Bay and Koajiro Bay (B)

The innermost area of Aburatsubo Bay was off limits because of its use as a marina (Fig. 3). On the bank near the marina, there were several vacation houses with private pleasure boats. No coral bugs were found around the marina. The middle areas of the bay of both shores were steep cliffs covered with dense vegetation dangling above the sea surface (Fig. 4, 6). Around the mouth of the bay was a rocky shore with some vegetation (Fig. 5). Around both the mouth and middle areas of the bay, which were accessible on foot, aggregations of several individuals were occasionally seen (July 12-13 in 2011, July 9-11 in 2013, September 19 in 2013). In the middle areas of the bay, which were accessible only by boat, coral bugs were found to be abundant on September 19, 2013. There, large numbers of aggregations were found close to the rocky shore under the overhanging vegetation.

In Koajiro Bay (B), a stream of water flowed from the wooded hill into the innermost part of the bay and a large muddy tidal flat was exposed during the ebb tide (Fig. 7). The northern and southern shores of the middle area of the bay were rocky reefs covered with overhanging vegetation (Fig. 8). On the bank around the mouth of the bay, there was a number of houses with boats and piers (Fig. 9). The bank outside of the bay was used as a large marina and fishery harbor, and numerous boats were anchored or sailing (Fig. 10). No coral bugs were found in the tide pools formed in the muddy innermost areas of the bay and around the mouth of the bay. They were found only along the rocky reefs in the middle of the northern and southern shores. They were found in that area abundantly in July 2011, and July and September 2013. Coral bugs were striding around the rocks singly or in aggregations of several to several tens of individuals. Especially under the overhanging vegetation large aggregations were formed. However, in November 2013, the number of coral bugs in the same area had greatly decreased. Aggregations of several individuals were seen occasionally.

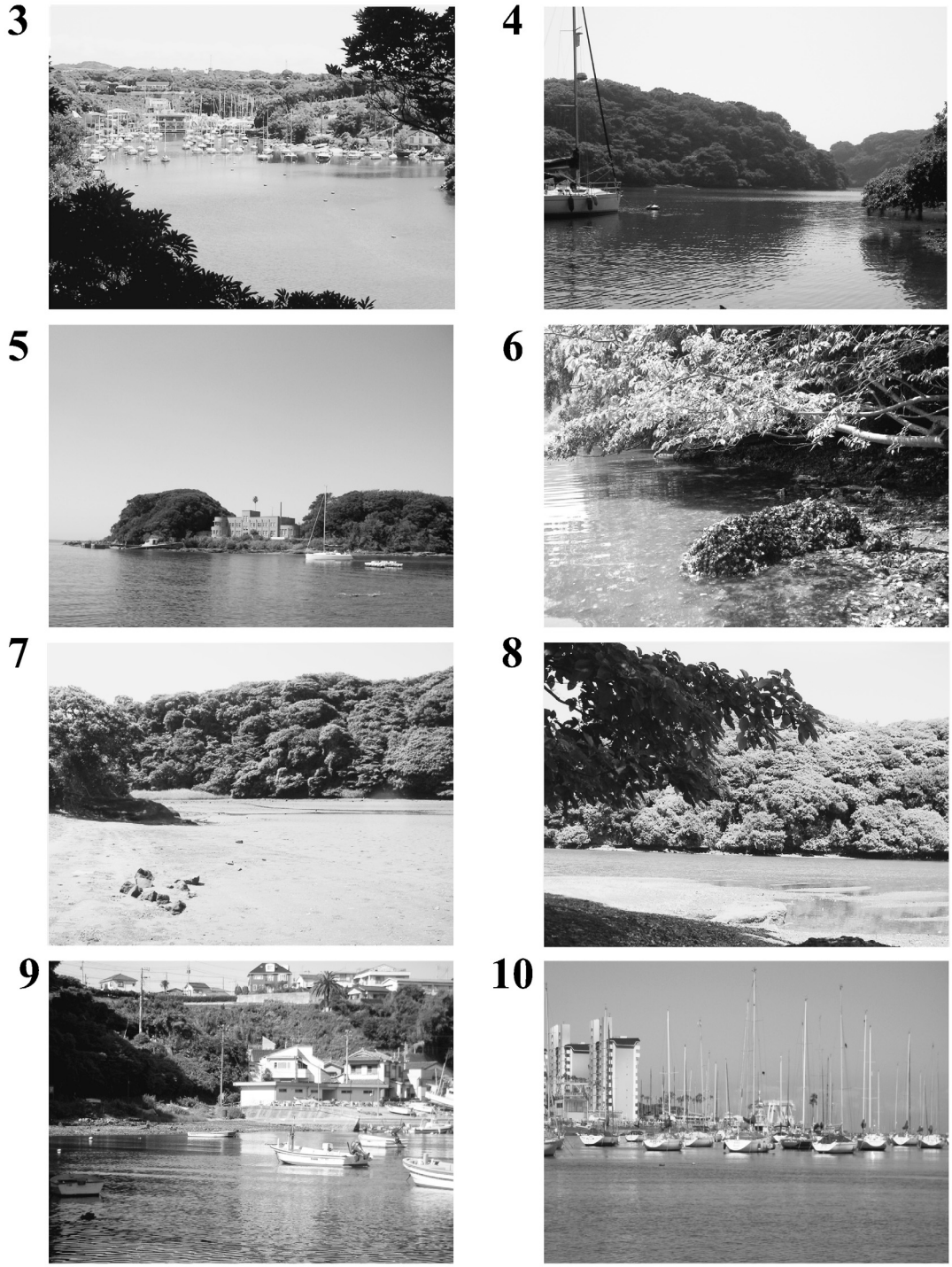

Fig. 3-10. Pictures of sites surveyed. [3]: Aburatsubo Bay with numerous boats anchored in the innermost part. [4]: Middle area of Aburatsubo Bay. [5]: Mouth of Aburatsubo Bay. [6]: Rocky shore with overhanging vegetation where *H. septentrionalis* was abundant. [7]: Innermost part of Koajiro Bay (B). [8]: Middle area of Koajiro Bay (B). [9]: Mouth of Koajiro Bay (B). [10]: Marina right outside of Koajiro Bay (B).

Some individuals were skating singly. In the temperate region of Japan, diapause is a prerequisite for the insects to survive the winter. The drastic decrease in the number of *H. septentrionalis* in November 2013 suggests that this species would go into diapause in the late autumn in the Miura Peninsula. *Halobates matsumurai* and probably also *Asclepios shiranui* overwinter in the egg stage along the coasts of Kujukushima, Nagasaki (Ikawa et al. 2012a). Nothing is known about the overwintering of any *Halovelia-species*.

4. Habitat requirements of *H. septentrionalis* and *H. japonicus*

In Aburatsubo Bay and Koajiro Bay (B), coral bugs were found close to the rocky shore. They were abundant under overhanging vegetation. No individuals were seen in the muddy tidal pools, off shore, or outside the bays. The lives of *Halovelia*-species appear to be heavily dependent on corals and rocks (Andersen 1989b). During the full tide, *H. malaya* retreats into the holes of submerged blocks of dead corals (Andersen 1989b). Kellen (1959) observed that at high tide individuals of *H. bergroth* hide in the air pockets trapped in the holes of submerged volcanic rocks. It is highly probable that these two species lay eggs in the holes of dead coral blocks or volcanic rocks (Andersen 1989b). Esaki (1924b) suspects that *H. septentrionalis* may climb on the rocks when waves wash the beach. *Halovelia*-species would feed on mites, springtails, or dipteran insects, which are abundant on the rocks of the coasts, and on land insects blown onto the reef (Andersen 1989b). Obviously, insects falling from overhanging vegetation onto the sea surface would also serve as their food. These observations suggest that *Halovelia*-species would remain in rather small areas close to the coral reefs or rocky shores, preferably with overhanging vegetation, and complete their life-cycle. This would allow *H. septentrionalis* to survive in Aburatsubo Bay and Koajiro Bay (B). Along the coast of the Miura Peninsula, rocky shores with fringed vegetation are still found, although fragmented by piers and/or revetments. Therefore, it might be possible for this species to survive at certain sites on the Miura Peninsula although the population densities would be low.

Compared to *H. septentrionalis, H. japonicus* appears to require a much wider range for its habitat (Ikawa et al. 2006, 2008; Ikawa personal observation). In Kabira Bay, Ishigaki Island, numerous young nymphs of this species were found in the tide pools of the innermost part of the bay, while older nymphs and adults were skating not only in the inner part but also around the mouth of the bay. They were skating both near the shore and off shore. For *H. japonicus*, to complete its life cycle, the whole sea surface and shore of a bay would be necessary as its habitat. In the sites surveyed, the coasts have been more or less altered by construction of vacation houses and marinas, and the sea surface was busy with numerous boats. This would have caused a fragmentation of the habitat for *H. japonicus* and might have caused a drastic decrease in its population if not its extinction.

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