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Cover: Little Andaman is part of the island chain with incredible biodiversity, but these amazing species are threatened by development projects, and need our support. Pen and ink artwork by Priyanka Iyer.

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ARTICLE

Tectonic turmoil: consequences of violent earthquake-2025 on biodiversity collapse in Myanmar

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Abstract: This study provides a preliminary rapid-response assessment of the immediate impacts of the 2025 violent earthquake in Myanmar on biodiversity. The photographic evidence and communication with the local communities reported mass mortality of freshwater gastropods in Inle Lake, with predictions of substantial losses among several bithyniid species, including endemic ones. Additionally, the unnatural deaths of freshwater fishes (e.g., carps and catfishes) in the Mahamuni Pagoda Pond, Mandalay, indicate that the earthquake also affected larger freshwater vertebrates. This first documentation highlights the need for further investigations into freshwater ecosystems, particularly within the Irrawaddy River basin, to comprehensively assess the earthquake's impact on native biodiversity. The study also recommends further scientific validation and long-term monitoring efforts in Inle Lake to support the restoration of lost biodiversity and to safeguard the livelihoods of the native Intha communities that depend on this freshwater ecosystem.

Keywords: Aquatic species, biodiversity loss, conservation, Gastropods, freshwater fishes, seismic impact, southeastern Asia.

Burmese: ဤလေ့လာမှုသည် ၂၀၂၅ ခုနှစ်တွင် မြန်မာနိုင်ငံ၌ ဖြစ်ပွားခဲ့သော ပြင်းထန်သည့် ငလျင်ကြောင့် စီဝမျိုးစုံမျိုးကွဲများအပေါ် ချက်ချင်းနီးကပ်ဆန်းစစ်ချက် တစ်ရပ်ကို ပုံပြိုးဖော်ပြပေးထားသည်။ ဓာတ်ပုံမှတ်တမ်းများနှင့် ဒေသခံကျေးရွာများ၏ ဆက်သွယ်ပြောဆိုမှုများအရ အင်းလေးကန်အတွင်းရှိ ရေချိုခရုပက်ကျိများ အစုလိုက် သေဆုံးမှုကို တွေ့ရှိရပြီး ဒေသရင်း အပါအဝင် ဆက်စပ်မျိုးစိတ်များစွာတွင် သိသာထင်ရှားသော ဆုံးရှုံးမှုများ ရှိနိုင်ကြောင်း လေ့လာတွေ့ရှိရသည်။ ထို့အပြင် မန္တလေးမြို့ရှိ မဟာမုနိရေကန်တွင် ရေချိုငါးများ၏ သဘာဝအရ မဟုတ်သော သေဆုံးမှုများကိုကြည့်ခြင်းအားဖြင့် အဆိုပါ ငလျင်သည် ရေချိုကျောရိုးရှိသက်ရှိများ အပေါ်ပါ သက်ရောက်မှုရှိကြောင်း ညွှန်ပြနေသည်။ ဤလေ့လာမှုသည် မြန်မာနိုင်ငံအတွက် ပထမဆုံးမှတ်တမ်းတင်ချက်ဖြစ်ပြီး ဒေသရင်း စီဝမျိုးစုံမျိုးကွဲများအပေါ် ငလျင်၏သက်ရောက်မှုကို နက်ရှိုင်းစွာ အကဲဖြတ်နိုင်ရန်အတွက် အထူးသဖြင့် ဧရာဝတီမြစ်ဝှမ်းဒေသ အတွင်းရှိ ရေချိုဂေဟစနစ်များကို နောက်ထပ်လေ့လာမှုများ ပြုလုပ်ရန် လိုအပ်ကြောင်း ထင်ဟပ်ဖော်ပြလျက်ရှိနေသည်။ ယခုလေ့လာမှုတွင် ဆုံးရှုံးသွားသော စီဝမျိုးစုံမျိုးကွဲများ ပြန်လည်ထူထောင်ရေးနှင့် ဤရေချိုဂေဟစနစ်ကို မှီခိုနေရသော ဒေသခံအင်းသားကျေးရွာများ၏ ရှင်သန်ရပ်တည်ရေးကို ပံ့ပိုးရန်အတွက် အင်းလေးကန်အတွင်း နောက်ထပ်သိပ္ပံနည်းကျ စိစစ်အတည်ပြုမှုများနှင့် ရေရှည်စောင့်ကြည့်လေ့လာမှုများ ဆောင်ရွက်ရန် အကြံပြုထားပါသည်။

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BACKGROUND

Earthquakes occur when stress accumulates at plate boundaries due to friction and is suddenly released, causing fault movement, and generating seismic waves (Ide 2010). These natural phenomena significantly affect the environment through ground shaking, surface rupture, landslides, soil liquefaction, and tsunamis, leading to both immediate and long-term consequences (Ratnapradipa et al. 2012). Specifically, earthquakes trigger tsunamis that flood coastal areas, alter salinity, deposit harmful sediments, and damage critical marine habitats such as coral reefs, mangroves, and seagrass beds, disrupting aquatic biodiversity (Lebrato et al. 2019). In freshwater systems, earthquakes can shift river courses or create new reservoirs, hindering species migration, and water quality. Furthermore, the soil liquefaction can collapse habitats, particularly in reservoirs and lakes, causing further decline in many aquatic species. Moreover, the groundwater biodiversity is also significantly impacted by seismic activity, with loss of subterranean species (Galassi et al. 2014). It has been shown previously that the 2011 Tohoku earthquake and tsunami caused notable shifts in species diversity in rocky intertidal zones (Urabe et al. 2013). Additionally, earthquakes can trigger biogeochemical shifts in hydrothermal vents, disrupting aquatic ecosystems (Lebrato et al. 2019). A previous global study shows that earthquakes increase extinction risks for various species (Gonçalves et al. 2024).

In particular, the 2009 earthquake that affected the karstic Gran Sasso Aquifer in Italy is presumed to have induced significant biogeographical and ecological disturbances, altering habitats, disrupting ecosystem dynamics, and influencing species distribution patterns (Fattorini et al. 2017). Such seismic activity likely caused physical damage to critical ecosystems, including forests, wetlands, and agricultural lands, leading to habitat loss for numerous species, as observed across various biogeographic regions (Qiu et al. 2015; Sidle et al. 2018). The displacement of flora and fauna due to land shifts, landslides, and infrastructure damage has altered local biodiversity patterns, while disruption to natural habitats may impede species migration, reproduction, and access to food sources, potentially leading to long-term ecological imbalances (Li et al. 2022; Yuan et al. 2024). Additionally, earthquake impact on soil stability, and water systems has been reported to exacerbate threats to vegetation growth, and aquatic ecosystems, jeopardizing both terrestrial, and aquatic biodiversity (Galassi et al. 2014).

On 28 March 2025, Myanmar was struck by a series of earthquakes, beginning with a magnitude 7.7 tremor near Mandalay at 0620 h UTC (Coordinated Universal Time) (United States Geological Survey, https://earthquake.usgs.gov/earthquakes/eventpage/us7000pn9s/executive), followed by a 6.7-magnitude quake at 0632 h UTC in the western part of the country, and several subsequent aftershocks (Image 1). These included a magnitude 4.8 quake near Taungdwingyi at 06:39 UTC, a 4.9-magnitude tremor in Sagaing at 0642 h UTC, and a 4.9-magnitude earthquake near Taungngu at 0645 h UTC. Additional aftershocks continued throughout the morning, with several quakes of magnitudes 4.5–4.6, impacting areas such as Shwebo, Pyinmana, and Mandalay. The earthquake, caused by a strike-slip movement along the Sagaing Fault, underscores the ongoing tectonic strain between the Indian and Eurasian Plates (Shahzada et al. 2025). This event serves as a reminder of the region's high seismic risk, where the continuous pressure from the plate collision leads to the release of energy through fault ruptures. The earthquake sequence caused over 2,700 civilian deaths, 4,500 injuries, and 450 missing, with widespread destruction in Mandalay, Myanmar, and tremors spreading up to Thailand. Subsequently, countries like China, India, and the U.S. provided emergency aid, including supplies, medical help, and rescue teams, while the UN coordinated relief efforts. The immediate consequences of this natural disaster shift focus to human casualties, infrastructure damage, and emergency response, temporarily overlooking biodiversity loss. In the face of immediate humanitarian needs, attention is often distracted from ecological concerns, eventually relegating the habitat damage, ecosystem disruption, and species loss. Therefore, long-term recovery efforts must prioritize both human well-being, and biodiversity conservation by identifying, and restoring key ecological habitats to enhance resilience, and ensure sustainable future ecosystems.

The seismotectonics of this region are primarily driven by the ongoing collision between the Indian Plate and the Eurasian Plate, which began approximately 50 million years ago and continues to this day (Hurukawa et al. 2012). This collision has resulted in the formation of the Himalayan Mountain range and the Tibetan Plateau, generating significant seismic activity (Shahzada et al. 2025). The region is characterized by several fault systems, including the Main Himalayan Thrust (MHT), the Main Boundary Thrust (MBT), and the Sagaing Fault, each of which plays a crucial role in earthquake generation (Li et al. 2024). Myanmar, located at the eastern edge

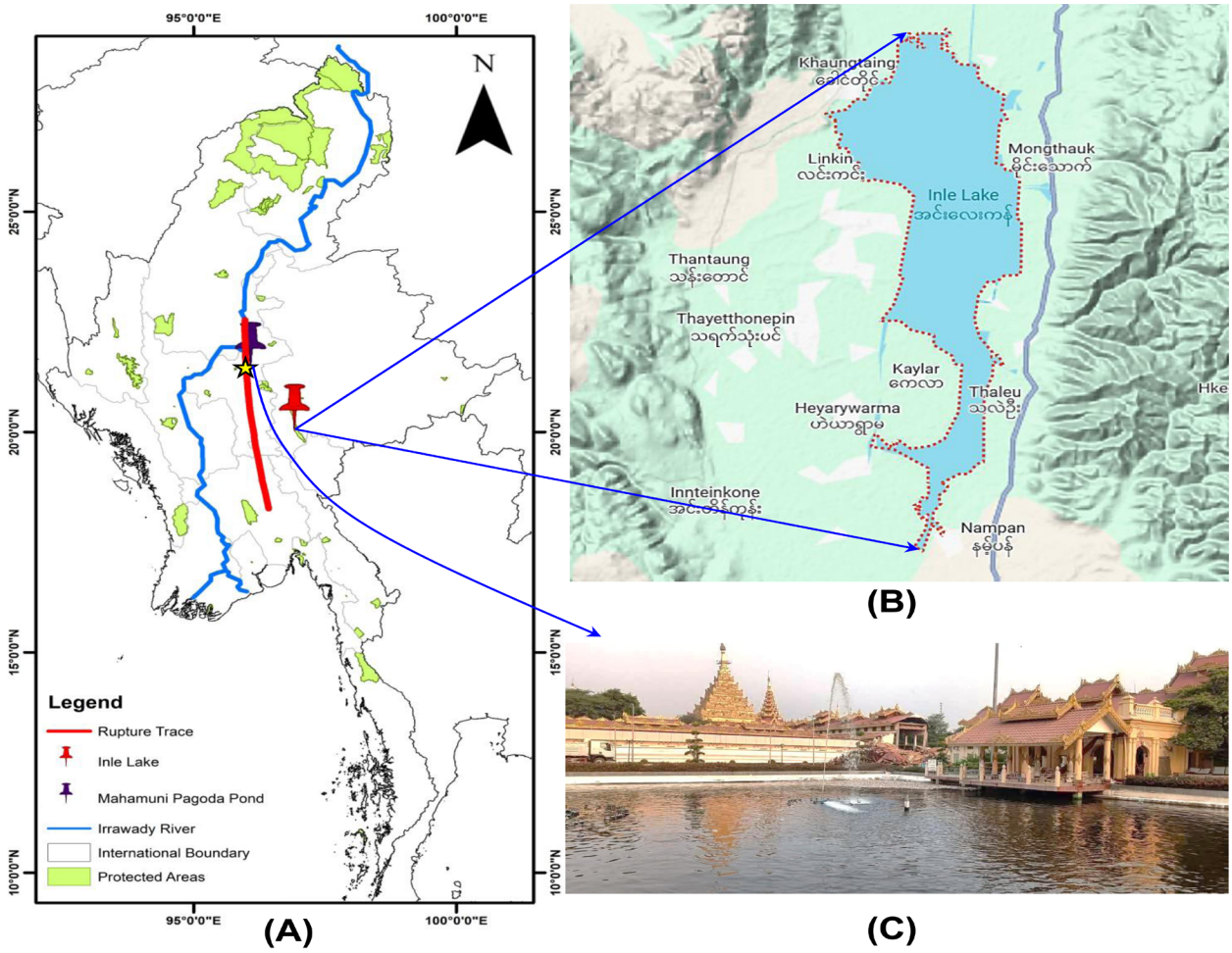

Image 1. A—map showing the rupture trace of the 28 March 2025, Myanmar earthquake in red. The underlying raster data was obtained from the United States Geological Survey. The yellow star marks the epicenter, the blue line represents the Irrawaddy River, and the green polygons indicate protected areas in Myanmar. The survey sites — Inle Lake and Mahamuni Pagoda Pond — are marked with color-coded pins. The map was manually edited using Adobe Photoshop CS 8.0 | B—location of Inle Lake | C—Mahamui Pagoda Pond in Myanmar.

of the Indian Plate's interaction with the Eurasian Plate, is influenced not only by Himalayan tectonics but also by the subduction zone off its coast, where the Indian Ocean Plate subducts beneath the Sunda Plate (Taylor & Yin 2009). The Sagaing Fault, a major strike-slip fault running through Myanmar, accommodates lateral motion between the Indian and Eurasian Plates, contributing to the region's seismic activity (Wang et al. 2014). Due to the relatively underdeveloped seismic monitoring and mitigation infrastructure in this region compared to other seismically active areas, there is a critical need for increased research into the region's seismotectonics for more effective risk assessment, and disaster preparedness in these earthquake-prone regions. Therefore, in light of the recent 2025 violent earthquake in Myanmar, the present study aims to undertake a rapid assessment of its immediate impacts on biodiversity in two ecologically and culturally significant sites: (i) Inle Lake, a naturally biodiversity-rich area located on the southern Shan Plateau and (ii) the Mahamuni Pagoda Pond in Mandalay, an artificial but conservation-relevant aquatic habitat. Given the critical role of both sites in regional biodiversity and conservation, this preliminary report offers an early overview of biodiversity loss resulting from the disaster. This study is intended to serve as a foundational baseline for more comprehensive post-disaster assessments of diverse biogeographic regions and native biota across Myanmar.

STUDY DESIGN

Following the earthquake on 28 March 2025, ecological alterations and biodiversity loss were assessed at Inle Lake (20.552° N, 96.916° E), located on the southern Shan Plateau, and at Mahamuni Pagoda Pond (21.951° N, 96.080° E) in Mandalay, Myanmar. Inle Lake is the second-largest lake in Myanmar and the only ancient lake on the Indochinese Peninsula. Despite its relatively small size (~116 km²) and shallow depth (with an average of only two meters), this lake supports significant freshwater biodiversity and endemism, similar to other ancient lakes, such as Baikal in Russia, Tanganyika in Africa, and Biwa in Japan (Hampton et al. 2018). Furthermore, the Mahamuni Pagoda Pond harbours a diverse assemblage of aquatic fauna, including various species of carp (Cyprinidae), catfish (Siluriformes), and freshwater turtles. These animals are frequently released by pilgrims as part of long-standing religious and cultural rituals that symbolize the act of merit-making. The recent assessment was carried out at both study sites through a randomized questionnaire survey conducted among local inhabitants and community volunteers. The field documentation was supported by photographic evidence captured using a Canon EOS 7D Mark II camera equipped with an 18–135 mm lens.

The generation of the maps involved multiple stages of data retrieval and processing of vector files. Initially, global administrative boundary shapefiles were obtained from the DIVA-GIS platform (https://diva-gis.org/data.html), which provides high-resolution vector datasets suitable for spatial analysis. These shapefiles were imported into ArcMap (ArcGIS v10.6) for subsequent processing and overlay analysis. Furthermore, the rupture trace associated with the violent earthquake 2025 in Myanmar was obtained from the United States Geological Survey (USGS) Earth Explorer platform (https://www.usgs.gov/). Data on Myanmar's protected areas were acquired from the Protected Planet database (https://www.protectedplanet.net/en). This dataset includes officially designated protected regions and supports the assessment of environmental vulnerability. All spatial datasets were standardized by reprojecting them into the WGS 84 geographic coordinate system to ensure consistency and compatibility across layers. The processed data were compiled and exported for the generation of the final thematic maps.

OBSERVATION

Gastropod mortality in Inle Lake

This study documents the sudden mortality of millions of gastropods from multiple species in Inle Lake (Image 1). To date, 36 species of freshwater molluscs, including 18 endemic species, have been recorded from the Inle Lake basin (Annandale 1918a; Annandale & Rao 1925). The family Bithyniidae, one of the most common groups of freshwater snails within the basin, is widely distributed across Africa, Eurasia, and Australia, inhabiting rivers, wetlands, ponds, and lakes. Six species of bithyniid snails have been documented in the Inle Lake basin and surrounding regions, viz., *Hydrobioides turrita*, *H. nassa*, *H. physcus*, *H. avarix*, *Gabbia nana*, and *G. alticola*. Four of these species (*H. physcus*, *H. avarix*, *G. nana*, and *G. alticola*) are considered endemic to the Inle Lake basin (Zhang et al. 2025). In light of the recent earthquake in Myanmar, the widespread mortality of molluscs in Inle Lake suggests a dramatic loss of native biodiversity, including many endemic species (Image 2). The decaying carcasses of these snails have contributed to the rapid deterioration of water quality, potentially exacerbated by the release of unpleasant odours and the proliferation of harmful microbes. This microbial surge poses further risks to the remaining native freshwater species in the lake.

Fish mortality at Mahamuni Pagoda Pond

The study also documents the unnatural mortality of sacred freshwater fish in the Mahamuni Pagoda Pond following the recent earthquake (Images 1 & 2). This seismic disturbance appears to have triggered adverse ecological conditions in the confined aquatic environment, including potential shifts in water chemistry, hypoxia, and the suspension of sediment-bound pollutants, all of which could have contributed to the observed fish die-offs (Devane et al. 2014). This pond also supports breeding activities, where fish populations occasionally reach densities high enough to require transfer or release into nearby natural water bodies, most notably the Irrawaddy River (Global new light of Myanmar 2024). Such movement of fauna between managed and wild habitats presents both ecological opportunities and biosecurity risks, particularly following stress events like earthquakes. Furthermore, the presence of several freshwater turtle species within the pond is of particular conservation concern, including the Critically Endangered Burmese Roofed Turtle *Batagur trivittata*, and the Burmese Peacock Softshell *Nilssonia formosa* (Calle et al. 2021). Both species are endemic to

Image 2. Consequences of the 28 March 2025 violent earthquake on Myanmar's Biodiversity. A–D—mass mortality of millions of gastropods in Inle Lake | E—unnatural death of freshwater fish in the captivity at Mahamuni Pagoda, Mandalay. © July Hnin and Thadoe Wai.

Myanmar and are facing severe threats due to habitat loss, overexploitation, and illegal trade (Platt et al. 2019; Horne et al. 2021).

COMMENTARY

Earlier evidence suggests that earthquakes and their subsequent effects can influence the ecological

dynamics, genetic composition, and structural changes within molluscan communities in Japan (Sato & Chiba 2016; Miura et al. 2017). Additionally, studies have documented that earthquakes impact molluscan species and their toxic metal accumulation, potentially posing significant risks to human health (Tapia et al. 2019). Thus, immediate intervention by local governments and conservation agencies is crucial to mitigate the ecological impacts of this event and protect the lake's unique biodiversity. In addition to its rich biodiversity, Inle Lake in Myanmar plays a pivotal role in supporting the livelihoods of the local Intha communities (Htwe et al. 2015). This aquatic ecosystem is also regarded as United Nations Educational, Scientific and Cultural Organization (UNESCO) — Man and the Biosphere Reserve (MAB) and is a wetland of International Importance designated under the Ramsar Convention (Oo et al. 2022). Furthermore, this ecosystem is also designated as a Wildlife Sanctuary and ASEAN Heritage Park in Myanmar. The lake serves as a critical source of several endemic freshwater fish and other aquatic species, providing essential sustenance and income through fishing activities (Annandale 1918b; Michalon 2015; Kano et al. 2016, 2022; Win 2018; Fuke et al. 2021, 2022; Musikasinthorn et al. 2023). A recent assessment of endemic fish species in Inle Lake revealed that Cypriniformes were the most dominant (70%), followed by Synbranchiformes (20%) and Anabantiformes (10%) in terms of relative abundance (Naing & Tun 2022). Aside from the discovery of new species of decapods and gastropods (Annandale 1918a; Kemp 1918; Annandale & Rao 1925; Ng et al. 2000; Sawada 2022; Zhang et al. 2025), the abundance, and diversity of other freshwater invertebrates in the lake have not yet been systematically assessed. Furthermore, the surrounding wetlands are home to distinctive floating gardens, where crops and vegetables are cultivated on platforms made from vegetation, enabling year-round agriculture in the nutrient-rich waters (Win 1996). Inle Lake also draws significant tourism, contributing to the local economy through hospitality services, guided tours, and the sale of regional crafts (Su & Jassby 2000**)**. As an important transportation hub, the lake facilitates daily commutes for those residing in stilted houses along its shores, ensuring access to essential services and trade. Moreover, the lake is intricately linked to the cultural heritage of the area, with traditional crafts such as silk and lotus fiber weaving, alongside religious, and cultural practices centered around numerous pagodas, and monasteries. In addition, recent studies have documented significant alterations in land use and land cover change (LULCC) in the Inle Lake region, characterized by declining trends in forest, and perennial wetland areas primarily due to anthropogenic pressures (Karki et al. 2018; Michalon et al. 2019). The recent earthquake may have further intensified LULCC patterns in this ecosystem, underscoring the urgent need for comprehensive investigation to understand its dynamics, and ecological implications.

The artificial pond at Mahamuni Pagoda has been designated as a conservation priority site, where the resident turtles are afforded daily offerings and protection. This site serves as a semi-natural refuge that complements ex-situ conservation initiatives. The earthquake may have compromised water quality parameters such as dissolved oxygen levels, ammonia concentration, and temperature fluctuations, all of which are critical to the health of ectothermic reptiles (Qian et al. 2013). Given the ecological significance of the Mahamuni Pagoda reservoir, further interdisciplinary research is essential to evaluate the earthquake's impact on both aquatic biodiversity and water quality. This includes post-seismic monitoring and management of physicochemical parameters, histopathological assessments and treatments of affected fauna, and population surveys of key species. The results will be pivotal in formulating evidence-based conservation strategies to protect these culturally and biologically important aquatic organisms from future disturbances.

A key limitation of this study is its exclusive reliance on photographic evidence and information obtained through local communication following the March 2025 seismic event in Myanmar. Estimating the number of snails that died was based on visual documentation alone, which may have introduced significant biases in quantification. The lack of pre-event baseline data further complicates the assessment of how much of the population was impacted, making it difficult to determine whether the mortality event signifies a threat of extinction or a temporary fluctuation in population size. These constraints highlight the challenges of accurately assessing the biodiversity impacts of this natural calamity through remote observations. Additional scientific validation through water quality assessments, histopathological analyses of deceased species, and genetic studies aimed at evaluating ecosystem resilience is urgently needed to monitor the native biodiversity in this key ecosystem following the earthquake. Several protected areas in Myanmar are located in close proximity to active fault lines, including those possibly affected by the Violent March 2025 earthquake. In addition to Inle Lake, the region encompasses several protected areas located to the east of the fault line,

including Panlaung & Padalin Cave Wildlife Sanctuary (WS), Pyin-O-Lwin Bird Sanctuary, Shwe-U-Daung WS, Minwuntaung WS, and Taunggyi Bird Sanctuary. On the western side of the fault line, key protected areas such as North Zamrari WS, Moeyungyi Wetland Ramsar Site, Minsontaung WS, Moeyungyi Wetland WS, and Popa Mountain Park harbour ecologically significant floral, and faunal assemblages. Given the ecological sensitivity of these areas, further investigation into the impacts of the March 2025 earthquake is essential to inform comprehensive post-disaster ecological assessments, and conservation strategies.

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