Emerald Ash Borer Impact and Response on The University of Michigan Biological Station Main Campus

Mitchell Calvin, Joe Hazelton, Jacob Inosencio, Max Miley

Abstract

Since its introduction to North America in 2002, the emerald ash borer has decimated Ash populations across the United States and Canada causing forest degradation and damaging economies. This investigation includes a survey of a developed plot of land at The University of Michigan Biological Station in Pellston, MI, and examines the impact of the emerald ash borer (EAB) on ash trees (*Fraxinus sp.*), as well as the response regionally. The primary focus of the survey is on the impacted ash populations on the main campus and to analyze and propose various treatment methods. These treatment methods mainly include classical biological control and insecticide application. We propose that both insecticides containing emamectin benzoate and introducing non-native hymenopteran parasitoids are viable options for future EAB control for part of the UMBS main campus area surveyed.

Introduction

The emerald ash borer (EAB; *Agrilus planipennis*), a phloem-feeding beetle native to Asia, was first detected on the North American continent in the Detroit area in 2002. Trees in the family Fraxinus, ash trees, lack strong defenses to the EAB and are rapidly killed after infestation. Since 2002 the EAB has spread rapidly through the United States and Ontario, Canada. Despite the efforts of regulators in both countries, by 2004 the beetle was reported in Ontario, Canada and Ohio, Indiana, Maryland, and Virginia, USA (Duan, Jian et al. 2018). By 2018 reports of EAB reached 32 U.S. states and 3 Canadian provinces (BenDor, Todd K. et al. 2006).

The human and environmental impacts of EAB spread have been devastating. Across the U.S. and Canada estimates place the cost of treating, removing, and replacing ash killed in one decade (2009 and 2019) at $25 billion (Duan, Jian et al. 2018). This estimate, if correct, makes the EAB the most destructive and costly beetle to invade either nation.. Since 2002, the beetle has killed more than 30 million ash trees in southeastern Michigan alone (McCullough et. al. 2015). In response to this threat the International Union for Conservation of Nature listed as critically endangered the six species of fraxinus native to Eastern North America: white ash (F. americana L.), Carolina ash (F. caroliniana), black ash (F. nigra), green ash (F. pennsylvanica), pumpkin ash (F. profunda), and blue ash (F. quadrangulata) (BenDor, Todd K. et al. 2006).

In Michigan, the species most affected by the EAB infestation, by number of individuals, has been white Ash (F. Americana) (Robinett, M.A., and D.G. Mccullough, 2019.). F. Americana is the most common ash tree in North America with a native range extending across the Midwestern United States and reaching the cardinal extremes of Nova Scotia and eastern Texas. A pioneer species, white ash trees grow in the early and intermediate stages of succession. In the Central United states white ash is most common on slopes along major streams, less common in upland forests, and rare in the flat bottoms of major streams. White ash tolerates temporary flooding but grows best on deep, well drained soils with other hardwoods. Stumps of freshly cut seedling and sapling white ash exhibit vegetative reproduction, growing several stems from the same root system (Schlesinger, 1990).

White ash trees have been a popular source of wood for the American lumber industry for use in baseball bats, furniture, flooring, doors, and cabinetry. The EAB epidemic, as a major scale case of environmental degradation, has impaired human use of Ash trees. In the face of the EAB outbreak Ash timber production has seen a dramatic dip, resulting, for example in 60% reduction in baseball bat production (Fitzpatric, 2019). The cultural impact of tree death goes deeper than the American mainstream—ash features prominently in American indian mythology and is a staple product in traditional dyes, cradle boards, snowshoes, and baskets. The loss of mature ash trees, as in Southern Michigan where white ash mortality reached over 99%, is already eliminating the possibility of cultural practices for a generation of Americans.

Compounding this cultural threat, ash death may pose a broad scale public health risk. As the death of millions of ash trees release CO2 into the atmosphere, and reduce the carbon storing potential of forests, the epidemic has been linked with an increase in cardiovascular and lower-respiratory-tract illnesses (Donovan, Geoffrey et. al. 2013). A 2013 study found that in the 15 states then affected by EAB, 6,100 to 15,000 human deaths were attributable to the air quality impact of ash tree loss.

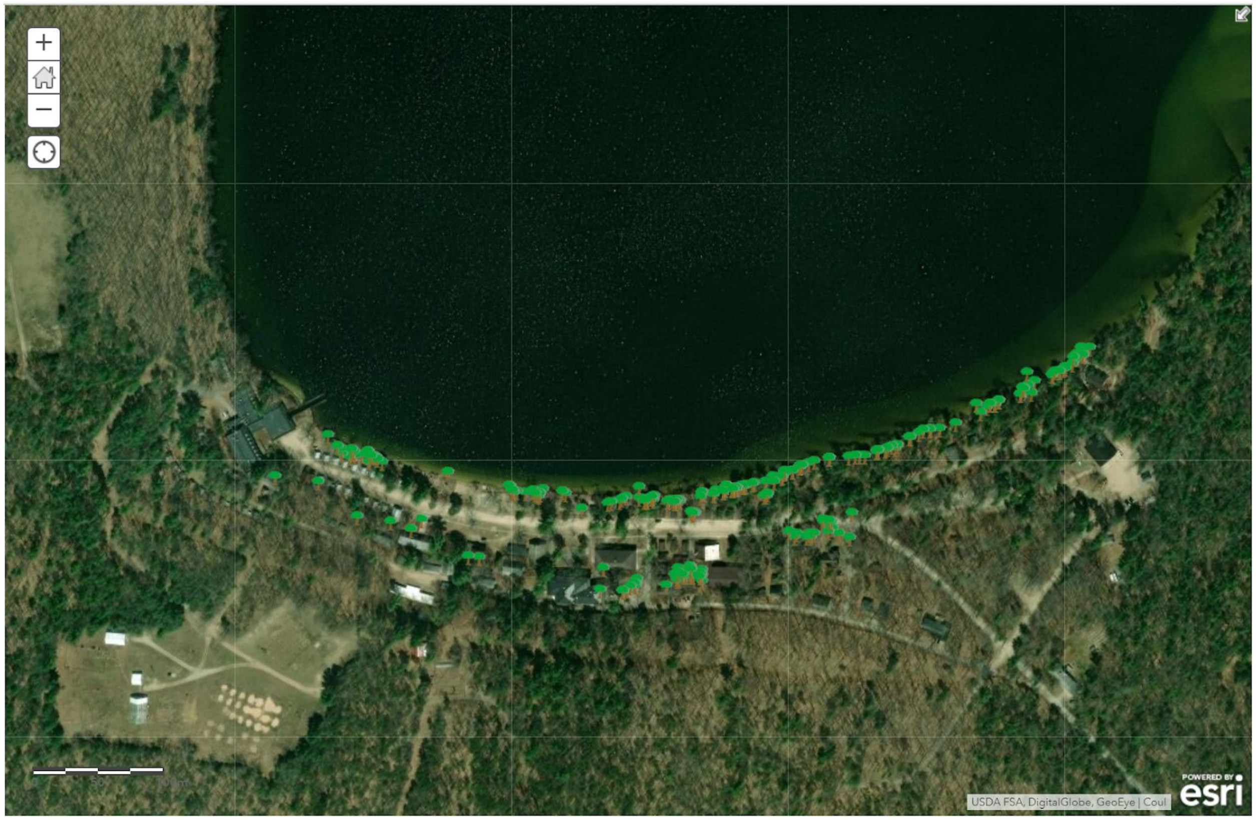
Understanding the recovery of ash trees in the wake of this loss will be key to projecting the future of ash trees in North America. In Michigan, the epicenter of the EAB dispersal, the seedlings of white ash trees are beginning to grow back. Our research aims to answer the question: How are ash trees recovering in the wake of EAB infestation on the UMBS main campus and how can UMBS management take steps to mitigate the loss of ash populations on their campus in the future?

Materials and Methods

Our investigation consisted of two parts. The first was an assessment of the health of the trees. The health of the trees was considered and analyzed in order to provide recommendations on treatment for EAB infestation. Height, diameter at breast height (DBH), and a ranking of infestation. The second was a survey of *Fraxinus sp.* for an ArcGIS map of the lake shore as well as plots on The University of Michigan Biological Station campus.

A 15m clinometer was used to measure the height of the trees. A second measurement taken for tree size was the DBH. DBH was measured using a metric DBH tool. Once a tree was measured it was tagged with a reference number, and the tree was classified as either living, infested, or dead. All information was then synthesized into a GIS map.

The coordinates of each tree were recorded with mobile phones using ArcGIS Collector and ArcGIS Classic. ArcGIS for desktop was used to add DBH, height, and infection status to each tree's coordinates using the reference number for the values recorded in the field.



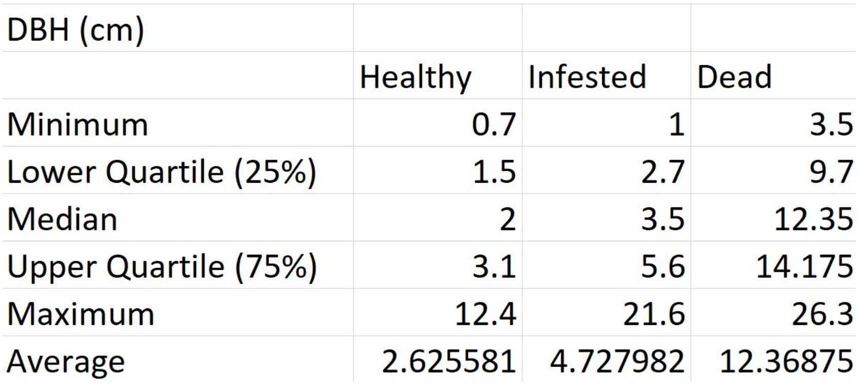
Screenshot of GIS map showing location of Fraxinus spp. *on UMBS property.*

Our research group broke into two teams. One team flagged and numbered trees, the second team measured and recorded data about the trees. After writing down the relative location, marking the tree on the map, and recording the information about DBH and height, the second group moved on. All members of the group were responsible for mapping coordinates of trees once all data were recorded.

Results

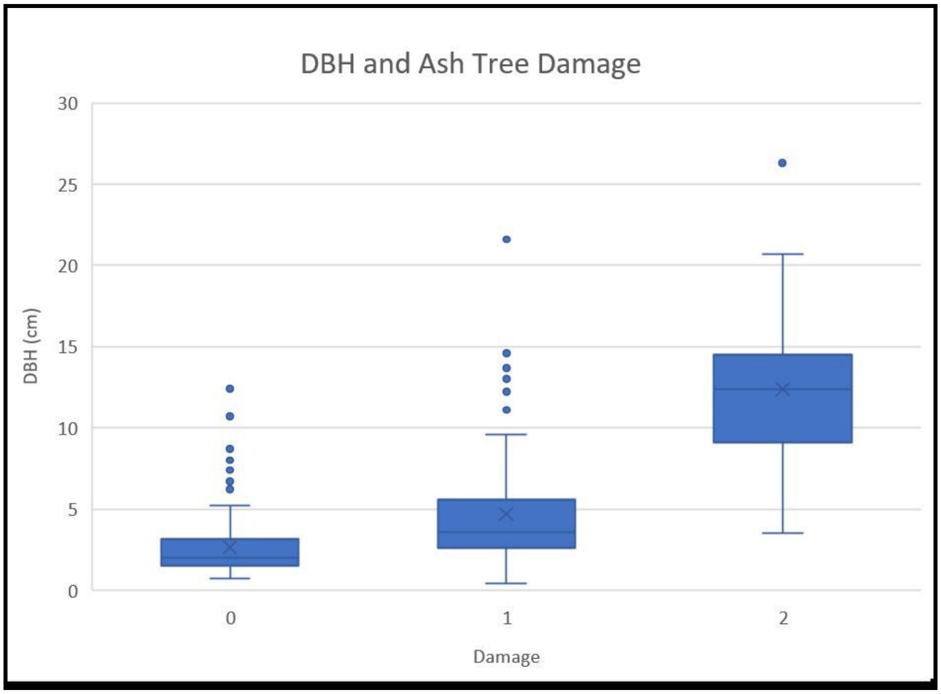
The survey of *Fraxinus spp.* showed the highest proportion of trees in the survey area were healthy (50.6%), followed by infested (43.1%) and dead (6.3%). The average DBH measurements were 2.62 cm, 4.73 cm, and 12.37 cm for healthy, infested, and dead trees respectively.

The upper quartile of DBH for healthy trees was found to be 2.7 cm, while the lower quartile for infested trees was 3.1 cm. Showing a crucial cutoff point for infestation somewhere in the range.



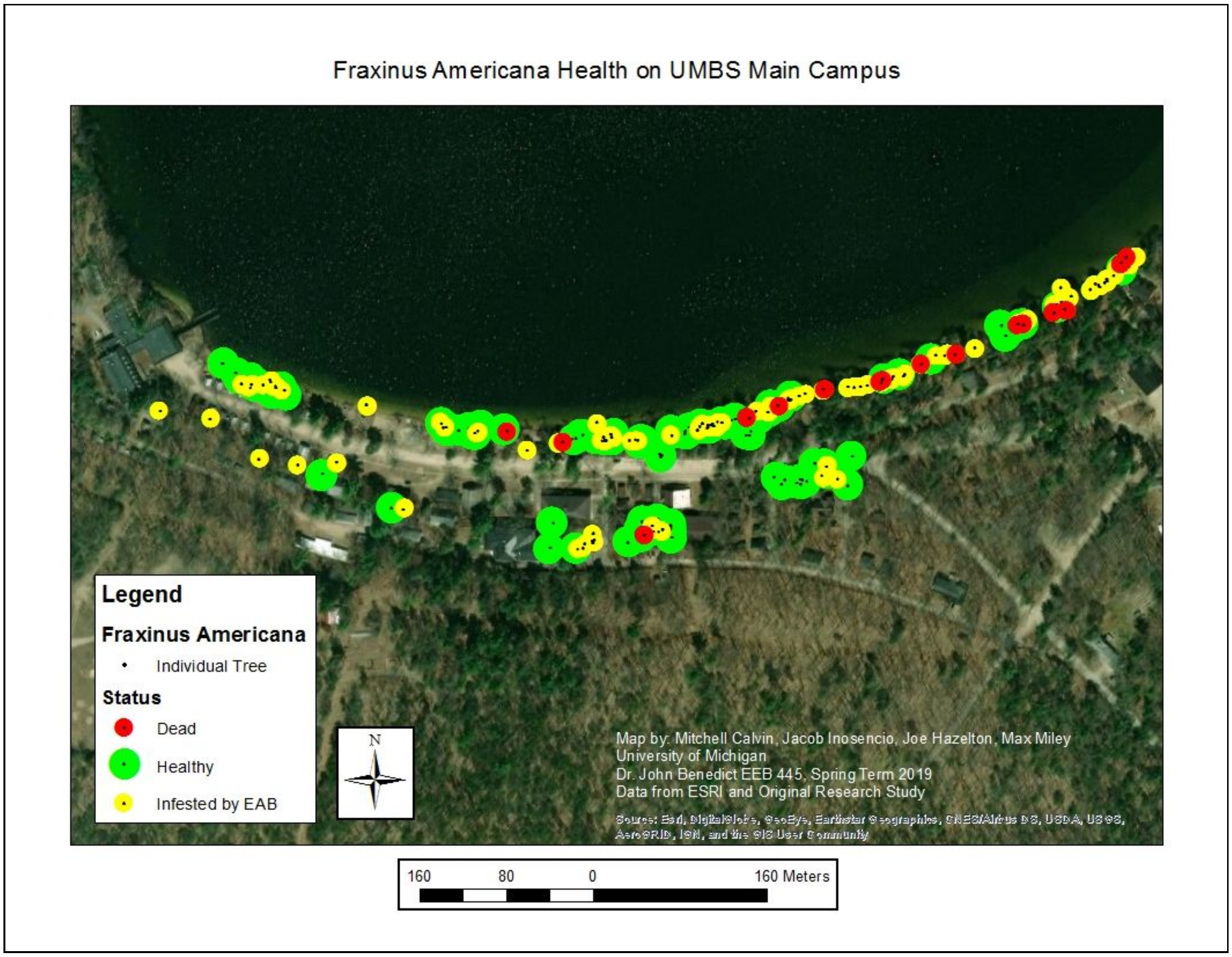
DBH (cm)			
	Healthy	Infested	Dead
Minimum	0.7	1	3.5
Lower Quartile (25%)	1.5	2.7	9.7
Median	2	3.5	12.35
Upper Quartile (75%)	3.1	5.6	14.175
Maximum	12.4	21.6	26.3
Average	2.625581	4.727982	12.36875

Chart of DBH statistics for each infestation status.



Boxplot of DBH for each level of affectedness. (0 = healthy, 1 = infested, 2 = dead) R=.553; p-value < 0.00001

A visual map of *Fraxinus spp.* location and infestation status was produced showing the distribution of trees along the shore of Douglas Lake and somewhat inland into UMBS campus. We observed a much higher concentration of trees near the water, as expected due to *Fraxinus'* propensity to grow in wet conditions. It also appears that some of the inland groves are less affected.



Map by: Mitchell Calvin, Jacob Inosencio, Joe Hazelton, Max Miley
University of Michigan
Dr. John Benedict EEB 445, Spring Term 2019
Data from ESRI and Original Research Study

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Screenshot of GIS map showing location of Fraxinus spp. *on UMBS property, including infestation status.*

Tree Health			
	Healthy	Infested	Dead
n	129	110	16
% Abundance	50.6	43.1	6.3

General distribution of infestation status among all trees surveyed.

Discussion

The annihilation of ash trees (*Fraxinus sp.*) in North America by the emerald ash borer since 2001 has drawn the attention of countless studies determined to mitigate the spread and impact of the EAB in this region (Herms & McCullough, 2014). Ash trees with a DBH of larger than 2.5 cm are susceptible to colonization by the EAB, of which 99% have been killed in regions near the epicenter in southeast Michigan (Herms & McCullough, 2014). The data collected in this survey which show a significant correlation between DBH and infestation is supported by similar trends in literature (Herms & McCullough, 2014). The main campus at the University of Michigan Biological Station has an above-average percentage of healthy *Fraxinus*, compared to other state-wide surveys (Robinett & McCullough, 2018). However, various white ash (*Fraxinus americana*) stands have been reported as unusually resistant to the EAB invasion, despite over a decade of borer activity in the area, though the mechanisms for this resistance is unknown. The entirety of the current survey found white ash and no other *Fraxinus* species, and thus follows this observed, state-wide unusual trend. Though it is noted that many mature ash trees have been compromised, there are abundant young white ash trees still within the area surveyed. For specificity, white ash are the focus of this investigation into control interventions against the EAB. Two main types of control methods have been assessed and implemented since 2001 (classical biological control and insecticidal control), with a third, supplemental method providing an aid to reduce the spread of EAB (girdling) (Duan et al., 2019; Duan et al., 2017; Duan et al., 2018; Flower et al., 2015; Herms & McCullough, 2014; McCullough et al., 2011; McCullough et al., 2016; Yang et al., 2018).

Classical Biological Control

Classical biological control of the EAB includes natural predators, such as woodpeckers and parasitoids (Robinett & McCullough, 2018). Though there are native hymenopteran parasitoids which interact with native North American beetles of the genus *Agrilus*, these native parasitoids have had very little impact on the spread of the EAB (Duan et al., 2017). It has been proposed to introduce non-native hymenopteran parasitoids of the emerald ash borer to successfully inhibit the maturation of EAB eggs (Herms & McCullough, 2014). Three Asian species of Hymenoptera are currently being bred and released: *Oobius agrili*, *Tetrastichus planipennisi*, and *Spathius agrili* (Herms & McCullough, 2014). Herms & McCullough (2014), Duan et al. (2017), and Duan et al. (2018) all found that *T. planipennisi* is an extremely effective parasitoid of the EAB, killing up to 80% of borer larvae; the two latter studies were notably done in the state of Michigan. This is compared to a less than 20% mortality rate of EAB from native parasitoids or woodpeckers in trials without non-native parasitoids (Duan et al., 2017). Duan et al. (2019) also found *O. agrili* and *S. galinae* to produce effective mortality of the EAB, though the results were less significant than those of *T. planipennisi* trials.

While these parasitoids have proven to be an effective control mechanism for the EAB, an ecological consideration when introducing species into a non-native habitat is its impact on non-target species. Recent studies have found that *T. planipennisi* is specifically attracted to volatiles from ash trees, and the level of attack on non-ash feeding *Agrilus* species is limited to none (Duan et al., 2018). Comparatively, *S. agrili* and *O. agrili* have been seen to attack some North American species of *Agrilus* (Duan et al., 2019; Yang et al., 2008). Additionally, *T. planipennisi* has been found to be especially successful at parasitising EAB in young ash trees (2.5-8.0 cm DBH) whose bark is thin and unlikely to impede oviposition, or in areas where EAB density is low (Herms & McCullough, 2104).

Insecticidal Control

Historical use of pesticides for EAB control include neonicotinoids, though more recently other compounds have been developed specifically for use on the EAB (Herms & McCullough, 2014). Neonicotinoids were shown to be a minimally effective mechanism for control against EAB, contributing to <10% mortality of EAB larvae (McCullough et al., 2011).

There is overwhelming evidence that insecticides with the active ingredient emamectin benzoate consistently produce high levels of EAB mortality (90-100%) in treated ash trees (Flower et al., 2015; Flower et al., 2014; McCullough et al., 2015; McCullough et al., 2011). This is due to a high translocation capacity of emamectin benzoate within the xylem of ash trees, making the foliage highly toxic quickly (McCullough et al., 2011). Emamectin benzoate is especially effective in populations of ash trees with low EAB density, making its use at UMBS attractive.

Another attractive attribute of emamectin benzoate is its treatment period. Most other insecticides used to control EAB colonies require annual application, while emamectin benzoate is only required once every three years (McCullough et al., 2015). The application schedule of emamectin benzoate reduces cost and environmental exposure to the pesticides.

Girdling and Treatment Combinations

Many studies have proposed using both biological control, insecticides, and a third method, girdling the ash trees, to maximize the effectiveness of control treatments (Herms & McCullough, 2014). McCullough et al., (2016) found that girdling, or removing a layer of bark around the entire tree, does not impede the translocation of insecticides. Using these techniques in tandem produces a “trap tree,” where the damage from girdling attracts the EAB, which subsequently perish from the insecticide (McCullough et al., 2016). Additionally, due to the different modes of reproduction, introduced parasitoids are not affected by the levels of insecticide required to kill EAB colonies (McCullough et al., 2015). Though the biological and insecticide control methods may be redundant, McCullough et al. (2015) note that the insecticide-treated trees allow the introduced parasitoid species to propagate and further aid in limiting EAB spread.

In the Case of UMBS

Much research has been done on protection of small to medium ash trees (8.7-12.1 cm DBH), though in the current survey, only three healthy ash trees identified had >8.7 cm DBH. Thus, immediate actions should be focused on ash sapling (2.5-5.8 cm DBH) protection, which consists of 40 healthy trees in the survey area. An additional 80 healthy trees <2.5 cm DBH were found in the survey which will soon be susceptible to EAB infestation. These trees in particular should be monitored annually without insecticide action until the DBH is within range of the EAB's preferred tree width.

For those trees which have DBH measurements greater than 2.5 cm, the most supportive direction of action through a literature review show that specific, healthy, medium to large trees (>5 cm DBH) should be treated with insecticides which include emamectin benzoate. Additionally, because it has specifically been tested for effectiveness in the region, and if an ecological impact assessment deems the UMBS environment well-suited, the non-native parasitoid *T. planipennisi* may be an effective suppressor of EAB populations. While the current size of ash trees on UMBS property are not very large, girdling may be an effective technique used in the future, especially if EAB populations show signs of growing in the area.

Many of the trees in the current survey were found on the shoreline of Douglas Lake, and therefore may not be ideal candidates for insecticide use due to the possible introduction of chemicals into an aquatic environment, though no studies were found which consider application of insecticides on lakeshore *Fraxinus* species.

Conclusion

To assess the quantity of ash trees in a given area for our map, information about each tree (height, DBH, and damage level) were recorded. This will allow future teams of researchers to use the locations of the trees, coupled with our findings on treatment and emerald ash borer prevention options, to ensure ash survival for future generations. Assessing the age of new young trees and cross-referencing that information with age of trees at time of infestation and time of death allows us to better recommend treatment plans. Including the age of the new growth gives treatment teams the tools they need to implement the plans.

We ask that this research is continued annually to reach a decision on treating EAB infestations, and that further surveys are conducted to broaden the scope of data spatially.

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