Stand- and Local-Level Analysis of Spreading Pattern of Oak Decline Using Aero Photos

Stand- and Local-Level Analysis of Spreading Pattern of Oak Decline Using Aero Photos

Naoto KAMATA[1*], Kojiro Esaki[2], and Mamoru Kubo[3]

[1] Department of Biology, Faculty of Science, Kanazawa University
Kakuma, Kanazawa 920-1192 Japan
[2] Ishikawa Forest Research Station
San-no-miya, Tsurugi, Ishikawa 920-2114 Japan
[3]Department of Information and Systems Engineering
Faculty of Engineering, Kanazawa University
2-40-20 Kodatsuno, Kanazawa 920-8667 Japan
*corresponding author: +81-76-264-5708, email: kamatan@kenroku.kanazawa-u.ac.jp

Key words: Oak dieback, Spreading pattern, Aero photo, Stratified diffusion model, Biological invasion

Abstract

Since the late 1980s, deciduous oak dieback has been prevalent in Japan. An unidentified ambrosia fungus, genus *Raffaelea*, is the causal agent in oak dieback. A symbiotic ambrosia beetle, *Platypus quercivorus* (Murayama) (Col.: Platypodidae) is the vector of this fungus. First, we summarized the spreading pattern of the dieback at nationwide level and at a forest stand level. Then, we analyzed a local-level pattern of the spreads by using aero photos. At a nation level, the spreading pattern of oak dieback showed the typical pattern of biological invasion: the incidence of oak dieback spread concentrically from the source population, which supported the hypothesis that the *Raffaelea* sp.-*P. quercivorus* was an invasive pest to this area. At a local level, oak dieback spread by a combination of long-distance dispersal and diffusion. At a stand level, the incidence of the dieback started to occur at mountain ridge then spread downwards along slopes because *P. quercivorus* has a habit to aggregate near mountain ridge or upper edge facing roads.

1. Introduction

Biological invasion have caused forest decline in many places in the world: the chestnut blight, gypsy moth in the North America, the Dutch elm disease in Europe, the pinewood nematode in Asia. Deciduous oak dieback in Japan has been known since the 1930s but in the last 10 years epidemics have intensified and spread into new west coastal areas [9]. An unidentified ambrosia fungus, genus *Raffaelea*, is the causal agent in oak dieback [Takanori KUBONO Pers. Comm.]. A symbiotic ambrosia beetle, *Platypus quercivorus* (Murayama) (Col.: Platypodidae) is the vector of this fungus. Although related beetles generally attack stressed trees, *P. quercivorus* attacks and kills vigorous trees. This is the first example of an ambrosia fungus carried by an ambrosia beetle that kills vigorous trees [7]. Although 45 species among 27 genera in 17 families of woody plants have been recorded as host plants of *P. quercivorus* [8, 18, 19, 21], woody plants belonging to the Fagaceae family are considered as an essential host of *P. quercivorus* because the beetle attack density was high on trees of the Fagaceae family but low on trees belonging to other families [8, 21]. There are many records of *P. quercivorus* outbreaks in evergreen oak stands in Japan, but few

evergreen oak trees were killed by this beetle even though many entry holes were found on the trunk surface [17, 21, 22, 23]. In Ishikawa, the mortality was ca. 40% for *Quercus crispula* but low for other concurrent Fagaceae species even though each species received a similar number of beetle attacks [12, 13]. Trees other than *Q. crispula* proved to be resistant to *Raffaelea* sp. The beetles showed the least preference for *Q. crispula* but they had their highest reproductive success in this species [13, 14]. Since these beetles can realize a higher reproduction rate on *Q. crispula*, the beetles can spread more rapidly in stands with a high composition of *Q. crispula* [13]. This situation, similar to an exotic pest introduced into a new environment, results in higher insect performance than on the original host. Among the Fagaceae species found in our research plots in Ishikawa, *Q. cripsula* is distributed in the coolest places [16]. Platypodids are abundant in tropical and subtropical regions [1, 2, 10, 11, 15]. *Platypus quercivorus* is also distributed in S to SE Asia, Taiwan, and the Japanese Archipelago [18, 19]. Japan is the northernmost region of the *P. quercivorus* distribution. Oak dieback occurs in the northern/high margins of the *P. quercivorus* distribution and in the southern/low margins of *Q. crispula* distribution. Oaks other than *Q. cripsula* are resistant to *Raffaelea* sp. probably because a stable relationship has been formed among these tree species, the fungus, and the insect in a long evolutionary process. *Quercus crispula* was probably left out of the coevolution [13].

In this paper, we analyzed three different levels of spreading pattern of oak dieback: nationwide, local and stand levels.

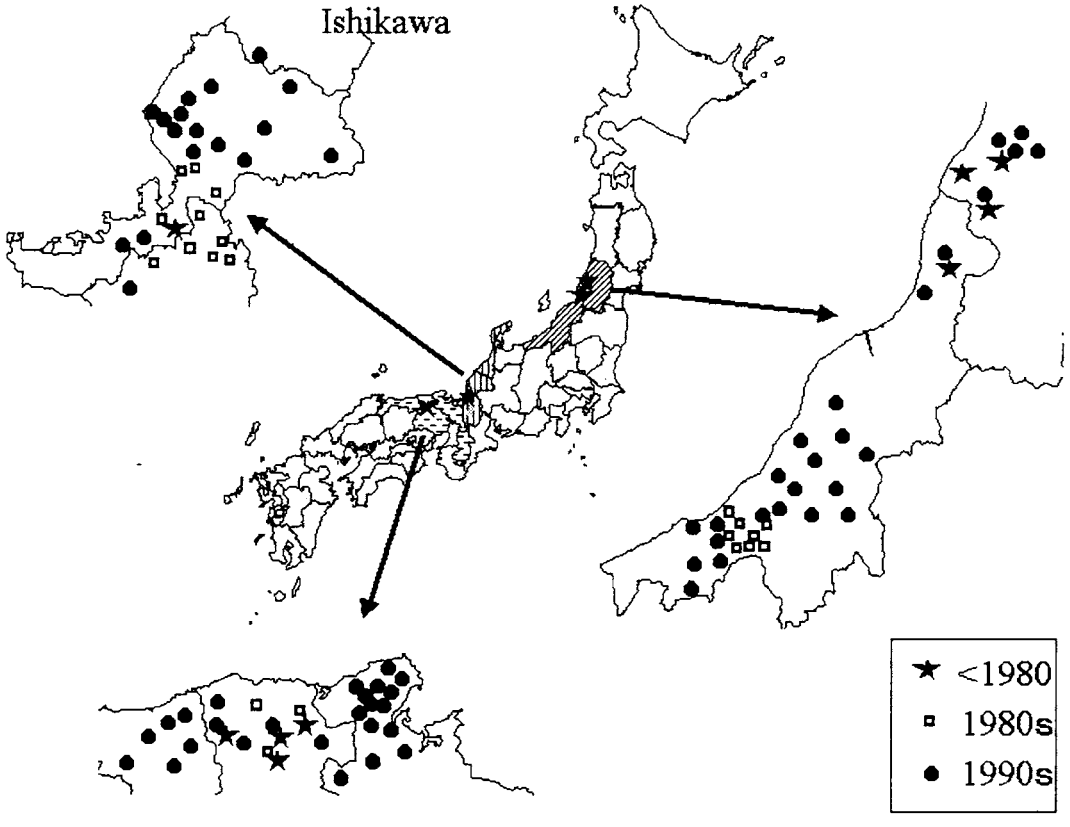

Fig. 1 Locations of incidence of oak dieback caused by *Raffaelea* sp. carried by *Platypus quercivorus*. [9].

2. Nationwide Level of Oak-Dieback Spreads

Since the late 1980s, deciduous oak dieback has been prevalent in Japan [9]. Oak dieback has been recorded since the 1930s, but up to 1980, the epidemics continued for only a few years in several areas on the west side of Japan (fig. 1). More recently, the epidemics have continued for more than 10 years, and the area of dieback has been spreading to new places where no dieback had been recorded in the past (fig. 1). The spreading pattern of oak dieback shows the typical pattern of biological invasion: new incidence of oak dieback spread concentrically from the source population [3, 20]. Considering the distribution of this insect and the results of preference-performance relationship of *P. quercivorus* at a tree species level, *P. quercivorus* was native in Japan but does not seem to be native in the places where the oak dieback is prevalent. The insect was probably introduced from the Kyushu Island, southernmost main island of Japan, and/or foreign countries by transportation of logs.

3. Stand Level Dynamics of *P. Quercivrus* Infestation

Because adult beetles tend to move upward along slopes and show positive phototaxis, the highest concentration of flying beetles usually occurs at the forest edge or at the edge of forest gaps [4,5]. The patterns of incidence of newly infested trees were as follows [4]: The infestation starts around the trees attacked in the previous year. With increasing density, it spreads out as concentric circles from the epicenter, which is formed near the upper forest edge fronting a road or mountain ridge (fig. 2). The occurrence of newly infested trees proceeded downwards along the slopes in the opposite direction to adult movement. Adult beetles select specific species of host trees but do not discriminate among trees of the same species [12]. They attack both healthy and weakened trees, and susceptible and resistant trees without any discrimination.

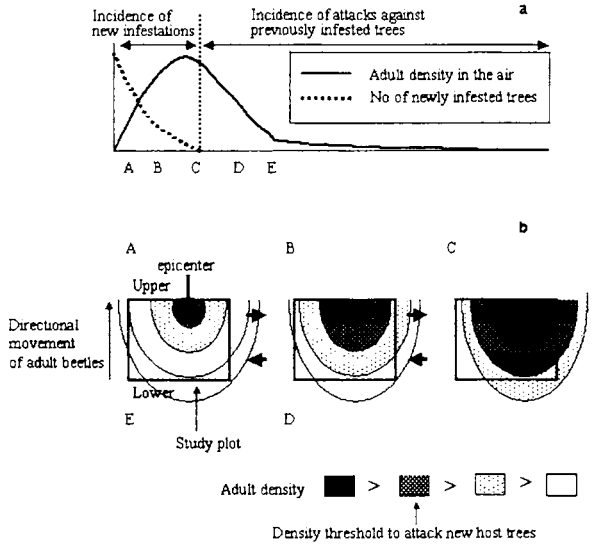

Fig. 2 Temporal and spatial models of directional movement and spatial distribution of *Platypus quercivorus* adults, and the incidence of new infestations. [5].

The total number of new entry holes of *P. quercivorus* on each tree and the reproductive success of this beetle was significantly affected by the infestation history of the tree up until the previous year, but it was not affected by whether the tree was alive or dead. Smaller numbers of *P. quercivorus* attacked trees that had been previously infested [12]. They could not reproduce at all on trees that were infested from the previous year [14]. The necrosis caused by *Raffaelea* sp. is likely to make the tree become an unsuitable substrate for ambrosia fungi and/or for *P. quercivorus* [6, 14]. Trees that were infested from the previous years seldom die from this insect-fungus relationship, which is one of the major causes of the phenomenon that, at a stand level, the number of incidence of the dieback peaked in a few years after invasion then decreased.

Because the occurrence of infestation proceeded downwards along the slope, and because trees that were infested from the previous years seldom die from this insect-fungus relationship, the incidence of oak dieback spreads downwards along the slope year by year (fig. 3).

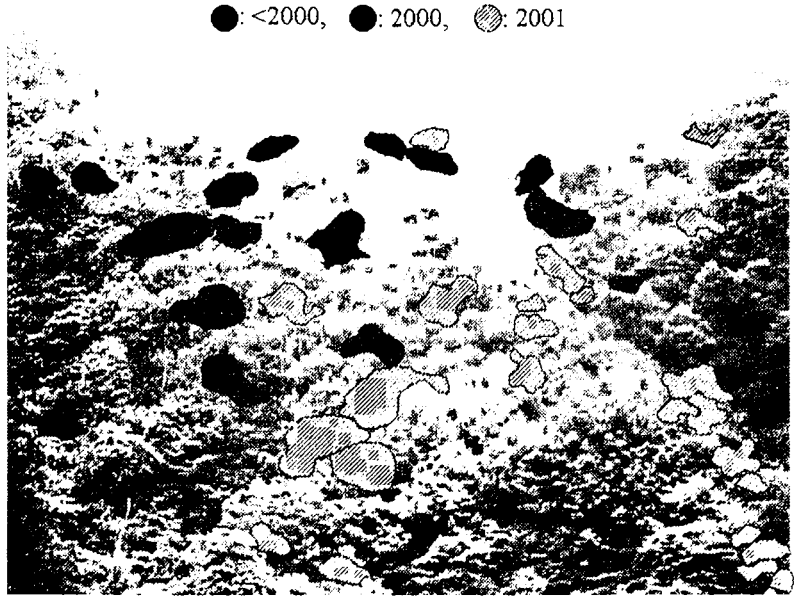

Fig. 3 Incidence of oak dieback proceeded downwards along the slope year by year.

4. Spreading Pattern of the Incidence of Oak Dieback at a Local Level

Figure 4A shows approximate range of areas that we investigated the local-level of a spreading pattern of the incidence of oak dieback and a location of the study plot in which we have investigated incidence of oak dieback at a stand level. Figures 4B-4E show the locations of individual oak tree that were killed by the insect-fungus relationship in each year of 1997-2000. In 1997, the oak dieback first spread along a mountain ridge (Fig. 4B), which seemed to be related to a habit of positive phototaxis of adult beetles and a habit flying upwards along slopes. In 1998, the pattern of stratified diffusion, a combination of diffusion and a long-distance dispersal from source populations, was recognized in the area (Fig. 4C): The occurrence of oak dieback spread downwards along a slope in some of the stands, in which oak dieback occurred in the mountain ridge in the previous year. The occurrence of oak-dieback also jumped into new places that were apart from the source populations. In 1999 and 2000, this pattern of stratified diffusion was more advanced (Fig.

4D, E). In 1999, incidence of dieback decreased in the places where the infestation started in 1997 but increased in the lower left portions of fig. 4. In 2000, incidence of dieback increased in the left portions and upper right of the fig. 4E where the dieback was not prevalent formerly. After the *P. quercivorus* invasion from Fukui Prefecture, the lower left portions of fig. 4, in 1995 or 1996, the oak dieback had become prevalent over the area in these 5 or 6 years.

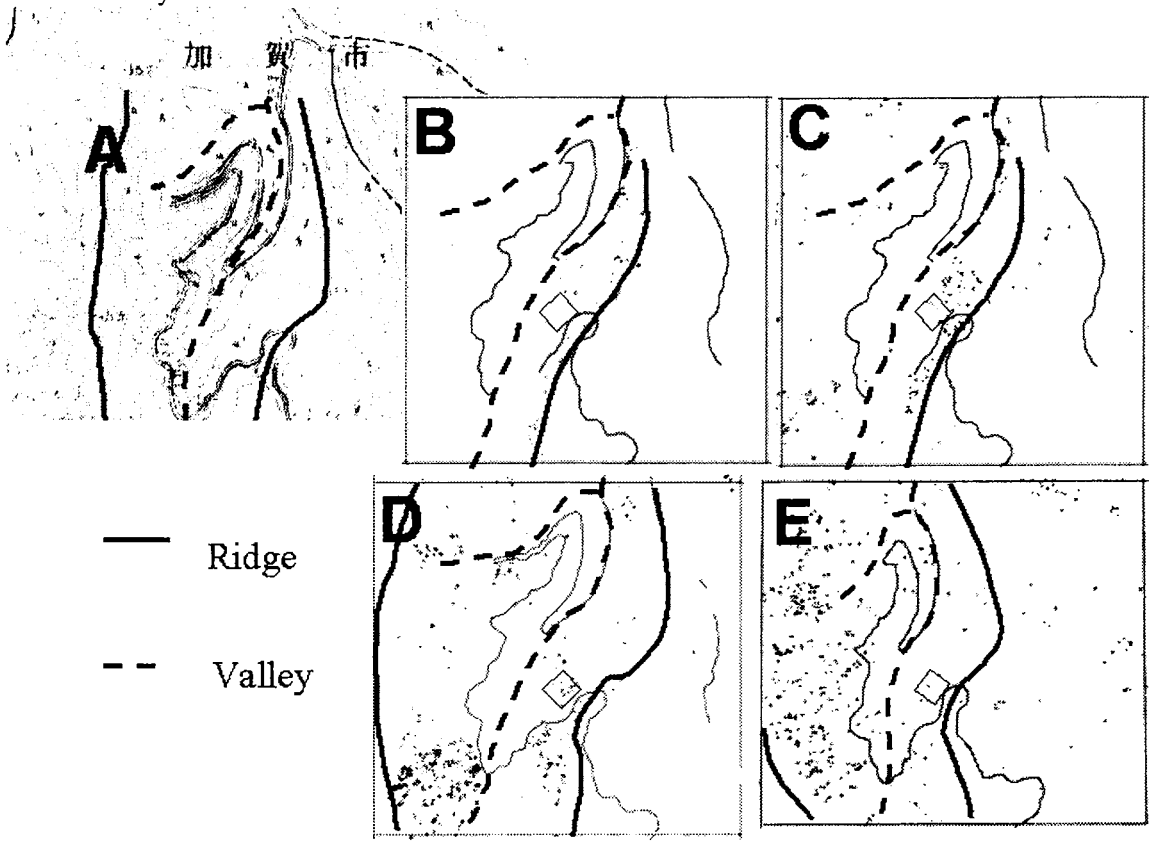

Fig. 4 Locations of incidence of oak dieback caused by *Raffaelea* sp. carried by *Platypus quercivorus* before 1980 (a) and after 1980 (b). [9].

5. Conclusions

At a nation level, the spreading pattern of oak dieback showed the typical pattern of biological invasion: the incidence of oak dieback spread concentrically from the source population, which supported the hypothesis that the *Raffaelea* sp.-*P. quercivorus* was not an exotic pest but new to this area. At a local level, oak dieback spread by a combination of long-distance dispersal and diffusion. At a stand level, the incidence of the dieback started to occur at mountain ridge then spread downwards along slopes because *P. quercivorus* has a habit to aggregate near mountain ridge or upper edge facing roads.

References

[1] R. A. Beaver, "Bark and ambrosia beetles in tropical forests," *Proceedings of*

Symposium on Forest Pests and Diseases in Southeast Asia, 20-23 April, 1976, Bogor, Indonesia. BIOTROP special publication no. 2, Regional Center for Tropical Biology. pp. 133-149, 1977.

[2] R. A. Beaver, "Host specificity of temperate and tropical animals," *Nature (London)* vol. 281, pp. 139-141, 1979.

[3] C. S. Elton, *The ecology of invasions by animals and plants.* London : Methuen, 181 p., 1958.

[4] K. Esaki, N. Kamata, K. Kato, "Stand level distribution and movement of *P. quercivorus* adults and patterns of incidence of new infestation," *Applied Entomology and Zoology*, submitted.

[5] Y. Igeta, K. Kato, K. Esaki, N. Kamata, "Influence of light condition on stand level distribution and movement of the ambrosia beetle, *Platypus quercivorus* (Murayama) (Col, Platypodidae) adults," *Applied Entomology and Zoology*, submitted.

[6] M. Inoue, S. Nishigaki, N. Nishi, "Attack by the oak borer, *Platypus quercivoms,* to living oak trees," *Applied Forest Science*, vol. 9, pp. 127-131, 2000 .

[7] S. Ito, T. Kubono, N. Sahashi, T. Yamada, "Associated fungi with the mass mortality of oak trees," *Journal of the Japanese Forestry Society*, vol. 80, pp. 170-175, 1998.

[8] S. Ito, A. Takeda, H. Kajimura, "Host plant species of the ambrosia beetle, Platypus quercivorus (Murayama) (Col, Platypodidae), in Japan," *Proceedings of the 49th Annual Meetings of Chubu Branch of the Japanese Forestry Society*, p. 16, 2000.

[9] S. Ito, T. Yamada, "Distribution and spread of mass mortality of oak trees," *Journal of the Japanese Forestry Society*, vol. 80, pp.229-232, 1998.

[10] L. G. E. Kalshoven, "Studies on the biology of Indonesian Scolytoidea. 1. *Xyleborus fornicatus* Eichh. As a primary and secondary shot-hole borer in Java and Sumatra," *Entomologische Berichten, Amsterdam*, vol. 18, pp. 147-160, 1958.

[11] L. G. E. Kalshoven, "Studies on the biology of Indonesian Scolytoidea. 7. Data on the habits of Platypodidae," *Tijdschrift voor entomologie*, vol. 103, pp. 31-50, 1960.

[12] N. Kamata, K. Esaki, K. Kato, "Stand-level dynamics of the ambrosia beetle, *Platypus quercivorus* and occurrence of oak dieback (III): Analysis of factors influencing tree mortality," *Proceeding of the 111th Annual Meetings of Japanese Forestry Society*, pp. 307-308, 2000.

[13] N. Kamata, K. Esaki, K. Kato, Y. Igeta, "Stand-level dynamics of the ambrosia beetle, *Platypus quercivorus* and occurrence of oak dieback (VII): Why oak dieback have been spreading since early '90s?" *Proceeding of the 112th Annual Meetings of Japanese Forestry Society*, pp. 276, 2001.

[14] K. Kato, K. Esaki, Y. Igeta, N. Kamata, "Preliminary report on comparison of reproductive success of *Platypus quercivorus* among four species of the family Fagaceae. *Chubu Forest Research* , vol. 49, pp. 81-84, 2001.

[15] L. R. Kirkendall, "Ecology and evolution of biased sex ratios in bark and ambrosia beetles (Scolytidae)," *Evolution and Diversity of Sex Ratio: Insects and Mites* (Eds. D. L. Wrensch, M. A. Ebbert). New York, Chapman & Hall, pp. 235-345, 1993.

[16] S. Kurata, *Illustrated Important Forest Trees of Japan. vol. 1-5.* Tokyo, Chikyu Shuppan, 1964-1976.

[17] K. Matsumoto, "An outbreak of *Platypus quercivorus* and the control," *Forest Pests*, vol. 4, pp. 74-75, 1955.

[18] A. Nobuchi, "*Platypus quercivorus* (Murayama) (Coleoptera, Platypodidae) attacks to living oak trees in Japan, and information of Platypodidae (I)," *Forest Pests*, vol. 42, pp. 85-89, 1993.

[19] A. Nobuchi, "*Platypus quercivorus* (Murayama) (Coleoptera, Platypodidae) attacks to living oak trees in Japan, and information of Platypodidae (II) ," *Forest Pests*, vol. 42, pp. 109-114, 1993.

[20] N. Shigesada, K. Kawasaki, *Biological invasions: theory and practice.* Oxford, Oxford University Press, 205 p., 1994.

[21] K. Sone, T. Ushijima, T. Mori, M. Ide, H. Umata, "Insidence and spatial distribution of trees infested by the oak borer, *Platypus quercivorus* (Murayama) (Coleoptera: Platypodidae), in a stand," *Bulletin of the Kagoshima University Foroests*, vol. 23, pp. 11-22, 1995.

[22] M. Sueyoshi, "The incidence of broadleaved trees attacked by *Platypus quercivorus* (Coleoptera : Platypodidae) (1)," *Forest Pests,* vol. 39, pp. 58-61, 1990.

[23] M. Sueyoshi, "The incidence of broadleaved trees attacked by *Platypus quercivorus* (Coleoptera : Platypodidae) (2). *Forest Pests,* vol. 39, pp. 242-245, 1990.