Rikunomizu (*Limnology in Tokai Region of Japan*) **74** : 23 - 28 (2016)

Report

Comparison of fish fauna in a river that received pyroclastic flow from the volcanic eruption of Mt. Ontake in 2014 with that in neighboring rivers

Yukio Onoda[1),3),4)] and Yuichi Kayaba[2)]

Abstract

Impacts of the 2014 eruption of Mt. Ontake on fish distribution were preliminarily evaluated by undertaking fish censuses in five streams near the mountain in 2015. The Nigorigawa River, which received pyroclastic flow, was used as an impact site. Another two rivers (the Shinokurosawa River neighboring the Nigorigawa and the Ohtakigawa River, which has confluence with the Nigorigawa) were used for evaluating whether the impacts extended beyond the Nigorigawa River. The other two rivers (the Shirakawa and Kurokawa), which received no pyroclastic flow from Mt. Ontake, were used as control sites. Fish censuses were conducted from September to November in 2015 by snorkeling for 5 to 50 minutes, according to observed fish density, the exception being the upstream site of the Ohtakigawa where collection was conducted for 5 minutes using a brail net. Approximately 1800 individual belonging to six taxa (Japanese charr, *Salvelinus leucomaenis*; red spotted masu trout, *Oncorhynchus masou ishikawae*; Japanese dace, *Tribolodon hakonensis*; Japanese fat minnow, *Rhynchocypris logowskii steindachneri*; juvenile cyprinidae; common freshwater goby, *Rhinogobius* sp.) were observed. Although no fish was observed at the Nigorigawa site or in the Ohtakigawa River downstream of its confluence with the Nigorigawa, the same absence of fishes had been reported before the eruption occurred. Additionally, the other censused sites, including those in the neighboring streams, contained some fishes, suggesting that the impacts of the eruption (if any) were locally limited. The fact that the Nigorigawa had previously experienced disturbance following a landslide suggests that mountain streams that have undergone disturbance once may tend to experience successive disturbances due to geomorphic changes such as valley deepening. Accordingly, even neighboring mountain streams may have contrasting disturbance regimes that influence the recovery of fish fauna from stream disturbances. Further studies involving large-scale and long-term surveys are necessary to accumulate data on the relationships between the presence/absence of fishes and water environments associated with disturbance.

Key words: fish assemblage, mountain stream, disturbance regime, refugia, spatial heterogeneity

(*Received*: *30 July 2016*; *Accepted*: *6 September 2016*)

Introduction

Volcanic eruptions are among the largest and most broad-scale disturbances, and assessing the associated destruction and recovery of ecosystems can provide opportunities for elucidating the important processes that determine the distribution of organisms. Accordingly, the effects and impacts of volcanic eruptions on ecosystems and organisms

[1)] Aqua Restoration Research Center, Public Works Research Institute, Kawashima Kasada, Kakamigahara, Gifu 501-6021, Japan
[2)] River Restoration Team, Water Environment Research Group, Public Works Research Institute, 1-6, Minamihara, Tsukuba, Ibaraki 305-8516, Japan
[3)] Mie University Research Center, 1577 Kurimamachiya, Tsu, Mie 514-8507, Japan
[4)] Mount Ontake Volcanic Eruption Research Group of *the Tokai Branch of the Japanese Society of Limnology* (with Drs. Kentaro Nozaki, Takashi Tashiro, and Tomomasa Taniguchi)

should be examined. In previous studies, the repercussions of such eruptions have been almost exclusively assessed in terrestrial ecosystems (Griggs, 1915; Yoshii, 1932; Yoshioka, 1966; Tagawa, 1989; reviewed in Tsuji and Kosugi, 1991; Nakashizuka *et al*., 1993; Hasegawa and Abe, 2006), with few surveys in aquatic ecosystems, particularly in Japan (but see Kimura *et al*., 1978; in addition to Newcomb and Flagg, 1983; Brusven and Horning, 1984; Martin *et al*., 1984). However, volcanic eruptions can also have impacts on aquatic organisms by causing changes in water quality, such as decreases in pH and increases in turbidity, due to inflows of tephra into streams and rivers (Stewart *et al*., 2006). For example, low pH and high turbidity can impact fish species in a number of ways, including perturbation of responses, such as avoidance behavior; reduced feeding and growth; immunological depression; and decreases in migration and reproductive success (for pH: Ishio, 1963; Ikuta, 1999; for turbidity: Japan Fisheries Resource Conservation Association, 1994; Waters, 1995). Of these reactions, the change in avoidance behavior is initially caused by moderate changes in pH and turbidity, and this may potentially change fish distribution (see Waters, 1995; Ikuta, 1999). Thus, impacts associated with volcanic eruptions can be examined by assessing changes in fish distribution (before–after design). In cases without data collection before eruptions, however, a viable alternative is to compare fish distribution among both impacted and non-impacted streams (control–impact design).

Mount Ontake, a volcanic peak locates on the border between Nagano and Gifu prefectures in central Japan, erupted on September 27, 2014 (see Oikawa *et al*., 2014; Iguchi and Nakamichi, 2015), and in this study we conducted a preliminary evaluation of the impacts of this eruption on aquatic organisms by comparing fish distribution among streams in the vicinity of the volcano.

Methods

Six sites were established in five streams to assess impacts of the eruption on fish distribution (Fig. 1). A site in the Nigorigawa River (st.1) was used as an impact site since this river received considerable amounts of pyroclastic flow following the eruption (Oikawa *et al*., 2014; Yamamoto, 2014). This was a consequence of the deepening of the valley of a tributary, the Denjogawa River, by land-sliding associated with an earthquake in 1984 (Nakamura *et al*., 1987). To assess the effects of the inflow, two sites (st. 2 and 3) in the Ohtakigawa River were located downstream and upstream, respectively, of its confluence with the Nigorigawa. A site in the Shimokurosawa River (st. 4)

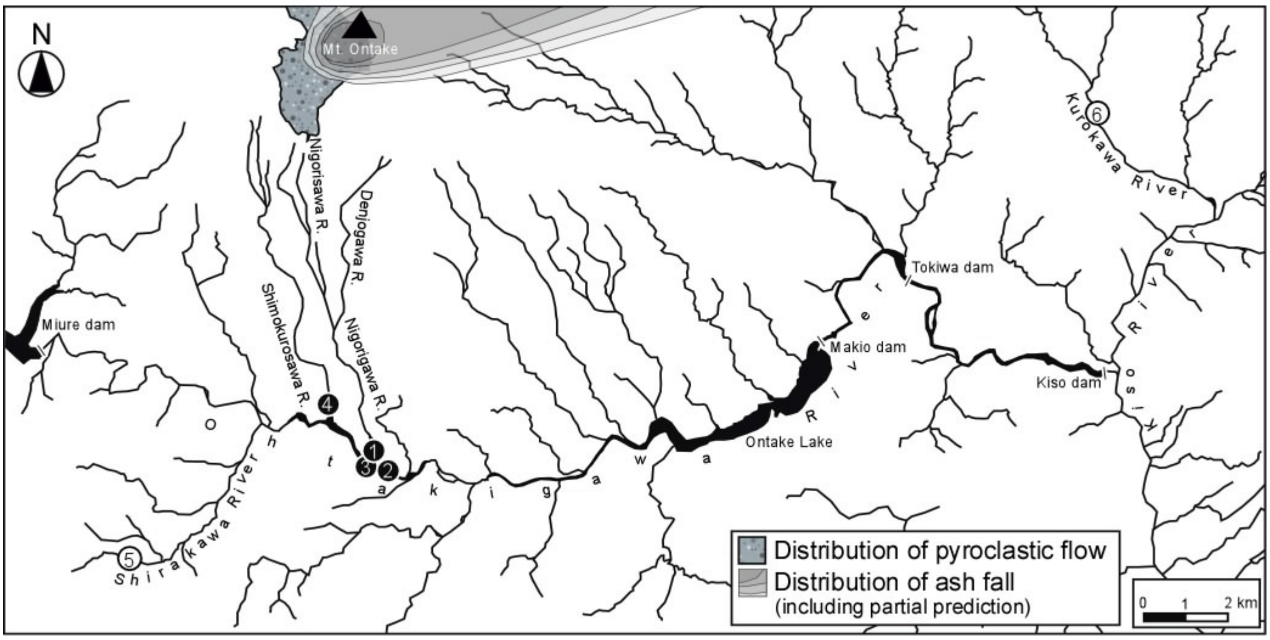

Fig. 1. Study sites and streams around Mt. Ontake. Filled and open circles indicate potentially impacted (Nos. 1–4, with inflow from southern side of Mt. Ontake) and reference (Nos. 5 and 6) sites, respectively. The distribution of pyroclastic flow and ash fall was redrawn from Iguchi and Nakamichi (2015).

was used to examine whether the eruption (pyroclastic flow, in particular) also has impacts on neighboring rivers. These four sites could potentially have been impacted by pyroclastic flow because they are located on the southern side of Mt. Ontake, parts of which experienced heavy pyroclastic flow (Oikawa *et al*., 2014; Yamamoto, 2014). Sites in the Shirakawa River (without inflow from Mt. Ontake) and Kurokawa River (on the western side of Mt. Ontake) (st. 5 and 6, respectively) were used as reference sites, since they were likely to receive little pyroclastic flow. In each of the six sites, a study section was established to include one or more of pool-riffle sequences, so as to potentially encompass all species within the reach.

Fish censuses were performed in all sections from September to November in 2015 by snorkeling for 5 to 50 minutes according to observed fish density and river width; the exception being st. 3, at which collection was performed for 5 minutes using a brail net. Numbers of individuals in fish schools, which consisted mainly of juveniles, were approximately estimated to the nearest ten or hundred. Fish species were identified as accurately as possible, with the exception of *Rhinogobius* sp. and juveniles of cyprinidae fishes, which are difficult to identify in water. Scientific and English names of fishes follow those of Nakabo (1993) and Yuma *et al*. (1998), respectively. Observed numbers were divided by searching times to convert counts into counts per unit effort (CPUE) as relative density. This was done because the area searched, which was inconsistent during the study period, is unsuitable for calculating relative density.

Results

A total of approximately 1800 individuals belonging to six taxa (Japanese charr, *Salvelinus leucomaenis*; red spotted masu trout, *Oncorhynchus masou ishikawae*; Japanese dace, *Tribolodon hakonensis*; Japanese fat minnow, *Rhynchocypris logowskii steindachneri*; juvenile cyprinidae; common freshwater goby, *Rhinogobius* sp.) were observed in this study (Table 1). Among the four sites located on the southern side of Mt. Ontake, no fish was observed in the Nigorigawa River (st. 1) or at the site in the Ohtakigawa River downstream of its confluence with the Nigorigawa (st. 2), whereas some fishes were observed in the Shimokurosawa River (st. 4) and in the Ohtakigawa site upstream of its confluence with the Nigorigawa (st. 3). The other two sites (st. 5 and 6) without inflow from the southern side of the mountain also contained some fishes. Although the Kurokawa site contained a greater number of fishes compared to those at the other sites, most of them were mainly consisted of juvenile cyprinidae, Japanese fat minnow, and common freshwater goby, which tend to be distributed further downstream than the red spotted masu salmon (Niwa, 1954). Thus, the relative density of the other species at the Kurokawa site was similar among all the sites where fishes were observed.

Discussion

Estimation of impacts of the eruption on fishes

The findings of this study indicate that the volcanic eruption of Mt. Ontake had little overall impact on fish distribution, and even if there were any impacts, these were likely to have been confined within narrow limits. Although the fact that no fish was observed at two sites [one in the Nigorigawa River and the other in the Ohtakigawa River downstream of its confluence with the Nigorigawa (Table 1)] might be indicative of an impact caused by the eruption, a similar distribution pattern of fishes had been reported under undisturbed conditions (Niwa, 1954; Takeda, 1985; Nagano Prefecture, 2011), probably because of the peculiar water quality, such as low pH, high turbidity, and iron-rich water (Tomatsu *et al*., 1994; Nagano Prefecture, 2011). Accordingly, the absence of fishes in the two aforementioned sites is not necessarily a consequence of the volcanic eruption. Moreover, even if the eruption did have effects on fishes, it may not have led to the disappearance of fishes from the sites. Additionally, neighboring sites (in the Shimokurosawa River and the Ohtakigawa River upstream of it confluence with the Nigorigawa River) had some fishes, suggesting that impacts of the eruption are unlikely to have been wide-ranging. However, the possibility of impacts caused by pyroclastic inflow from the Nigorigawa through diffusion to more downstream sites was not examined in detail in this study. To comprehensively examine the impacts of the eruption on fishes, extensive surveys of fish distribution along the Ohtakigawa will be necessary.

Significance of control sites and pre-disturbance data

Establishment of appropriate control sites and collection of pre-disturbance data are necessary for an accurate assessment of ecological impacts. The present study attempted to evaluate the impacts of volcanic eruption based on only limited data. For example, the two site in the

Table 1. List of observed fishes at the sites regarded as potentially impacted and reference sites.

Site no.[*1]	Observation		Species	Observed number and (CPUE[*2]/10 min.)	
	Date in 2015	Time (min.)			
Impact					
1	Oct. 9	5		0	(0)
	Oct. 10	30		0	(0)
2	Oct. 10	30		0	(0)
3	Nov. 29	5	*Rhynchocypris logowskii steindachneri*	1	(2.0[*3])
4	Sep. 6	10	*Salvelinus leucomaenis*	2	(2.0)
			Oncorhynchus masou ishikawae	3	(3.0)
			Tribolodon hakonensis	2	(2.0)
	Oct. 8	35	*Salvelinus leucomaenis*	9	(2.6)
			Rhynchocypris logowskii steindachneri	1	(0.3)
Reference					
5	Oct. 9	20	*Salvelinus leucomaenis*	2	(1.0)
6	Sep. 8	40	cyprinidae juvenile	1000	(250.0)
			Rhynchocypris logowskii steindachneri	27	(14.3)
			Oncorhynchus masou ishikawae	2	(0.5)
			Salvelinus leucomaenis	2	(0.5)
			Rhinogobius sp.	1	(0.3)
	Oct. 9	50	*Rhynchocypris logowskii steindachneri*	700	(140)
			Tribolodon hakonensis	6	(1.2)
			Oncorhynchus masou ishikawae	11	(2.2)
			Salvelinus leucomaenis	1	(0.2)
			Rhinogobius sp.	1	(0.2)

[*1] Detailed information on the sites is presented in the text and figure 1.
[*2] Counts per unit effort
[*3] No. of fishes caught using a hand net.

Shirakawa and Kurokawa rivers might not be appropriate as control sites. Given the fish fauna recorded in this study (Table 1) and by Niwa (1954), the Shirakawa site with only Japanese charr may be too far upstream or too far from the confluence of this river with the Ohtakigawa, whereas the Kurokawa site with common freshwater goby and many juvenile cyprinidae may be too far downstream to serve as a suitable control site. However, in this study, we identified different patterns of fish distribution among four sites (st. 1–4), which were initially assumed to have been impacted by the eruption because of their location. Therefore, the results of this study suggest that impacts, if any, were not extensive. Establishing suitable control sites, which have conditions similar to those of the impacted site, with the exception of water quality characteristics associated with volcanic eruptions, will make it possible to assess the impacts more precisely.

Further, collecting pre-disturbance data is essential when attempting to detect impacts using a before–after design. For example, in the present study, the fact that no fish was observed at the site in the Nigorigawa River and the site in the Ohtakigawa River downstream of its confluence with the Nigorigawa should not be interpreted as an impact of the eruption, because previous studies had shown that there had been no fish at these sites prior to the eruption (Niwa, 1954; Takeda, 1985; Nagano Prefecture, 2011). Without this knowledge, the observations made in this study could easily have led to a contrasting conclusion. Although pre-disturbance data is therefore essential for evaluating the impacts of disturbance, these data are not always available due to difficulty in predicting the occurrence of large-scale disturbances like volcanic eruptions. In the event of such cases, it will be useful to compile recent fish distribution data by integrating the substantiated records of fishes caught by individual fishermen (e.g., Niwa, 1954; Yamamoto, 2000) and data obtained in previous studies (Niwa, 1954; Takeda, 1985; Kobayashi *et al*., 2004; Kitano *et al*., 2005).

Toward understanding the mechanisms maintaining fish fauna in mountain stream systems

This study has indicated that there are marked differences in fish fauna even between neighboring streams (Table 1). This may be due to the high spatial heterogeneity of various factors such as water quality (Tomatsu *et al*., 1994) or disturbance regimes (Nakamura *et al*., 1987) in the Ohtakigawa watershed. Neighboring streams with high heterogeneity will function as refugia from disturbances and contribute to recovery through immigration, as pointed out by Sedell *et al*. (1990). Since fishes are sensitive to water quality and have relatively high mobility, temporal avoidance and recovery is likely to be a significant mechanism for maintaining fish metapopulations in mountain stream systems, where tributaries have high spatial heterogeneity and are closely located. To obtain a more thorough understanding of the underlying mechanisms, further studies need to accumulate data on the relationships between the presence or absence of fishes and water environments (e.g., water quality) associated with disturbances in many streams.

Acknowledgments

The authors thank K. Nozaki, T. Taniguchi, and T. Tashiro for cooperation in the field survey and valuable suggestions, the Education Board of Otaki Village, and the Makio Dam Operation and Management Office for their valuable information. This study was partly supported by grants from the Water Resources Environment Center to K. Nozaki (2015-04).

References

Brusven, M. A. and C. E. Hornig (1984): Effects of suspended and deposited volcanic ash on survival and behavior of stream insects. *Journal of the Kansas Entomological Society*, **57** (1): 55-62.

Griggs, R. F. (1915): The effect of the eruption of Katmai on land vegetation. *Bulletin of the American Geographical Society*, **47**(3): 193-203.

Hasegawa, M. and H. Abe (2006): Impacts of volcanic eruption on insular ecosystem of Miyake Island — aspects of ecosystem processes in view of species interaction network. *Shinrin Kagaku*, **46**: 24-27 (*in Japanese*).

Iguchi, M. and H. Nakamichi (2015): Successive occurrence of phreatic eruptions in Japan. *Disaster Prevention Research Institute Annuals*, **58** A: 1-7 (*in Japanese with English abstract*).

Ikuta, K. (1999): *Sanseiu ha wagakuni no gyorui seitaikei ni eikyou wo ataeruka?* (Does acid rain effect on fish ecosystems in Japan?) *Center for Global Environmental Research Report*, **10** (7): 1-7 (*in Japanese*).

Ishio, S. (1963): The reactions of fishes to toxic substances — III. The reactions of fishes to hydrogen ion. *Bulletin of the Japanese Society of Scientific Fisheries*, **29** (7): 682-690 (*in Japanese with English abstract*).

Japan Fisheries Resource Conservation Association (1994): Kankyou ga kasenseibutsu oyobi gyogyou ni oyobosu eikyou wo handansuru tameno [handankijun] to [jirei] (“Criteria” and “cases” to assess the effect of environment on riverine organisms and fisheries) (*in Japanese*).

Kimura, T., M. Yoshimizu and H. Sannohe (1978): Bacteriological study on lake as ambient water for fish — I. Effects of the volcanic ashes after the eruption of Mt. Usu on Lake Toya, 1977. *Bulletin of the Faculty of Fisheries Hokkaido University*, **29** (4): 363-377.

Kitano, S., M. Yagyu, H. Akiyama, S. Kobayashi, H. Ichikawa, S. Endo and S. Yamamoto (2005): Fish fauna of Outaki stream of the Kiso River in central Nagano Prefecture. *Bulletin of Nagano Environmental Conservation Research Institute*, **1**: 9-13 (*in Japanese with English abstract*).

Kobayashi, S., S. Kitano, T. Yamagata and T. Uehara (2004): Distribution of *Niwaella delicata* in the upper Kiso River drainage, Nagano Prefecture. *Bulletin of Nagano Nature Conservation Research Institute*, **7**: 23-28 (*in Japanese with English abstract*).

Martin, D. J., L. J. Wasserman, R. P. Jones and E. O. Salo (1984): Effects of Mount St. Helens eruption on salmon populations and habitat in the Toutle River. UW Technical Report, 147 p.

Nagano Prefecture (2011): Proposal for type designation of water quality criteria for conservation of aquatic organisms: http://www.pref.nagano.lg.jp/kankyo/kensei/soshiki/shingikai/ichiran/kankyo/documents/2-6_3.pdf (accessed 22 June in 2016).

Nakabo, T. (1993): Fishes of Japan with pictorial keys to the species. Tokai University Press, Tokyo (*in Japanese*).

Nakamura, K., I. Moriya and T. Matsuda (1987): *Kazan to jishin no kuni* (Country of volcanoes and earthquake). Iwanami Shoten, Tokyo (*in Japanese*).

Nakashizuka, T., S. Iida, W. Suzuki and T. Tanimoto (1993): Seed dispersal and vegetation development on a debris avalanche on the Ontake volcano, Central Japan. *Journal of Vegetation Science*, **4** (4): 537-542.

Newcomb, T. W. and T. A. Flagg (1983): Some effects of Mt. St. Helens volcanic ash on juvenile salmon smolts. *Marine Fisheries Review*, **45** (2): 8-12.

Niwa, H. (1954): Fish of Kiso valley. Ecological Studies of the river fish fauna. Part I. Investigation of upper parts of the River Kiso and its tributaries. Kiso Kyoiku-kai, Nagano (*in Japanese*).

Oikawa, T., Y. Suzuki and T. Chiba (2014): Eruption history and 2014 eruption of Ontake volcano. *Kagaku*, **84**: 1218-1225 (*in Japanese*).

Sedell, J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford and C. P. Hawkins (1990): Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. *Environmental Management*, **14**: 711-724.

Stewart, C., D. M. Johnston, G. S. Leonard, C. J. Horwell, T. Thordarson and S. J. Cronin (2006): Contamination of water supplies by volcanic ashfall: A literature review and simple impact modelling. *Journal of Volcanology and Geothermal Research*, **158** (3): 296-306.

Takeda, K. (1985): *Ohtakigawa siryuu Denjougawa no zetsumetsusita yamatoiwana* (Extinction of *Salvelinus leucomaenis japonicas* in the Denjougawa River, a tributary of the Ohtakigawa River). *Tansuigyo*, **11**: 151-153 (*in Japanese*).

Tagawa, H. (1989): Process of vegetational recovery on the Krakatau Islands, Indonesia. *Japanese Journal of Ecology*, **39** (3): 203-217 (*in Japanese with English abstract*).

Tomatsu O., C. Takenaka and J. Wakamatsu (1994): Water qualities of natural waters in Ohtaki Village. *Journal of Japan Landslide Society*, **31** (3): 43-46 (*in Japanese with English abstract*)

Tsuji S. and M. Kosugi (1991): Influence of Aira-Tn Ash (AT) eruption on ecosystem. *The Quaternary Research*, **30** (5): 419-426 (*in Japanese with English abstract*).

Waters, T. F. (1995): Sediment in streams: sources, biological effects, and control. American Fisheries Society.

Yamamoto, T. (2000): Changes in the performance of ayu angling tracked from a personal diary. *Report of Yahagi River Institute*, **4**: 169-175 (*in Japanese with English abstract*).

Yamamoto, T. (2014): The pyroclastic density currents generated by the September 27, 2014 phreatic eruption of Ontake Volcano, Japan. *Bulletin of the Geological Survey of Japan*, **65** (9/10): 117-127 (*in Japanese with English abstract*).

Yoshii, Y. (1932): Revegetation of volcano Komagatake after the great eruption in 1929. *The Botanical Magazine*, **46**: 208-215.

Yoshioka, K. (1966): Development and recovery of vegetation since the 1929 eruption of Mt. Komagatake, Hokkaido. I. Akaikawa pumice flow. *Ecological Review*, **16** (4): 271-292.

Yuma, M., K. Hosoya and Y. Nagata (1998): Distribution of the freshwater fishes of Japan: an historical overview. *Environmental Biology of Fishes*, **52**: 97-124.

（Editor: Dr. Toshiya YAMAMOTO, Toyota Yahagi River Institute）

摘　要

2014年の御嶽山の噴火で火砕流の流入のあった河川と
その周辺の河川での魚類相の比較.

小野田幸生・萱場祐一

2014年の御岳山の噴火が魚類の分布に及ぼす影響を予備的に評価するために、御岳山周辺の5つの河川で魚類センサスを実施した。火砕流が流入した濁川は影響区として、他の隣接する2河川は、影響の拡散を評価するために設定された。御岳山からの流入のない残りの2河川は対照区として設定された。2015年の9～11月にかけて、魚類密度に応じて5～50分間のスノーケリング（1地点のみ5分間の手網採集）で魚類センサスを実施した結果、6分類群（イワナ属、アマゴ、ウグイ、アブラハヤ、コイ科魚類、ヨシノボリ属）、約1800個体が観察された。濁川と濁川合流後の王滝川では魚類が観察されなかったが、同じパターンは噴火前から報告されていた。さらに、隣接する河川の調査地点を含む他の地点では魚類が観察された。これらの結果は、今回の噴火による魚類への影響はそれほど大きくなく、影響があったとしても局所的だったことを示唆する。より詳細な評価や回復過程の把握のためには、広域的かつ長期的な魚類調査を継続していく必要があるだろう。

キーワード：魚類群集，山地河川，撹乱体制，避難場所，空間的異質性

　