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Fish Fauna and Community Structure in the Deogyusan National Park, Korea

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ABSTRACT Fauna of freshwater fish and community structure were investigated at 13 sites in the Deogyusan National Park, Korea from 2014 to 2018. During the period, a total of 8 families, 21 species, and 8,716 individuals of fishes were collected. The number of fish collected over the past five years from 2014 to 2018, were 17 species and 2,280 individuals, 17 species and 1,579 individuals, 17 species 1,905 individuals, 17 species and 1,384 individuals, and 15 species and 1,568 individuals, respectively. There were 13 Korean endemic species including *Iksookimia koreensis* and *Coreoleuciscus splendidus*, etc. Only in Wondangcheon Stream, two endangered species were identified, and *Hemibarbus mylodon* was collected continuously except in 2015, and *Pseudopungtungia nigra* was observed every year. And two exotic species such as *Oncorhynchus masou masou* and *Oncorhynchus mykiss* occurred in Gucheongdongcheon Stream sites. The dominant species was *Rhynchocypris oxycephalus* and the sub-dominant species was *Zacco koreanus* and there was no difference by year. The fish community structure of Deogyusan National Park was varied depending on the sites and the year. Most of the survey sites located upper stream where the river structure is Aa river type showed poor community analysis results. On the other hand, the upper-mid stream sites including the Bb type showed better results. As a result, the Wondangcheon Stream sites had the most diverse and stable community structure. Similarity dendrogram was divided into 4 groups, mainly reflecting the characteristics of the habitat. The flagship species of the Deogyusan National Park, *Rhynchocypris kumgangensis*, was constantly observed during the investigation period. Compared to the previous survey, the number of species increased from 2004 (12 species) and decreased from 2009 (22 species).

Key words: Fish fauna, community structure, Deogyusan National Park, Geum River

INTRODUCTION

National Park of Korea, which is rich in biodiversity and has a large number of protected species, has been designated and protected 22 places since the beginning of Jirisan Mountain (MC, 1967; ME, 2002). As the tenth, Deogyusan National Park is located in Muju-gun, Jangsu-gun, Geochang-gun, and Hamyang-gun and has a very important biogeographical significance as it includes the origin of the Namdaecheon Stream in the Geumgang River basin to the west and the Namgang River and Hwanggang River in the Nakdonggang River basin to the southeast (DNP, 2009; Kim *et al*., 2013). Major streams flowing through the park include Gucheongdongcheon Stream (main channel length (MCL): 6 km), Wondangcheon Stream (MCL: 27.3 km), Bukchangcheon Stream (MCL: 3.1 km), and Myeongcheon Stream (MCL: 11.7 km), notably, among them, the importance of Gucheongdongcheon as the southern limit habitat except for the Han River basin of *Rhynchocypris kumgangensis* has been noted (Kim, 1997). Researches on the fish fauna in these areas were carried out by Natural Environment Survey (ME, 1999, 2011) and Stream/River Ecosystem Survey and Health Assessment (NIER, 2007～2018). However, these surveys are limited to mountain streams due

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to the geological character of the mountain-type national park, and therefore, investigation of this area must rely entirely on monitoring conducted by the national park. And hence, KNPS has continuously observed the changes of fish fauna in the streams belonging to the park since 2000.

Such continuous monitoring of biological resources in national parks is an essential activity to preserve ecosystems, natural and cultural landscapes, and promote sustainable use. Therefore, this study aims to contribute to the efficient management of national parks by analyzing the results of monitoring fish fauna over the past five years from 2014 to 2018 to assess the artificial or natural changes in the ecosystem over the long term.

MATERIALS AND METHODS

The collection of fishes was carried out in four streams in 13 sites, three times (April, July or August, October) annually (Fig. 1, Table 1) using cast net (6×6 mm), kick net (5×5 mm) and fish trap (5×5 mm). And the physical characteristics of each site are described in Table 2 by Cummins (1962). Also, the river type followed Kani (1944). All fish were released after identification by Kim and Park (2002). And the data were sorted according to the classification system of Nelson *et al*. (2006) and Chae *et al*. (2019). Annual changes in precipitation were observed by citing data from the Water Resources Management Information Information System (WAMIS).

Fish community indices analysis is based on the number of species and individuals that appeared at each survey site. The dominance, diversity, evenness, and species richness were calculated using: Margalef, 1958; Pielou, 1966, 1975; McNaughton, 1967. Similarity and dendrogram construction was established with the Bray-Curtis similarity method using Primer 7.0 (PRIMER-E Ltd, UK).

RESULTS AND DISCUSSION

1. Habitat characteristics

The habitat characteristics of each study site are shown in Table 2.

Gucheondongcheon Stream is a mountainous stream flowing to the north of Deogyusan Mountain, and all sampling sites located here also showed typical valley-type river structure of Aa type. The water width was narrow compared to the downstream sites (3~15 m), but the water depth was not relatively shallow due to the nature of

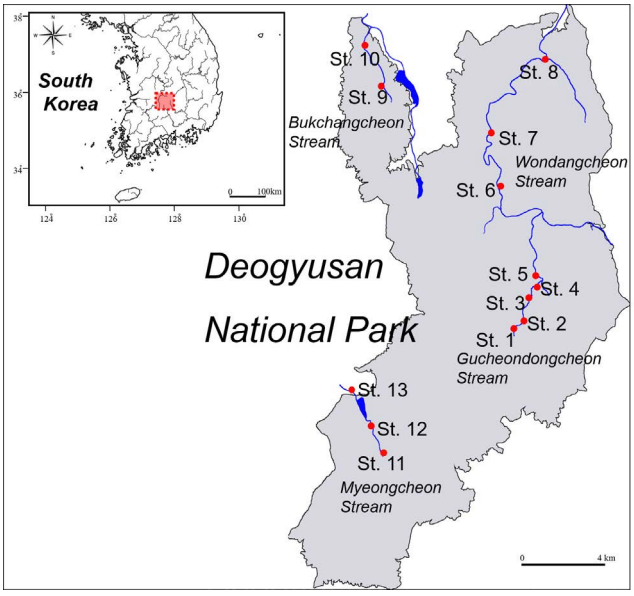

Fig. 1. Map showing the sampling sites in the Deogyusan National Park, from 2014 to 2018.

the valley. The bottom of the structure mainly consisted of boulder, cobble, and pebble, and the ratio of gravel and sand increased as it descended, but did not change significantly.

In Wondangcheon Stream sites, St. 6 and St. 7 located in the upper stream showed Aa-Bb river type, and St. 8 showed Bb river type which is different from Gucheondongcheon Stream. As a typical flat-form stream, the bottom structure contained more sand and mud than the Gucheondongcheon Stream sites.

Bukchangcheon Stream, where St. 9 and St. 10 are located, is a very short river with a length of about 3.1 km. It flows under Jeoksangsan Mountain, and the overall water width was narrow, about 2~7 m and the water depth was also shallow, below 0.9 m. The river type was typical Aa.

The Sites of Myeongcheon Stream showed more diverse habitat structures. The upper two Sites, St. 11 and St. 12 were valley-type, Aa, and the lowermost site, St. 13 is Aa-Bb, showed the characteristic that the valley-type stream was converted into a flatland-type stream. Therefore, it was observed that the ratio of sand and mud increases in the bottom structure composition as it goes to the downstream site.

2. Species composition from 2014 to 2018

1) 2014

In the 2014 survey, a total of 4 orders, 6 families, 17 species, and 2,280 individuals were collected (Table 3), and 5

Table 1. Study sites of fish fauna in the Deogyusan National Park, from 2014 to 2018

No.	Stream	Site	GPS	
St.1	Gucheondongcheon Stream	Isokdae, Samgong-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°46′09.01″N	35°51′40.09″E
St.2		Myungkyungdam, Samgong-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°46′19.02″N	35°51′51.07″E
St.3		Geumpotan, Samgong-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°46′34.05″N	35°52′35.03″E
St.4		Guwoldam, Samgong-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°46′54.00″N	35°52′44.07″E
St.5		Inwoldam, Samgong-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°46′39.02″N	35°52′56.00″E
St.6	Wondangcheon Stream	Daepyeong, Simgok-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do	127°45′35.10″N	35°55′28.07″E
St.7		Majeon, Dugil-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do*	–	–
St.8		Dugilgyo, Dugil-ri, Seolcheon-myeon, Muju-gun, Jeollabuk-do*	–	–
St.9	Bukchangcheon Stream	Bukchang-ri, Jeoksang-myeon, Muju-gun, Jeollabuk-do	127°41′50.84″N	35°57′59.71″E
St.10		Bukchang-ri, Jeoksang-myeon, Muju-gun, Jeollabuk-do	127°41′23.48″N	35°58′53.95″E
St.11	Myeongcheon Stream	Jukcheon-ri, Anseong-myeon, Muju-gun, Jeollabuk-do	127°41′38.88″N	35°48′44.84″E
St.12		Choyeongyo, Jukcheon-ri, Anseong-myeon, Muju-gun, Jeollabuk-do	127°41′27.94″N	35°49′09.82″E
St.13		Gwansujeong, Jukcheon-ri, Anseong-myeon, Muju-gun, Jeollabuk-do	127°40′49.34″N	35°49′56.62″E

*Detailed addresses and GPS of sites where endangered species have been identified are not displayed according to the Ministry of Environment notification (ME, 2019).

Table 2. Physical characteristics of each site in the Deogyusan National Park

No.	Stream	Water width (m)	Water depth (m)	River type*	Bottom structure (%)**					
					B	C	P	G	S	M
St.1	Gucheondongcheon Stream	3∼5	0.2∼0.5	Aa	30	30	20	10	10	
St.2		5∼15	0.5∼1.2	Aa	25	25	30	15	5	
St.3		5∼10	0.5∼0.8	Aa	30	30	20	10	10	
St.4		3∼8	0.5∼1.5	Aa	20	30	30	10	10	
St.5		3∼7	0.3∼0.6	Aa	20	15	20	25	20	
St.6	Wondangcheon Stream	10∼20	0.5∼1.0	Aa-Bb	10	30	20	15	15	10
St.7		15∼20	0.5∼1.2	Aa-Bb	10	20	25	20	15	10
St.8		20∼22	0.7∼1.5	Bb	5	15	20	20	25	15
St.9	Bukchangcheon Stream	2∼5	0.2∼0.4	Aa	30	40	30			
St.10		3∼7	0.5∼0.9	Aa	20	30	20	10	20	
St.11	Myeongcheon Stream	5∼8	0.3∼0.5	Aa	40	30	20	10		
St.12		15∼20	0.5∼1.0	Aa	25	25	25	15	10	
St.13		5∼15	0.3∼1.5	Aa-Bb	10	20	20	15	25	10

*River type: by Kani (1944); **B: Boulder (>256 mm), C: Cobble (64∼256 mm), P: Pebble (16∼64 mm), G: Gravel (2∼16 mm), S: Sand (0.1∼2 mm), M: Mud (<0.1 mm) by Cummins (1962).

species from Gucheondongcheon Stream, 11 species from Wondangcheon Stream, 5 species from Bukchangcheon, and 6 species from Myeongcheon Stream, respectively. The dominant species were *R. oxycephalus*, showing a relative abundance of 55.5%, and the subdominant species were *Z. koreanus* (22.1%) and *R. kumgangensis* (9.8%). Among them, a total of 10 endemic species were identified and their relative abundance was 37.9% of the total. As endangered species, *H. mylodon* (0.2%) and *P. nigra* (0.1%.) were collected only in Wondangcheon Stream. As an exotic species, river trout, *O. masou masou* (0.6%), and rainbow trout, *O. mykiss* (0.6%) were only identified in Gucheondongcheon Stream.

2) 2015

In the 2015 survey, a total of 4 orders, 7 families, 17 species, and 1,579 individuals were collected (Table 3), and 6 species from Gucheondongcheon Stream, 11 species from Wondangcheon Stream, 3 species from Bukchangcheon Stream, and 5 species from Myeongcheon Stream, respectively. The dominant species were *R. oxycephalus*, showing a relative abundance of 41.9%, and the subdominant species were *Z. koreanus* (32.1%) and *R. kumgangensis* (9.2%). Among them, a total of 10 endemic species were identified and their relative abundance was 48.1% of the total. As endangered species, *P. nigra* (0.7%) was collected only in Wondangcheon Stream. As an exotic species, *O. masou masou* (2.0%), and *O. mykiss* (1.3%) were only identified in Gucheondongcheon Stream.

3) 2016

In the 2016 survey, a total of 4 orders, 7 families, 17 species, and 1,905 individuals were collected (Table 3), and 6 species from Gucheondongcheon Stream, 11 species from Wondangcheon Stream, 5 species from Bukchangcheon Stream, and 5 species from Myeongcheon Stream, respectively. The dominant species were *R. oxycephalus*, showing a relative abundance of 45.2%, and the subdominant species were *Z. koreanus* (23.7%) and *R. kumgangensis* (12.3%). Among them, a total of 10 endemic species were identified and their relative abundance was 42.8% of the total. As endangered species, *H. mylodon* (0.1%) and *P. nigra* (0.5%) were collected only in Wondangcheon Stream. As an exotic species, *O. masou masou* (3.7%), and *O. mykiss* (0.1%) were only identified in Gucheondongcheon Stream.

4) 2017

In the 2017 survey, a total of 4 orders, 7 families, 17 species, and 1,384 individuals were collected (Table 3), and 3 species from Gucheondongcheon Stream, 11 species from Wondangcheon Stream, 3 species from Bukchangcheon Stream, and 5 species from Myeongcheon Stream, respectively. The dominant species were *R. oxycephalus*, showing a relative abundance of 46.8%, and the subdominant species were *Z. koreanus* (31.9%) and *R. kumgangensis* (7.7%). Among them, a total of 12 endemic species were identified and their relative abundance was 45.5% of the total. As endangered species, *H. mylodon* (0.4%) and *P. nigra* (1.2%) were collected only in Wondangcheon Stream. As an exotic species, *O. masou masou* (1.1%) was only identified in Gucheondongcheon Stream.

5) 2018

In the 2018 survey, a total of 3 orders, 5 families, 15 species, and 1,568 individuals were collected (Table 3), and 3 species from Gucheondongcheon Stream, 11 species from Wondangcheon Stream, 4 species from Bukchangcheon Stream, and 5 species from Myeongcheon Stream, respectively. The dominant species were *R. oxycephalus*, showing a relative abundance of 48.3%, and the subdominant species were *Z. koreanus* (30.0%) and *R. kumgangensis* (8.2%). Among them, a total of 9 endemic species were identified and their relative abundance was 42.2% of the total. As endangered species, *H. mylodon* (0.2%) and *P. nigra* (0.5%) were collected only in Wondangcheon Stream. As an exotic species, *O. masou masou* (1.6%) was only identified in Gucheondongcheon Stream.

3. Characteristics of the total fish fauna and annual fluctuation in species composition

The number of fish collected over the past five years from 2014 to 2018, were 17 species and 2,280 individuals, 17 species and 1,579 individuals, 17 species 1,905 individuals, 17 species and 1,384 individuals, and 15 species and 1,568 individuals, respectively (Table 3). Since it is a protected area in the Deogyusan National Park, artificial disturbances are well forbidden, so the drastic decrease in the total number of individuals observed in 2015 and 2017 compared to the previous year is thought to be closely related to precipitation, another physical factor. According to the measurement results of major observatories in the national park, both 2015 and 2017 had less annual precipitation than the previous year, and furthermore, in 2014 and 2016, the previous year, precipitation tended to be concentrated in July and August, summer (Fig. 3). In valley-type streams where there is usually not much flow, the summer rainy season can be fatal to fish habitats. High current velocity due to the increase in flow requires high energy consumption for fish, which most adult fish can afford to,

Table 3. List of fish species and number of fish collected in the Deogyusan National Park, from 2014 to 2018

	St. 1					St. 2					St. 3					St. 4					St. 5					Sub total
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	
Cypriniformes																										
Cyprinidae																										
Rhynchocypris oxycephalus	75	65	63	30	114	177	104	100	46	101	203	88	96	35	158	98	77	155	67	5	70	72	54	45	42	2,140
Rhynchocypris kumgangensis[1]	28	21	13	8	5	59	29	19	25	18	38	25	24	10	48	69	36	81	36	21	30	34	98	27	36	838
Pseudorasbora parva																										
Pungtungia herzi																										
Pseudopungtungia nigra[1, 2]																										
Coreoleuciscus splendidus[1]																						3	24			27
Squalidus gracilis majimae[1]																										
Hemibarbus mylodon[1, 2]																										
Pseudogobio esocinus																										
Microphysogobio yaluensis[1]																										
Zacco koreanus[1]																										
Zacco platypus																										
Cobitidae																										
Misgurnus anguillicaudatus																										
Iksookimia koreensis[1]																										
Siluriformes																										
Siluridae																										
Silurus microdorsalis[1]																					3		2			5
Bagridae																										
Pseudobagrus koreanus[1]																										
Amblycipitidae																										
Liobagrus mediadiposalis[1]																						1				1
Salmoniformes																										
Salmonidae																										
Oncorhynchus masou masou	1		3			3		6			3	3	4		5	6	22	23	11	8	1	6	34	4	12	155
Oncorhynchus mykiss[3]																9	18	1			4	2				34
Gobiiformes																										
Odontobutidae																										
Odontobutis platycephala[1]																										
Perciformes																										
Centropomidae																										
Coreoperca herzi[1]																										
No. Species	3	2	3	2	2	3	3	3	2	2	3	3	3	2	3	4	4	4	3	3	5	6	5	3	3	7
No. Individuals	104	86	79	38	119	239	133	125	71	119	244	116	124	45	211	182	153	260	114	34	108	118	212	76	90	3,200

Table 3. Continued

	St. 6					St. 7					St. 8					Sub total	St. 9					St. 10					Sub total
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018		2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	
Cypriniformes																											
Cyprinidae																											
Rhynchocypris oxycephalus	24	1								1	10				1	37	128	44	64	113	66	51	27	56	35	21	605
Rhynchocypris kumgangensis[1]																											
Pseudorasbora parva																											
Pungtungia herzi	24	13	14	12	28	38	26	58	27	30	28	27	43	39	23	430						4					4
Pseudopungtungia nigra[1, 2]											2	11	10	17	8	48											
Coreoleuciscus splendidus[1]	14	25	30	2	1	27	26	31	3	1	17	5		4		186								1			1
Squalidus gracilis majimae[1]																											
Hemibarbus mylodon[1, 2]								1	3	2	4			2	1	13											
Pseudogobio esocinus	2											11		2	2	17											
Microphysogobio yaluensis[1]																											
Zacco koreanus[1]	76	121	110	104	95	108	121	152	110	113	147	166	82	140	119	1,764						50	27	30	14	60	181
Zacco platypus											12	12	16	3	17	60											
Cobitidae																											
Misgurnus anguillicaudatus													10			10											
Iksookimia koreensis[1]	10	1							2			5	1	1	4	24										1	1
Siluriformes																											
Siluridae																											
Silurus microdorsalis[1]																						3		4	1		8
Bagridae																											
Pseudobagrus koreanus[1]		1				1	2				1		1	1		7											
Amblycipitidae																											
Liobagrus mediadiposalis[1]																											
Salmoniformes																											
Salmonidae																											
Oncorhynchus masou masou																											
Oncorhynchus mykiss[3]																											
Gobiiformes																											
Odontobutidae																											
Odontobutis platycephala[1]	13		6	15	3	7	7	5	4	4	11	6	4	3	5	93						5	7	2		5	19
Perciformes																											
Centropomidae																											
Coreoperca herzi[1]					1				2	5		2	2	5	4	21											
No. Species	8	7	4	4	5	5	5	5	7	7	9	9	9	11	10	13	1	1	1	1	1	5	3	5	3	4	7
No. Individuals	163	162	160	133	128	181	182	247	151	156	232	245	169	217	184	2,710	167	78	64	113	66	113	61	93	50	87	819

Table 3. Continued

	St. 11					St. 12					St. 13					Sub total	Year total					Ind.	R.A.
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018		2014	2015	2016	2017	2018		
Cypriniformes																							
Cyprinidae																							
Rhynchocypris oxycephalus	187	78	148	80	30	176	83	67	67	49	67	23	58	129	169	1,411	1,266	662	861	647	757	4,193	48.11
Rhynchocypris kumgangensis[1]																	224	145	235	106	128	838	9.61
Pseudorasbora parva											4	5	8		6	23	4	5	8		6	23	0.26
Pungtungia herzi											11	12	8	10	19	60	105	78	123	88	100	494	5.67
Pseudopungtungia nigra[1, 2]																	2	11	10	17	8	48	0.55
Coreoleuciscus splendidus[1]																	58	59	86	9	2	214	2.46
Squalidus gracilis majimae[1]														1		1				1		1	0.01
Hemibarbus mylodon[1, 2]																	4		1	5	3	13	0.15
Pseudogobio esocinus																	2	11		2	2	17	0.20
Microphysogobio yaluensis[1]											12	6		15	17	50	12	6		15	17	50	0.57
Zacco koreanus[1]								15		9	122	72	62	74	75	429	503	507	451	442	471	2,374	27.24
Zacco platypus																	12	12	16	3	17	60	0.69
Cobitidae																							
Misgurnus anguillicaudatus																			10			10	0.11
Iksookimia koreensis[1]																	10	6	1	3	5	25	0.29
Siluriformes																							
Siluridae																							
Silurus microdorsalis[1]						7		5					1			13	13		12	1		26	0.30
Bagridae																							
Pseudobagrus koreanus[1]																	2	3	1	1		7	0.08
Amblycipitidae																							
Liobagrus mediadiposalis[1]																		1				1	0.01
Salmoniformes																							
Salmonidae																							
Oncorhynchus masou masou[3]																	14	31	70	15	25	155	1.78
Oncorhynchus mykiss[3]																	13	20	1			34	0.39
Gobiiformes																							
Odontobutidae																							
Odontobutis platycephala[1]																	36	20	17	22	17	112	1.28
Perciformes																							
Centropomidae																							
Coreoperca herzi[1]																		2	2	7	10	21	0.24
No. Species	1	1	1	1	1	2	1	3	1	2	5	5	5	5	5	7	17	17	17	17	15	21	
No. Individuals	187	78	148	80	30	183	83	87	67	58	216	118	137	229	286	1,987	2,280	1,579	1,905	1,384	1,568	8,716	

1, endemic species; 2, endangered species; 3, exotic species; Ind., individuals; R.A., relative abundance.

however, developing embryos and larvae are washed away (Moyle and Cech, 1996; Gebrekiros, 2016). Therefore, the number of individuals decreases observed in 2015 and 2017 in the Deogyusan National Park is also estimated to be the result of a decrease in population size as fish born in the previous year were washed out by heavy rain before fully growth.

A total of 21 species and 8,716 individuals of fish were collected over five years, of which 13 species, *I. koreensis*, *C. splendidus*, *H. mylodon*, *Microphysogobio yaluensis*, *P. nigra*, *R. kumgangensis*, *Squalidus gracilis majimae*, *Z. koreanus*, *Coreoperca herzi*, *Odontobutis platycephala*, *Liobagrus mediadiposalis*, *Pseudobagrus koreanus*, *Silurus microdorsalis* were endemic. The rate of endemic species at all sites of Deogyusan National Park was 42.8%, higher than the rate of freshwater fish observed in entire South Korea, 28.8% (Kim *et al*., 2005).

The total dominant species was *R. oxycephalus* (48.1%), and the subdominant species was *Z. koreanus* (27.2%), which did not change during the five-year survey. The appearance pattern of dominant species was characterized by river type, *R. oxycephalus* mainly dominated in the Aa type of habitat (Gucheongdongcheon, Bukchangcheon Stream, Myeongcheon Stream), while *Z. koreanus* dominated in the Bb type of habitat (Wondangcheon Stream), thus exhibiting their habitat characteristics well (Kim, 1997; Kim and Park, 2002). The characteristics of fish fauna by study sites are that the number of species and individuals in the Bb type is higher than that of the Aa type and this is a result of the scale of the river. As it is located upstream, its habitat is narrow and not diverse, so it seems that it cannot support large amounts of living things because it has less organic matter (Chae *et al*., 2014).

The major fish species in Gucheondongcheon Stream were *R. oxycephalus* and *R. kumgangensis*, and the occurrence of the exotic fishes, *O. mykiss* and *O. masou masou* tended to increase toward the downstream. In the case of St. 5, *C. splendidus* was observed in 2015 and 2016, and *L. mediadiposalis* was only observed in the 2015 survey, but not since then. As *S. microdorsalis* are nocturnal fish, they are not commonly observed during daytime surveys, so if additional nighttime surveys are performed, observation will be possible. In the case of *C. splendidus* and *L. mediadiposalis*, they mainly live in the torrent of the upper-mid or mid-stream rather than the valley-type stream with low water temperature. Therefore, it seems that continuous monitoring is necessary as there is a possibility that what has been observed at this site may have been accidentally introduced.

Annual changes in the fish composition at the three sites of Wondangcheon Stream were more pronounced than those of other streams, which is likely due to the relatively large number of fish species. Meanwhile, in the case of St. 6, the *I. koreensis* and the *R. oxycephalus* were observed until 2015, but have not been confirmed thereafter, which was thought to be the result of the survey from 2016 when the survey spot was slightly moved downstream. Especially St. 8, where the number of species was the most, *Z. koreanus*, *Pungtungia herzi*, *P. nigra*, *Z. platypus*, *C. herzi*, and *O. platycephala* have been steadily caught, while *P. koreanus* has a tendency to appear infrequently. *C. splendidus* gradually decreased in number, and *H. mylodon* was not collected in 2015 and 2016 but was observed again thereafter. These irregular changes in the fish composition are thought to be due to the seasonal characteristics observed in Korean rivers that rapidly increase inflow during the rainy season in summer (DNP, 2009). Namely, it seems to be a change that occurs when fish are pushed downstream due to a rapid increase in flow and then ascending again after the flow stabilizes.

St. 9 of Bukchangcheon Stream, only *R. oxycephalus* was steadily observed, and the downstream St. 10, the number of individuals was different, but *R. oxycephalus* and *Z. koreanus* were consistently identified throughout the overall survey period. Besides, a small number of *I. koreensis* was collected in 2018, *C. splendidus* in 2016. In the case of *O. platycephala*, it was found except in 2017, and the *S. microdorsalis* was collected from 2014 to 2017, except in 2015 but was not confirmed in the last survey.

The fish composition in Myeongcheon Stream was divided into valley-type St. 11 and St. 12 and valley-flat type St. 13, and most of *R. oxycephalus* and a small number of *Z. koreanus* were observed at valley-type sites, and there was no significant change annually. At St. 13, five species were continuously observed every year, and *R. oxycephalus* and *Z. koreanus* were dominant in similar proportions. Also, *S. microdorsalis* and *S. gracilis majimae* were collected only in 2016 and 2017, respectively, while *M. yaluensis* and *P. parva* were constantly observed except in 2016 and 2017, respectively.

4. Changes of flagship species and exotic fishes in the Deogyusan National Park

R. kumgangensis, the flagship species of Deogyusan National Park, is a representative cold-water freshwater fish that lives in clear, low water temperatures in mountain streams, and is known to feed mainly on aquatic insects (Kim and Park, 2002; Kim *et al*., 2005). It is known

Fig. 2. Annual fluctuations of fish fauna in the Deogyusan National Park, from 2014 to 2018. Asterisks indicate the relative abundance within Gucheondongcheon Stream of flagship species, *Rhynchocypris kumgangensis* and exotic fishes, *Oncorhynchus masou masou* and *Oncorhynchus mykiss* of Deogyusan National Park.

to be distributed in the uppermost stream of the Hangang River, but Choi and Kim (1972) reported that it is additionally distributed in Deogyusan Mountain and received attention as it was known to be the southern limit of its geographical distribution (ME, 1999). *R. kumgangensis* was observed only in the Gucheondongcheon Stream, which was thought to be because the fact that the habitat of *R. kumgangensis*, a cold-water fish species, is limited to valleys that are maintained at low water temperatures even in summer. Within Gucheondongcheon Stream, *R. kumgangensis* was sub-dominant species after the dominant species, *R. oxycephalus*, and the annual fluctuation of relative abundance showed a slight increase from 2015 to 2017 and then decrease in 2018 (Fig. 2). However, the number of individuals, it was shown that 2015 and 2017 decreased compared to the previous year. Considering the factors that can affect the size of the *R. kumgangensis* population based on the total fish species in the present study, they are *R. oxycephalus* which is taxonomically closely related and has similar feeding habits, or *O. mykiss* and *O. masou masou*, which are large carnivore fish (Kim and Park, 2002; Kim *et al*., 2005). According to an additional study on the dietary properties of *R. kumgangensis*, it mainly feeds on land insects, Diptera, and Ephemeroptera (Baek *et al*., 2002; Choi *et al*., 2006). In particular, Lee (2020) reported that the stomach contents of *R. oxycephalus* in the Gucheondongcheon Stream are different from *R. kumgangensis* as a consequence of resource partitioning, furthermore, *O. masou masou* also did not feed *R. kumgangensis*. It means that the fluctuation of the size of *R. kumgangensis* population is unlikely to be due to the affected of the sympatric species. Thus, the decrease of *R. kumgangensis* individuals in Gucheondongcheon Stream 2015 and 2017 is considered to be a result of the effect of unstable precipitation mentioned above.

O. mykiss and *O. masou masou* were not originally inhabited in the Deogyusan National Park, but are invasive species that appeared after the fish farming facility was built around Gucheondongcheon Stream. According to the monitoring of Korea National Park Service, *O. mykiss* has been steadily observed since 2004, the first year of survey, and *O. masou masou* from 2007, the fourth year of survey (DNP, 2004, 2007), and especially *O. mykiss* has already been reported in 1999 (ME, 1999). *O. mykiss* and *O. masou masou* are also representatives of cold-water fish (Kim and Park, 2002; Kim *et al*., 2005), sharing habitat with *R. oxycephalus* and *R. kumgangensis*, the dominant fish species of Gucheondongcheon Stream. Also, due to their relatively large body size and carnivorous trophic level, it is likely to harm the *R. oxycephalus* and *R. kumgangensis* populations if they continue to

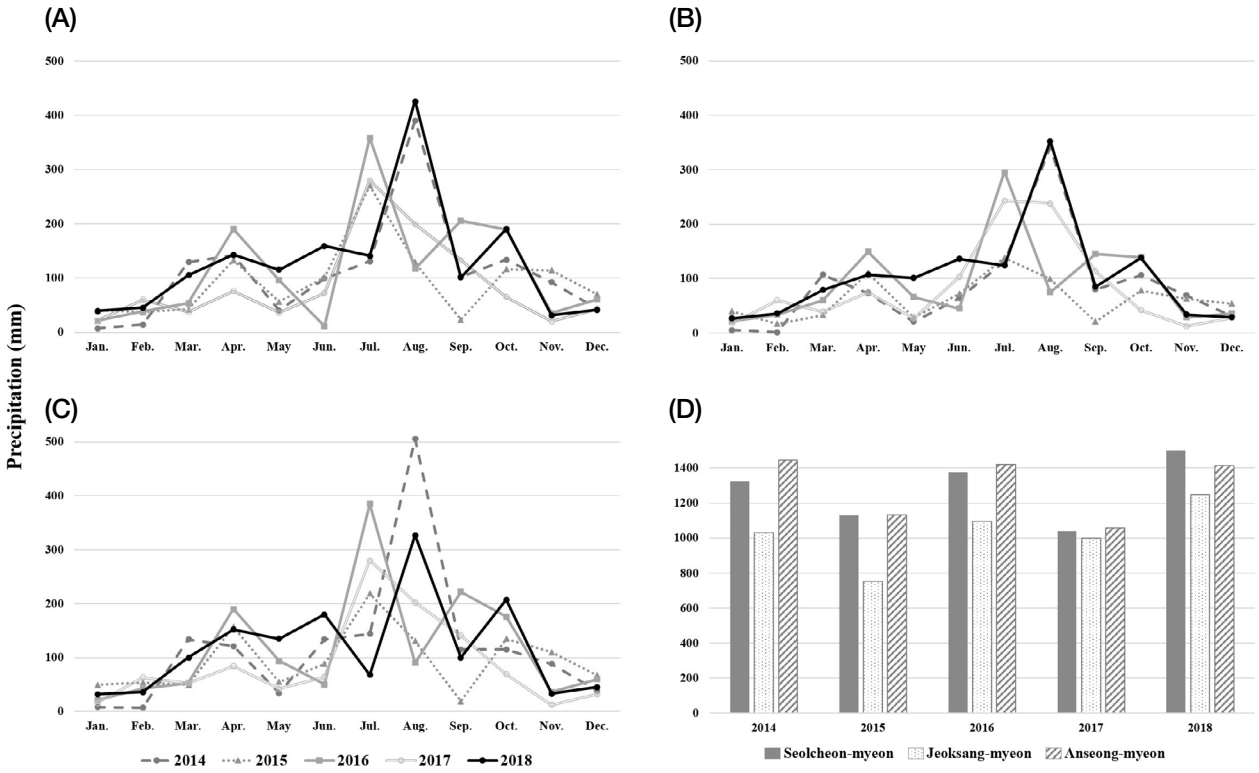

Fig. 3. Changes of monthly precipitation (A∼C) and annual cumulative precipitation (D) in the Deogyusan National Park from 2014 to 2018. A: Seolcheon-myeon observatory (Gucheondongcheon Stream and Wondangcheon Stream); B: Jeoksang-myeon observatory (Bukchangcheon Stream); C: Anseong-myeon observatory (Myeongcheon Stream) by WAMIS (2014∼2018).

coexist. Of course, several studies have shown that they prefer insects to fish (Riehle and Griffith, 1993; Bastardo *et al*., 1994; Yoon *et al*., 2013), and there are reports that only *O. mykiss* over two years old feed on fish at a rate as low as 2% (Oscoz *et al*., 2005). Although the causal-and-effect relationship of the *O. mykiss* and *O. masou masou* in Gucheondongcheon Stream on other sympatric fishes has not been fully revealed, according to Lee (2020), it could be a feed competitor, so continuous surveillance would be required. Notably, the population of *O. masou masou* did not increase significantly during the overall survey period, and *O. mykiss* was also identified in a small number until 2016 but was not observed in 2017 and 2018. However, it is difficult to capture due to the high velocity of swimming, and as they prefer deep water, more continuous monitoring is needed to verify that their population has decreased.

5. Community structure and similarity

An analysis of community structure by survey period was showed in Table 4. Because most of the survey sites were valley-type, the number of fish species at each site was small, and as a result, the dominance value has been analyzed high, over 0.9 in many sites (St. 1, St. 2, St. 3, St. 9, St. 11, and St. 12), on the other hand, in St. 8 where the most species were collected, the lowest value was 0.740∼0.825 during the overall survey. Diversity, evenness, and species abundance value tended to contradict the dominance overall and were lower at the upper stream sites and higher at the upper-mid stream sites. In particular, St. 9 and St. 11 showed the lowest analysis value because only one species of *R. oxycephalus* was observed during the entire survey period, and point St. 12 also obtained the lowest score as only *R. oxycephalus* was collected in 2015 and 2017. On the contrary, most of the Wondangcheon Stream sites (St. 6, St. 7, and St. 8), which had an abundant number of species and individuals, showed high values. Accordingly, it was considered that the Wondangcheon Stream sites had the most diverse and stable community structure in the Deogyusan National Park. One notable part of the annual change in St. 1 is the rapid decrease of the value of diversity in 2018 compared to 2017 (from 0.515 to 0.174), which is due to a significant increase in the number of *R. oxycephalus* collected from the previous year. By year, in 2016, when the dominant and subdomi-

Table 4. Community indices at each study site in the Deogyusan National Park, from 2014 to 2018

	Dominance					Diversity				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
St. 1	0.990	1.000	0.962	1.000	1.000	0.634	0.556	0.602	0.515	0.174
St. 2	0.987	1.000	0.952	1.000	1.000	0.623	0.524	0.611	0.649	0.425
St. 3	0.988	0.974	0.968	1.000	0.976	0.497	0.635	0.627	0.530	0.642
St. 4	0.918	0.739	0.908	0.904	0.853	0.962	1.217	0.908	0.902	0.920
St. 5	0.926	0.898	0.717	0.947	0.867	0.902	1.014	1.289	0.833	0.991
St. 6	0.613	0.901	0.875	0.895	0.961	1.558	0.803	0.908	0.719	0.718
St. 7	0.807	0.808	0.850	0.907	0.917	1.074	1.002	1.001	0.905	0.875
St. 8	0.754	0.788	0.740	0.825	0.772	1.304	1.222	1.459	1.206	1.268
St. 9	–	–	–	–	–	0.000	0.000	0.000	0.000	0.000
St. 10	0.894	0.885	0.925	0.980	0.931	1.072	0.970	0.937	0.684	0.815
St. 11	–	–	–	–	–	0.000	0.000	0.000	0.000	0.000
St. 12	1.000	–	0.943	–	1.000	0.162	0.000	0.668	0.000	0.432
St. 13	0.875	0.805	0.876	0.886	0.853	1.072	1.138	1.090	1.027	1.091
Total	0.776	0.740	0.689	0.787	0.783	1.399	1.600	1.612	1.441	1.434

	Evenness					Species richness				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
St. 1	0.577	0.802	0.548	0.742	0.251	0.431	0.224	0.458	0.275	0.209
St. 2	0.567	0.757	0.556	0.936	0.613	0.365	0.204	0.414	0.235	0.209
St. 3	0.452	0.578	0.571	0.764	0.584	0.364	0.421	0.415	0.263	0.374
St. 4	0.694	0.878	0.655	0.821	0.837	0.576	0.596	0.540	0.422	0.567
St. 5	0.560	0.566	0.801	0.758	0.902	0.854	1.048	0.747	0.462	0.444
St. 6	0.800	0.448	0.655	0.518	0.446	1.178	0.983	0.591	0.613	0.824
St. 7	0.667	0.623	0.622	0.465	0.450	0.769	0.769	0.726	1.196	1.188
St. 8	0.593	0.556	0.664	0.503	0.551	1.469	1.454	1.559	1.859	1.726
St. 9	–	–	–	–	–	0.000	0.000	0.000	0.000	0.000
St. 10	0.666	0.883	0.582	0.623	0.588	0.846	0.487	0.882	0.511	0.672
St. 11	–	–	–	–	–	0.000	0.000	0.000	0.000	0.000
St. 12	0.234	–	0.608	–	0.623	0.192	0.000	0.448	0.000	0.246
St. 13	0.666	0.707	0.677	0.638	0.678	0.744	0.838	0.813	0.736	0.707
Total	0.494	0.565	0.569	0.509	0.529	2.069	2.173	2.119	2.212	1.903

nant species, *R. oxycephalus* and *Z. koreanus*, were relatively less abundant than other species, the dominance was low and the value of diversity, evenness, and species abundance was relatively high (Fig. 2). On the other hand, despite a large number of total species and individuals, 2014, when the relative abundance of the dominant species, *R. oxycephalus* was high, and 2018, when both the number of species and individuals were small, showed overall poorer values than other years.

The results of analyzing the similarity of each site based on the number of species were classified into four clades at the level of similarity of 60% according to the characteristics of the stream and river type. Among them, Gucheongdongcheon Stream and Wondangcheon Stream, which are well divided into Aa type and Aa-Bb type, each formed a single clade, clade 2 and clade 3, respectively (Fig. 4). Clade 1 and clade 3 were slightly different, not bound to the same stream, but instead, more dependent on species composition, i.e. St. 9, St. 11, and St. 12 are the upper stream that belongs to clade 1, and St. 10 and St. 13 are the upper-mid streams belonging to clade 4. The similarity dendrogram is commonly arranged to be closely con-

Table 5. Historical record of fish fauna in the Deogyusan National Park

	DNP (2004)	KNPS (2004)	DNP (2009)	KNPS (2012)	Present study				
					2014	2015	2016	2017	2018
Cypriniformes									
Cyprinidae									
Carassius auratus			○						
Rhynchocypris oxycephalus	○	○	○	○	○	○	○	○	○
Rhynchocypris kumgangensis[1]	○	○	○	○	○	○	○	○	○
Pseudorasbora parva					○	○	○		○
Pungtungia herzi	○	○	○	○	○	○	○	○	○
Pseudopungtungia nigra[1, 2]	○	○	○	○	○	○	○	○	○
Coreoleuciscus splendidus[1]	○	○	○	○	○	○	○	○	○
Squalidus gracilis majimae[1]			○					○	
Hemibarbus longirostris		○	○	○					
Hemibarbus mylodon[1, 2]					○		○	○	○
Pseudogobio esocinus			○	○	○	○		○	○
Microphysogobio yaluensis[1]		○	○	○	○	○		○	○
Gobiobotia brevibarba[1, 2]	○	○	○						
Zacco koreanus[1]	○	○	○	○	○	○	○	○	○
Zacco platypus	○	○	○	○	○	○	○	○	○
Cobitidae									
Misgurnus anguillicaudatus			○		○	○	○		
Iksookimia koreensis[1]	○	○	○	○	○	○	○	○	○
Siluriformes									
Siluridae									
Silurus microdorsalis[1]			○		○	○	○	○	
Bagridae									
Pseudobagrus koreanus[1]			○	○	○	○	○	○	
Amblycipitidae									
Liobagrus mediadiposalis[1]			○	○		○			
Salmoniformes									
Salmonidae									
Oncorhynchus masou masou[3]			○	○	○	○	○	○	○
Oncorhynchus mykiss[3]	○			○	○	○	○		
Gobiiformes									
Odontobutidae									
Odontobutis platycephala[1]	○	○	○	○	○	○	○	○	○
Gobiidae									
Rhinogobius brunneus									
Perciformes									
Centropomidae									
Coreoperca herzi[1]	○		○	○	○	○	○	○	○
Centrarchidae									
Micropterus salmoides[3]			○						
No. Species	12	12	22	17	17	17	17	17	15
No. Individuals	2,086	−	2,001	1,598	2,280	1,579	1,905	1,384	1,568

1, endemic species; 2, endangered species; 3, exotic species.

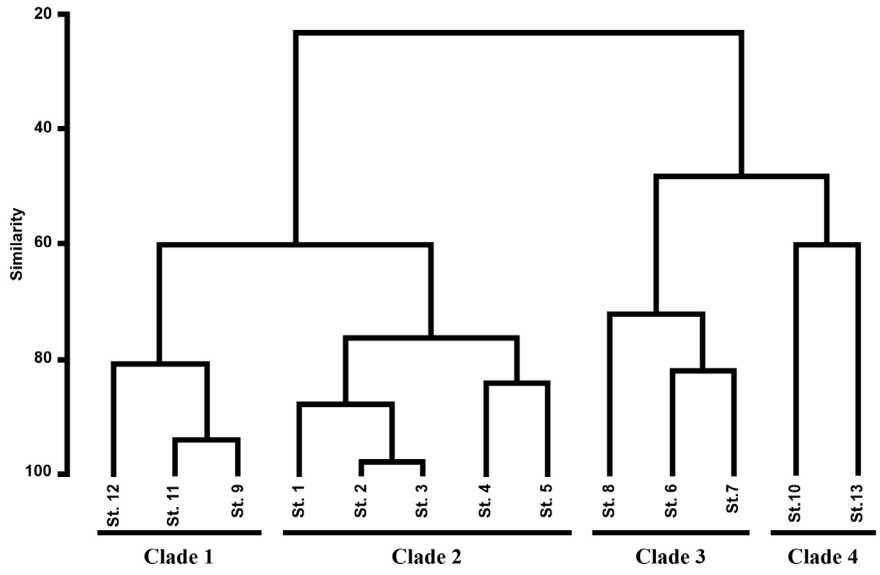

Fig. 4. Dendrogram for the cluster analysis based on similarity index of the fish species found among the study sites in the Deogyusan National Park, from 2014 to 2018.

nected to an adjacent site (Chae *et al*., 2014), but similar to the result of Songnisan National Park (Ko *et al*., 2019), sampling sites of Deogyusan National Park are considered to be more influenced by species composition than by distance on account of their valley-type sites with poor species diversity.

6. Compared to previous survey

Fish fauna in the Deogyusan National Park has been continuously investigated by Deogyusan National Park and National Park Research Institute (DNP, 2004, 2009; KNPS, 2004, 2012). These results are shown in Table 5 with the present study. A total of 12 species of fish were identified in the two surveys in 2004, although *Misgurnus anguillicaudatus*, *Hemibarbus mylodon*, *Pseudorasbora parva*, *O. masou masou*, *L. mediadiposalis*, *P. koreanus*, and *S. microdorsalis* were not collected in the past but were collected in the present survey, while *Gobiobotia brevibarba* was identified in the past but not in the present survey. It was reported that the reason for the small number of species in the 2004 survey was that the survey was conducted in a state in which the habitat was not completely restored due to heavy rains in the summer of 2002 and 2003 (DNP, 2004). In the case of *G. brevibarba*, they were not collected in the present survey as they were observed in the past, but in the 2020 survey (unpublished data), which modified the survey site in Wondangcheon Stream, a small number were identified, so it is believed that they did not disappear fully from the national park.

22 species of fish were collected in the 2009 survey, especially *Carassius auratus* and *Micropterus salmoides*, which were not observed in other investigations, because included a site with a slow and large flow downstream of Bukchangcheon Stream. A notable aspect is the appearance of *O. masou masou*, which was not identified in 2004, but has been consistently collected since then. It seems to be the result of individuals who survived a local release event since 2005 was adapted after ascending into the Gucheondongcheon Stream, where the water temperature is low. Considering the negative aspects of introduced species (Dukes and Mooney, 2004; Charles and Dukes, 2008; Lee *et al*., 2008), it is believed that effective measures must be taken to adjust the population size of *O. masou masou*.

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REFERENCES

Baek, H.M., H.B. Song, H.S. Sim, Y.G. Kim and O.K. Kwon. 2002.

Habitat segregation and prey selectivity on cohabitation Fishes, *Phoxinus phoxinus* and *Rhynchocypris kumgangensis*. Korean J. Ichthyol., 14: 121-131.

Bastardo, H., O. Infante and S. Segnini. 1994. Habitos alimenticios de la tmcha arcoiris, *Oncorhynchus mykiss* (Salmoniformes: Salmonidae), en una quebrada altiandina venezolana. Rev. Biol. Trop., 42: 685-693.

Chae, B.S., H.B. Song and J.Y. Park. 2019. A field guide to the freshwater fishes of Korea. LG evergreen foundation, Seoul, Korea, 355pp.

Chae, B.S., Y.H. Kang, S.K. Kim, D.U. Yoo, J.M. Park, H.U. Ha and U.W. Hwang. 2014. Ichthyofauna and fish community structure in the Yeong River, Nakdong River system, Korea. Korean J. Ichthyol., 26: 50-69.

Charles, H. and J.S. Dukes. 2008. Impacts of invasive species on ecosystem services. In: Nentwig, W. (ed.), Biological Invasions. Ecological Studies (Analysis and Synthesis). Vol. 193. Springer-Verlag, Berlin, Germany, pp. 217-237.

Choi, J.S., K.Y. Lee, Y.S. Jang, J.H. Park and O.K. Kwon. 2006. Feeding habit of *Rhynchocypris kumgangensis* (Cyprinidae) from the Hongcheon River, Korea. Korean J. Environ. Biol. 24: 29-37.

Choi, K.C. and I.S. Kim. 1972. On the fish fauna in the Namdae River, Muju. Korean J. Limnol., 5: 1-12.

Cummins, K.W. 1962. An evolution of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Amer. Midl. Nat'l., 67: 477-504.

DNP (Deogyusan National Park). 2004. Resource Monitoring of Deogyusan National Park (1st year). Deogyusan National Park, Muju, Korea, 399pp.

DNP (Deogyusan National Park). 2007. Resource Monitoring of Deogyusan National Park (4th year). Deogyusan National Park, Muju, Korea, 416pp.

DNP (Deogyusan National Park). 2009. Resource Monitoring of Deogyusan National Park (6th year). Deogyusan National Park, Muju, Korea, 395pp.

Dukes, J.S. and H.A. Mooney. 2004. Disruption of ecosystem processes in western North America by invasive species. Rev. Chil. Hist. Nat., 77: 411-437. https://doi.org/10.4067/S0716-078X2004000300003.

Gebrekiros, S.T. 2016. Factors affecting stream fish community composition and habitat suitability. J. Aquac. Mar. Biol., 4: 00076. https://doi.org/10.15406/jamb.2016.04.00076.

Kani, T. 1944. Ecology of torrent-inhabiting insectsIn. In: Furukawa, H. (ed.), Insect 1. Kenkyu-sha, Tokyo, Japan, pp. 171-317.

Kim, C.H., J.G. Oh and N.S. Lee. 2013. A study on the forest vegetation of Deogyusan National Park. J. Ecol. Environ., 46: 33-40. https://doi.org/10.11614/KSL.2013.46.1.033.

Kim, I.S. 1997. Illustrated encyclopedia of fauna & flora of Korea. Vol. 37. Freshwater fishes. Ministry of Education, Yeongi, Korea, 629pp.

Kim, I.S. and J.Y. Park, 2002. Freshwater fishes of Korea. Kyohak Publishing Co., Ltd., Seoul, Korea, 465pp.

Kim, I.S., Y. Choi, C.L. Lee, Y.J. Lee, B.J. Kim and J.H. Kim. 2005. Illustrated book of Korean fishes. Kyohak Publishing Co., Ltd., Seoul, Korea, 615pp.

KNPS (Korea National Park Service). 2004. National resource survey of Deogyusan National Park (2nd). Korea National Park Research Institute, Muju, Korea, 783pp.

KNPS (Korea National Park Service). 2012. National resource survey of Deogyusan National Park (3rd). Korea National Park Research Institute, Muju, Korea, 606pp.

Ko, M.H., M.S. Han, R.Y. Myung and H.J. Yun. 2019. Fish community characteristics and habitats aspects of endangered species *Pseudopungtungia tenuicorpa* and *Acheilognathus signifer* in the Hwayangcheon Stream, Hangang River of Songnisan National Park, Korea. Korean J. Ichthyol., 31: 222-234. https://doi.org/10.35399/ISK.31.4.6.

Lee, W.O., K.H. Kim, J.H. Kim and K.E. Hong. 2008. Study of freshwater fish fauna and distribution of introduced species of Mankyeong River, Korea. Korean J. Ichthyol., 20: 198-209.

Lee, Y.G. 2020. The ecological study of fat minnow, *Rhynchocypris kumgangensis* (Cyprinidae) in Deogyusan National Park. Master's thesis, Chonbuk National University, Jeonju, Korea, 71pp.

Margalef, R. 1958. Information theory in ecology. Int. J. Gen. Syst., 3: 36-71.

McNaughton, S.J. 1967. Relationship among functional properties of California Grassland. Nature, 216: 144-168.

Ministry of Construction (MC). 1967. Parks Act, No. 1909.

Ministry of Environment (ME). 1999. Reports of 2nd survey of national natural environment.

Ministry of Environment (ME). 2011. Reports of 3rd survey of national natural environment.

Ministry of Environment (ME). 2002. Natural Parks Act, No. 6841.

Ministry of Environment (ME). 2019. Enforcement Decree Of The Natural Environment Conservation Act, No. 29950.

Moyle, P.B. and J.J. Cech. 1996. Fishes: An Introduction to Ichthyology, 3rd ed. Prentice-Hall Inc., Upper Saddle River, New Jersey, U.S.A., 590pp.

National Institute of Environmental Research (NIER). 2007-2018. Survey and evaluation method for river and stream ecosystem health assessment. National Institute of Biological Resources, Incheon, Korea.

Nelson, J.S., T.C. Grande and M.V.H. Wilson. 2016. Fishes of the world, 5th ed. John Wiley & Sons Inc., Hoboken, New Jersey, U.S.A., 707pp.

Oscoz, J., P.M. Leunda, F. Campos, M.C. Escala, C. Garcia-Fresca and R. Miranda. 2005. Spring diet composition of Rainbow Trout, *Oncorhynchus mykiss* (Walbaum, 1792) in the Urederra River (Spain). Ann. Limnol. Int. J. Lim., 41: 27-34. https://doi.org/10.1051/limn/2005003.

Pielou, E.C. 1966. Shannon's formula as a measure of diversity. American Natural., 100: 463-465.

Pielou, E.C. 1975. Ecological diversity. John Wiley & Sons Inc., New York, U.S.A., 165pp.

Riehle, M.D. and J.S. Griffith. 1993. Changes in habitat use and feeding chronology of juvenile rainbow trout (*Oncorhynchus mykiss*) in fall and the onset of winter in Silver Creek, Idaho. Can. J. Fish. Aquat. Sci., 50: 2119-2128. https://doi.org/10.1139/f93-237.

Water Resources Management Information System (WAMIS). 2014~2018. Hydrological weather. Retrieved from http://www.wamis.go.kr/

Yoon, H.N., K.D. Kim, Y.L. Jeon, J.H. Lee and Y.J. Park. 2013. Stomach contents of the manchurian trout (*Brachymystax lenok tsinlingensis*) and river salmon (*Oncorhynchus masou masou*) in the Odae Mountain, Gangwondo. Korean J. Ichthyol., 25: 90-105.

덕유산국립공원의 어류상과 군집구조

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요 약 : 2014년부터 2018년까지 덕유산국립공원 내 13개 지점에서 담수어류상을 조사한 결과 총 8과 21종 8,716개체의 어류가 확인되었다. 연도별 개체수는 각각 17종, 2,280개체, 17종 1,579개체, 17종 1,905개체, 17종 1,384개체, 15종, 1,568개체였다. 한국 고유종은 참종개(*Iksookimia koreensis*), 쉬리(*Coreoleuciscus splendidus*) 등 13종이 있었다. 원당천에서만 2종의 보호종이 확인되었는데, 2015년을 제외하고 지속적으로 천연기념물인 어름치(*Hemibarbus mylodon*)가 확인되었으며, 멸종위기 야생생물 1급 어류인 감돌고기(*Pseudopungtungia nigra*)는 매년 꾸준히 관찰되었다. 외래종으로는 산천어(*Oncorhynchus masou masou*)와 무지개송어(*Oncorhynchus mykiss*) 2종이 구천동천에서 확인되었다. 우점종은 버들치(*Rhynchocypris oxycephalus*), 아우점종 참갈겨니(*Zacco koreanus*)로써 연도별 변화는 없었다. 덕유산국립공원의 어류 군집 구조는 조사 지점과 연도에 따라 달랐는데, 하천형태가 Aa 형인 상류에 위치한 조사시점 대부분은 군집분석 결과가 좋지 않은 반면 Bb 형을 포함한 중상류 지점은 더 나은 결과를 보였다. 분석결과 원당천에 위치한 조사지점들이 가장 높은 다양성과 안정적인 군집구조를 보여주었다. 지점별 유사도 분석 결과는 지점 간 거리보다는 서식지의 특성을 반영하여 4개의 그룹으로 나뉘었다. 덕유산국립공원의 깃대종인 금강모치(*Rhynchocypris kumgangensis*)는 조사기간 동안 구천동천에서 지속적으로 관찰되었다. 기존 연구와 비교한 결과 12종이 확인된 2004년 조사에 비해서 종수는 증가하였으나, 22종이 채집된 2009년 조사에 비해서는 감소하였다.

찾아보기 낱말 : 어류상, 군집구조, 덕유산국립공원, 금강