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Southern Asian Dolly Varden Charr, *Salvelinus curilus* on the Higashi-Nodottomari River in Rishiri Island

—Along with a review of the distribution of the charr in northern Hokkaido—

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Abstract. Southern Asian Dolly Varden charr, *Salvelinus curilus* (syn. *S. malma kraschenninnikovi*), is a salmonid fish and distributed in northeastern Asia. Rishiri Island represents the northern edge of the distribution range for the charr in Japan, and several studies have reported their presence. However, no basic ecological information, such as body size distribution and population densities, have been reported for the charr population of Rishiri Island. In this paper, we report the body size distribution and population density of the Southern Asian Dolly Varden charr in the Higashi-Nodottomari River on Rishiri Island and review previous reports regarding the charr on Rishiri Island. In the Higashi-Nodottomari River, 76 immature individuals, 12 mature males, and 5 mature females were collected. The fork length distribution showed a multi-modal distribution, and the smallest size group (ranging from 40–70 mm) is considered to represent age 0+ years (Kitano & Nakano, 1991; Kitano, 1995; Sahashi & Morita, 2018). The estimated population density was 0.37 ind./m^2. Based on the literature survey, collection records reporting the charr were confirmed in five rivers on Rishiri Island. In the Higashi-Nodottomari River, collection records of the charr dated back to 1947, before the hatchery transplantation of salmonid. In addition, Yamamoto *et al.* (2020) reported that the Southern Asian Dolly Varden charr collected from the Higashi-Nodottomari River had a unique haplotype that was not found in the fish collected from rivers on Hokkaido or Sakhalin islands. These findings suggested that the Higashi-Nodottomari River represents a natural distribution area for this species.

Introduction

Dolly Varden charr is a salmonid fish that can be found along the Pacific Rim and North America (Dunham *et al.*, 2009). A subspecies of Dolly Varden charr, Southern Asian Dolly Varden charr, *Salvelinus curilus* (syn. *S. malma kraschenninnikovi*) is distributed in northeastern Asia (Shedko *et al.*, 2007; Dyldin & Orlov, 2016). In Japan, the Southern Asian Dolly Varden charr is distributed only on Hokkaido Prefecture (Morita, 2019) and is classified as a vulnerable (VU) species on the Red List of the Ministry of the Environment (Ministry of the Environment, Government of Japan, 2020). Most Southern Asian Dolly Varden charr in Japan are nonanadromous (Morita *et al.*, 2005).

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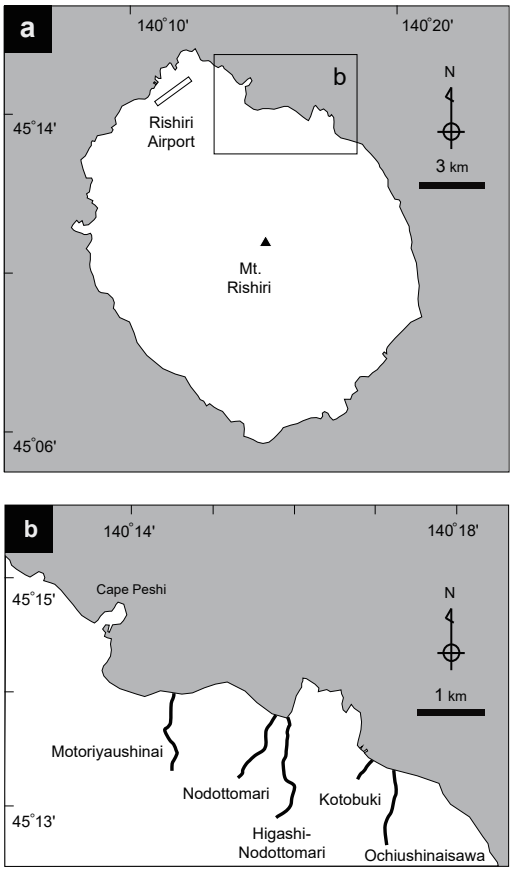

Fig. 1. (a) Location of Rishiri Island. (b) Locations of the five rivers where Southern Asian Dolly Varden charr distribution has been confirmed in the literature.

Rishiri Island represents the northern edge of the charr distribution in Japan (Morita, 2019), and several studies have confirmed their presence (e.g. Nakajima, 1969; Yoshiyasu, 1996). However, no basic ecological information, such as body size distribution or population density, has been reported for the population of Rishiri Island. In addition, although many anecdotes have reported the occurrence of Southern Asian Dolly Varden charr on Rishiri Island, no comprehensive reports have described their distribution, to date.

In this paper, we report the body size distribution and population density of the Southern Asian Dolly Varden charr in the Higashi-Nodottomari River on Rishiri Island and review the distribution of the charr on Rishiri Island.

Materials and methods

Fish were collected from the Higashi-Nodottomari River on November 28–29, 2019 (45.23° N, 141.27° E; Figs. 1 and 2). The study area was a 724 m long section of the river, featuring two erosion control dams (Fig. 2; Table 1). The study area was divided into three study reaches: upper, middle, and lower (Fig. 2). The charr were collected in the study reaches by a dip netting (30 cm width, 3 mm mesh), or bait fishing. To perform bait fishing, we used a 4.5 m rod (long rod, without a reel), a 2 pound line, a 0.5 g sinker, and a small barbed hook, to which salmon eggs were attached, as natural bait. We

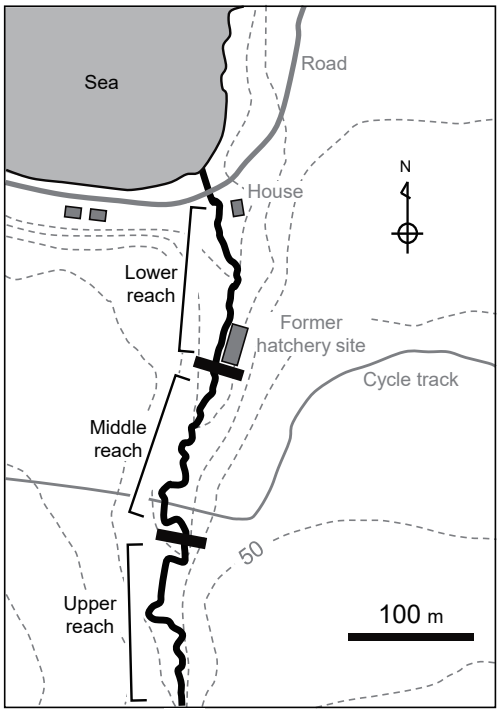

Fig. 2. Locations of three study reaches on the Higashi-Nodottomari River. Black lines indicate the river's course, thick gray lines show roads, thin gray lines show bicycle tracks, and dotted lines show topographic contours. The hatchery was built to release chum salmon.

Table 1. Length of the study reach, river width, and river depth in the three study reaches on the Higashi-Nodottomari River (mean ± SD)

	Upper	Middle	Lower
Study reach (m)	260	237	227
River width (m)	1.3 ± 0.6	1.5 ± 0.5	1.5 ± 0.5
River depth (cm)	6 ± 5	7 ± 4	9 ± 4

measured the fork length and determined the sexual maturity of each captured individual. Sex determination was performed on sexually mature individuals. To calculate population density estimates, individuals captured on the first day of the study had their adipose fin removed, as fin-clipping markers. On the second day of the study, the presence or absence of markings was determined during the fish measurements. The population density was estimated in the middle and lower reaches using Ricker's modification of the Petersen formula (Ricker, 1975; Urabe, 2019). The equation used to estimate the population size (N) was $N = (M + 1)(C + 1) / (R + 1)$, where N was the population estimate at the time of marking, M was the number of individuals marked in the first sample, C was the total number of individuals captured in the second sample, and R was the number of individuals collected in the second sample that were marked from the first sample. The equation used to calculate the variance of the estimated population size (V) was $V(N) = (M + 1)^2(C + 1)(C - R) / (R + 1)^2(R + 2)$. The equation used to calculate the 95% confidence interval (CI) of the estimated population size was $CI=N\pm1.96\sqrt{V(N)}$. To measure the size of the river, we measured the width and depth of the river (Table 1). The river width was measured at 20 m intervals, in each study reach. The river depth was measured at 20 m intervals, with three evenly spaced transects (1/4, 1/2, and 3/4).

We searched for collection records describing Southern Asian Dolly Varden charr on Rishiri Island, from books, magazines, and articles on

Fig. 3. Southern Asian Dolly Varden charr in the Higashi-Nodottomari River: upper image shows a mature male and the lower image shows an immature fish.

Table 2. Collection records for Southern Asian Dolly Varden charr from Rishiri Island, Rebun Island, and other northern regions of Hokkaido. * The Mumeisawa River on the Rishiri Island is most likely the Higashi-Nodottomari River.

Place	River	Reference	Year of research	Memo
Rishiri Island	Ochiushinaisawa	Nakajima (1969)	1947	
	Kotobuki	Tanaka (1994)	1993	The possibility of transplantation.
	Higashi-Nodottomari	Nakajima (1969)	1947	
		Yoshiyasu (2003)	1982	
	Nodottomari	Nakajima (1969)	1947	
	Motoriyaushinai	Noburogu (2009)	2009	
	Mumeisawa ※	Maekawa (1977)	1971–1975	
		Takeda & Yoshiyasu (1982)	1981–1982	
		Yoshiyasu (1996)	1982	
Rebun Island	Nairo	Dolly Varden charr's forest blog 5 (2014)	1986	Only one individual was captured.
	Kafukai	Yamamoto *et al*. (1994)	1990–1991	Only three individuals were captured. The possibility of transplantation.
Other northern regions of Hokkaido	Toimaki	Morita K. (personal observation)	1993	

the Internet. For this report, we selected literature in which the river names could be identified. We also examined the collection records that describe the charr in the rivers in the northern part of Hokkaido, north of ca. 45°N.

Results

A total of 93 charr were collected from the Higashi-Nodottomari River. The sampled individuals included 76 immature individuals, 12 mature males, and 5 mature females (Fig. 3). The fork lengths ranged from 41–138 mm among immature individuals, 105–195 mm among mature males, and 134–184 mm among mature females (Fig. 4). The fork length distribution showed a multi-modal distribution, and the smallest size group was found in the 40–70 mm individuals (Fig. 4) . The estimated population size was 252 ± 160, and the estimated population density was 0.37 ± 0.24 ind./m^2 (estimates ± 95% CI). No other fish species were collected.

The literature survey confirmed collection records of the charr from five rivers on Rishiri Island (Table 2; Fig. 1b). The collection records were concentrated in the northern part of the island (Fig. 1b). In the northern part of Hokkaido, outside of Rishiri Island, collection records for the Southern Asian Dolly Varden charr were limited to three rivers (Table 2).

Discussion

Southern Asian Dolly Varden charr that were collected from the Higashi-Nodottomari River included immature, mature male, and mature female individuals. In terms of body size distribution, the smallest size group was found in the 40–70 mm individuals. Based on previous studies that examined the relationship between body sizes and age (Kitano & Nakano, 1991; Kitano, 1995; Sahashi & Morita, 2018), individuals in the 40–70 mm range were considered as age 0+ years. In addition, most of the collected mature fish were post-spawning, and spawning redds were also identified (Sahashi & Morita, personal observation). Thus, the reproduction of the charr would occur in the Higashi-Nodottomari River.

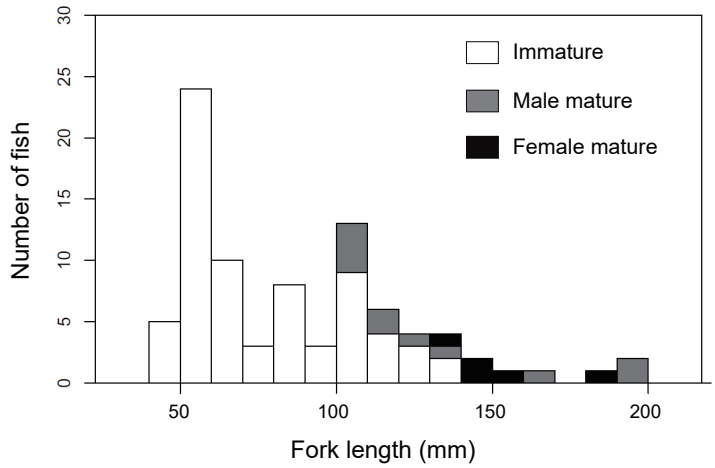

Fig. 4. Fork length distribution of Southern Asian Dolly Varden charr from the Higashi-Nodottomari River. Open bars: immature; gray bars: male mature; and black bars: female mature.

The density of the charr in the Higashi-Nodottomari River was estimated at 0.37 ind./m^2. Population densities in the rivers of the Shiretoko peninsula, which represents a major charr habitat on Hokkaido Island, generally range from 0.1–0.8 ind./m^2 (Kishi & Maekawa, 2009; Sahashi *et al.*, 2018). Therefore, the currently estimated charr density in the Higashi-Nodottomari River is not considered to be particularly low.

Some references described the possibility of charr transplantation to Rishiri Island (Yoshiyasu, 1996; Shimoda, 2003), but no specific information was specified in either study. In this study, when we checked collection records of the charr on Rishiri Island, we confirmed that chum salmon fry was transplanted from the hatchery in Hamatonbetsu Town, in 1954, and masu salmon fry was transplanted from the Soya Branch Office of the Hokkaido Fish Hatchery (Wakkanai City), in 1955, to the Higashi-Nodottomari River (Sakano, 1985). However, based on the distribution of the charr in the northern part of Hokkaido, the charr was unlikely to have been introduced during the transplantation of either the chum or masu salmon. In addition, the charr was reportedly collected from the Higashi-Nodottomari River as early as 1947, before these transplantations occurred (Nakajima, 1969). Even more noteworthy, the analysis of mitochondrial DNA revealed that the charr collected from the Higashi-Nodottomari River have a unique haplotype that was not found in any of the rivers on Hokkaido or Sakhalin islands (Yamamoto *et al.*, 2014; Yamamoto *et al.*, 2020). Therefore, the charr in the Higashi-Nodottomari River are likely to represent a native population, rather than of transplant-released origins.

The Higashi-Nodottomari River, like other rivers on Rishiri Island, is highly fragmented by erosion dams. Erosion control dams reduce the density of the charr by reducing the canopy cover and increasing the maximum water temperatures (Kishi & Maekawa, 2009). Habitat fragmentation also increases the probability of charr species extinction (Morita & Yamamoto, 2002; Morita *et al.*, 2019). Furthermore, the genetic analysis demonstrated that the charr in the Higashi-Nodottomari River had minimal

genetic diversity (Yamamoto *et al.*, 2020). Thus, future extinction of the charr in the Higashi-Nodottomari River may be possible, if the effects of habitat fragmentation become more apparent.

The literature review confirmed collection records of the charr from four rivers on Rishiri Island, except for the Higashi-Nodottomari River. However, all of these fish collection records were reported over a decade ago, and more than 70 years had passed since the reported fish collection for two of these rivers. Thus, the current status of charr populations outside of the Higashi-Nodottomari River must be reassessed, as soon as possible.

Acknowledgments

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Reference

Dolly Varden charr’s forest blog 5, 2014. https://blog.goo.ne.jp/dollyvardensalvelinus/e/5e544059ec2e2ab0121ef8fb65d4a382 (accessed on 6 August 2020). (In Japanese).

Dunham, J., C. Baxter, K. Fausch, W. Fredenberg, S. Kitano, I. Koizumi, K. Morita, T. Nakamura, B. Rieman, K. Savvaitova, J. Stanford, E. Taylor & S. Yamamoto, 2008. Evolution, ecology, and conservation of Dolly Varden, white spotted char, and bull trout. *Fisheries*, 33(11): 537–550.

Dyldin, Yu. V. & A. M. Orlov, 2016. Ichthyofauna of fresh and brackish waters of Sakhalin Island: an annotated list with taxonomic comments: 2. Cyprinidae-Salmonidae families. *Journal of Ichthyology*, 56(5): 656–693.

Kishi, D. & K. Maekawa, 2009. Stream-dwelling Dolly Varden (*Salvelinus malma*) density and habitat characteristics in stream sections installed with low-head dams in the Shiretoko Peninsula, Hokkaido, Japan. *Ecological Research*, 24(4): 873–880.

Kitano, S., 1995. Intra-population variation in growth and reproduction in the stream-dwelling Dolly Varden charr. Doctoral Thesis. (In Japanese).

Kitano, S. & S. Nakano, 1991. Growth, sexual maturity and diet of Dolly varden charr (*Salvelinus malma*) in the Horobetsu River system, Shiretoko Peninsula. *Bulletin of the Shiretoko Museum*, 13: 1–11. (In Japanese).

Maekawa, K., 1977. Studies on the variability of the land-locked Miyabe char, *Salvelinus malma miyabei* III. Geographical variations of the Dolly Varden, *Salvelinus malma*, and Morphological characters of the Miyabe char. *Japanese Journal of Ichthyology*, 24(1): 49–56. (In Japanese with English summary).

Ministry of the Environment, Government of Japan, 2020. Red List 2020 of Ministry of the Environment, Government of Japan. Ministry of the Environment, Government of Japan. (In Japanese).

Morita, K., 2019. Trout and Char of Japan. In Kershner, J. L., J. E. Williams, R. E. Gresswell & J. Lobón-Cerviá, (eds.), Trout and char of the world. pp. 487–515. American Fisheries Society, Maryland.

Morita, K., T. Arai, D. Kishi & J. Tsuboi, 2005. Small anadromous *Salvelinus malma* at the southern limits of its distribution. *Journal of Fish Biology*, 66(4): 1187–1192.

Morita, K., G. Sahashi, M. Miya, S. Kamada, T. Kanbe & H. Araki, 2019. Ongoing localized extinctions of stream-dwelling white-spotted charr

populations in small dammed-off habitats of Hokkaido Island, Japan. *Hydrobiologia*, 840(1): 207–213.

Morita, K. & S. Yamamoto, 2002. Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations. *Conservation Biology*, 16(5): 1318–1323.

Nakajima, K., 1969. Dolly varden charr in the Rishiri Island. *Sakana to Tamago*, 130: 24–25. (In Japanese).

Noburogu, 2009. http://nobu-log.jugem.jp/?eid=1420 (accessed on 6 August 2020). (In Japanese).

Ricker, W. E., 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191: 1–382.

Sahashi, G. & K. Morita, 2018. Adoption of alternative migratory tactics: a view from the ultimate mechanism and threshold trait changes in a salmonid fish. *Oikos*, 127(2): 239–251.

Sahashi, G., K. Morita & D. Kishi, 2018. Spatial expansion and increased population density of masu salmon parr independent of river restoration. *Ichthyological Research*, 65(4): 496–501.

Sakano, E., 1985. History of salmon hatchery in northern Hokkaido. Editorial committee of hundred-year history of Hokkaido salmon hatchery. Sapporo. 146 pp. (In Japanese).

Shedko, S. V., L. K. Ginatulina, I. L. Miroshnichenko & G. A. Nemkova, 2007. Phylogeography of mitochondrial DNA in south Asian Dolly Varden char *Salvelinus curilus* Pallas, 1814 (Salmoniformes, Salmonidae): mediated gene introgression? *Russian Journal of Genetics*, 43(2): 165–176.

Shimoda, K., 2003. Dolly varden charr *Salvelinus malma malma* (Walbaum). In Mizushima, T. & M. Torisawa, (co), Ueda, Y., K. Maeda, H. Shimada & T. Takami, (eds.), *Fisheries and Aquatic Life in Hokkaido*. pp. 122–125. The Hokkaido Shimbun Press. Sapporo. (In Japanese).

Takeda, K. & K. Yoshiyasu, 1982. Charr in Rishiri and Rebun Islands. *Tansuigyo*, 8: 107–108. (In Japanese).

Tanaka, H., 1994. Dolly varden charr. In Fisheries Agency (ed), *Basic information on Japan's rare wild aquatic organisms*. pp. 414–423. Hakushu arts. Tokyo. (In Japanese).

Urabe, H., 2019. Estimation of population size. In Inoue, M. & F. Nakamura, (eds.), *Field and analytical methods in stream ecology*. pp. 272–277. Kodansha. Tokyo. (In Japanese).

Yamamoto, S., N. Iida & S. Nakano, 1994. Freshwater fish fauna in Rebun Island, Hokkaido. *Rishiri Studies*, (13): 13–17. (In Japanese).

Yamamoto, S., K. Maekawa, K. Morita, P. A. Crane & A. G. Oleinik, 2014. Phylogeography of the salmonid fish, Dolly Varden *Salvelinus malma*: multiple glacial refugia in the North Pacific Rim. *Zoological Science*, 31: 660–670.

Yamamoto, S., K. Morita, G. Sahashi, K. Maekawa, G. Oleinik, E. Bondar & V. Brykov, 2020. Introgressive Hybridization between Southern Asian Dolly Varden, *Salvelinus curilus*, and Northern Dolly Varden, *S. malma malma*, on Sakhalin Island. *Russian Journal of Genetics*, (In press).

Yoshiyasu, K., 1996. The Book of Japanese Char. Sakuhusya. Tokyo. 255pp. (In Japanese).

Yoshiyasu, K., 2003. The album of Japanese Dolly Varden charrs. Self-publishing. 159pp. (In Japanese).

利尻島の東ノドットマリ川のオショロコマについて

—北海道北部におけるオショロコマの分布情報と併せて—

佐橋玄記・森田健太郎

サケ科魚類のオショロコマ *Salvelinus curilus* は，北東アジアに分布する．利尻島は日本におけるオショ

ロコマの分布北限であり，これまで複数の研究が生息確認の報告をしてきた．しかし，利尻島の個体群に関する情報は断片的であり，体サイズ分布や生息密度といった基礎的な生態情報はこれまで報告されてこなかった．本論文では，利尻島の東ノドットマリ川のオショロコマについて，体サイズ分布と生息密度を報告するとともに，北海道北部のオショロコマ生息情報を収集した．東ノドットマリ川では，未成熟魚 76 個体，雄成熟魚 12 個体，雌成熟魚 5 個体が採捕された．尾叉長分布は多峰型を示し、最も小さいサイズのグループ（40–70mm）は 0+ 幼魚と考えられた (Kitano & Nakano, 1991; Kitano, 1995; Sahashi & Morita, 2018)．生息密度は 0.37 ind./m^2 と推定された．文献調査の結果，利尻島内の 5 河川でオショロコマの採捕記録が確認された．東ノドットマリ川では，サケマス類の移植放流が行われるより前の 1947 年にオショロコマの採捕記録が存在した．また，Yamamoto *et al.* (2020) により東ノドットマリ川のオショロコマは北海道本島やサハリンには見られない固有のハプロタイプを有することが報告されている．以上の知見から，東ノドットマリ川のオショロコマは自然分布であることが示唆された．