Response of Juvenile Masu Salmon, *Oncorhynchus masou* to Habitat Change, and Habitat Rehabilitation

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Masu salmon is one of the most important commercial salmon in Hokkaido, however their landings have been decreasing since the 1970s in spite of the intensive enhancement programs. Masu salmon are dependent on freshwater environments because they live in streams for more than one year before they migrate to the ocean. However, the quality of freshwater environments has deteriorated due to man-made constructions, clear cut logging, and agricultural development, particularly since the 1950s. Accordingly, it is worthwhile to reduce the extent of stream degradation and to enhance fish habitat to restore our masu salmon resources.

In recent years, we have studied juvenile masu salmon and their relationships with the freshwater environments in several streams to allow us to restore masu salmon habitat. In this report we summarize this work and review other recent studies on masu salmon responses to environmental changes including water temperature and stream structure, and habitat rehabilitation and enhancement.

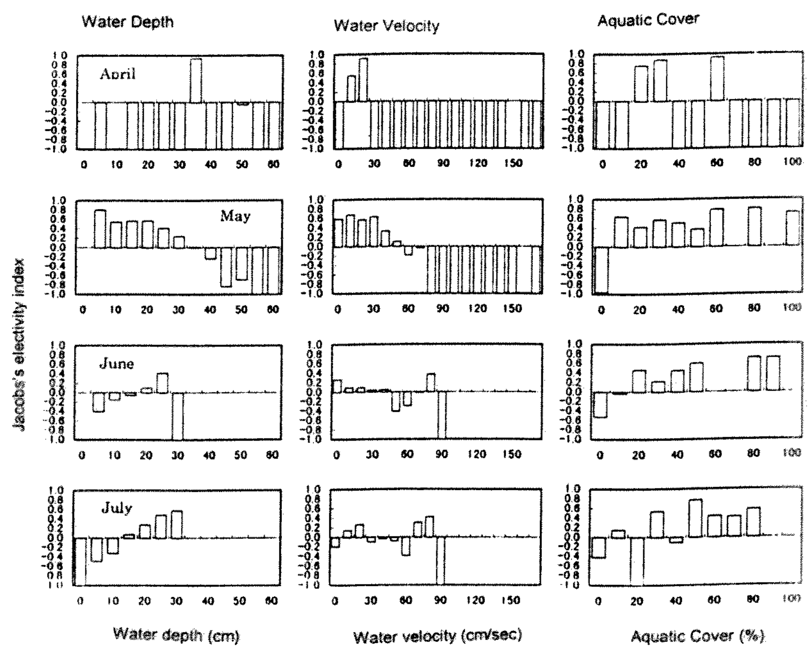
When masu salmon fry emerge from their redds, they are very sensitive to stream flow changes, and most of them go downstream and/or remain at the spawning area. The first feeding period for salmonids is a critical time, and population dynamics during this period affect their survival and growth. Therefore, it is important to know what physical environments masu salmon fry select actively, and how these habitat preferences shift with growth.

Our studies were conducted in the upper reach of the Shakotan and Masuhoro rivers of Hokkaido. Study sites in both streams were divided into individual cells (one cell: 1 m × 1 m) to survey detailed environments. We captured masu salmon juveniles in each cell by electrofishing. After fish sampling was completed, habitat variables were measured for each cell, including depth of water column, water velocities, substrate composition (dominant substrate size), and percentage covers of overhanging and aquatic vegetation.

Shortly after masu salmon fry emerged in the Shakotan River, they distributed contagiously at submerged stream margins (Nagata et al. 1998a). Newly emerged fry favored low water velocity areas, particularly less than 30 cm/sec (surface velocity), 20 cm/sec (bottom velocity), and shallow water less than 30 cm. Masu fry favored habitats with dense cover of aquatic vegetation (Fig. 1). Aquatic cover decreases water velocity because energy is lost when water passes through the cover. Cover also provides security from predation.

A distinct shift in the distribution of masu salmon juveniles occurred from May to June. Although some masu juveniles remained in the habitat with low water velocity, shallow water, and dense cover even in June, others moved to new habitats with high water velocity, deeper water, and less cover. From May to June, masu salmon juveniles grew rapidly and most exceeded 4 cm in fork length. These studies support the view that summer

Fig.1. Jacobs's electivity index (Jacobs, 1974) of water depth, water velocity and aquatic cover used by masu salmon from April to July in 1994. (from Nagata et al., 1998a).



habitat preferences of masu salmon juveniles are more variable as they become more competitive and require more food resources to grow.

Overwintering surveys in the Masuhoro River showed that masu juveniles shifted from the main channel to side channels. Overwintering juveniles favored lateral habitats with low water velocity, dense aquatic vegetation, and deep water in order to conserve energy (Suzuki et al. 2000).

Recently range land management has increasingly involved conservation and restoration of riverine environments because more attentions is being paid to the importance of rebuilding the natural ecosystem. As we showed for masu salmon, stream margins can make a unique contribution because they increase habitat diversity and provide rearing and refuge areas for juvenile masu salmon. Unfortunately, stream margins have been altered in many streams of Hokkaido by bank erosion and flood control measures. As stream margins, backwaters, and secondary channels are critical habitats for salmonids, it is essential to restore and conserve submerged areas.

We examined the relationship between masu salmon size and past stream temperature before early feeding to test the hypothesis that fish size at early feeding can be predicted by the past stream temperature. There are significant relationships between fish size and past stream temperature (Nagata, unpublished data), indicating that masu salmon fry in downstream areas with high past temperature tend to be larger than those in upstream areas and tributaries with low past temperature. However, high stream temperatures are not always desirable for masu salmon.

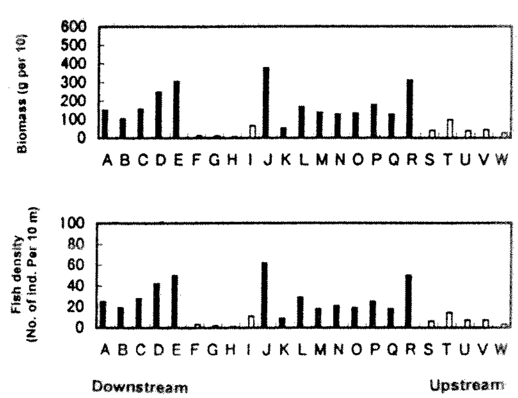
We also examined the influence of a loss of riparian vegetation on stream temperature, and resultant consequences on growth and survival of masu salmon juveniles (Nagata et al. 1998b). Five study stations along the Shakotan River were established to monitor changes in stream temperature, growth, condition factors, and population density of juvenile masu salmon in 1994 and 1995. The 1994 summer was so hot that stream temperature increased rapidly and exceeded 20°C in the middle reach with the least overhead cover. In contrast, the 1995 summer was cool and stream temperatures in the middle reach rarely exceeded 20°C. Masu salmon juveniles in the middle reach almost stopped growing, and their condition factor and population density also decreased from July to August in 1994. In contrast, masu salmon juveniles in the middle reach continued to grow and their condition factors increased from July to August in 1995. These results suggest that overhead cover by riparian vegetation contributes to maintaining low summer stream temperature that enables rapid growth of masu salmon juveniles during the summer.

Before smolting, masu salmon have to overcome severe winter conditions such as low water levels and shortages of food. Stocking experiments with different size groups of masu salmon juveniles showed that larger juveniles have higher survival during winter, presumably because energy supplies of large fish aid survival during times of cold water and shortages of food (Miyakoshi et al. 1999).

The middle portion of the Shakotan River was modified from 1969 to 1975 to assist with flood control. The meandering channel was straightened, the river bed was protected by setting gabionades; river gradient was increased; and all riparian vegetation was removed. Unfortunately, the riparian forest in part of the clear cut area has not yet recovered. In addition to low juvenile salmon growth because of high water temperature during summer in the non-forested reach, there are few spawning and rearing sites for masu salmon in the channelized reaches.

Channel restoration work was carried out in the summer of 1996 to rehabilitate the spawning and rearing sites (Yanai 1997). As a result of this rehabilitation, stream habitats in the restored section became more complicated and diverse, containing pools, riffles, and runs instead of the previous simple structure. Thanks to these improvements, several masu and chum salmon redds have been found in the restored spawning section, particularly in the tail of plunge pools (Yanai 1997). Many masu salmon fry remained in the restored section. A greater biomass of masu salmon juveniles in summer was found in restored spawning and rearing sections than the unimproved sections, particularly in pools (Ohmori 1999, Fig. 2). In conclusion, stream changes using log dams and deflectors can contribute to habitat improvements for masu salmon, and are a useful habitat enhancement technique for masu salmon resources in natural streams.

Fig. 2. Biomass and fish density of masu salmon juveniles (0+) in improved (black histograms) and unimproved (white histograms) sections. Each unit represents 10-m distance except for M unit (5 m). A value in M unit was doubled (from Ohmori, 1999).



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