Recent Analyses of Chum Salmon Homing Migration from the Bering Sea to Japan

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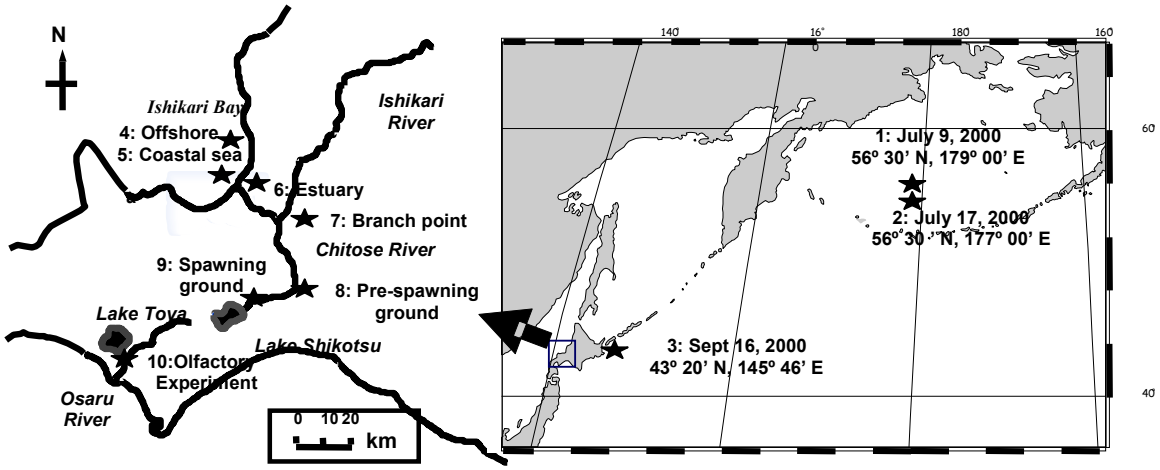
Keywords: Chum salmon, homing migration, biotelemetry, swimming speed, hormone profiles, salmon gonadotropin-releasing hormone, olfactory discrimination, natal river

A number of studies have investigated the amazing ability of salmon to migrate long distances from the ocean to their natal river for spawning (Ueda and Shoji 2002). For a better understanding on the mechanisms of salmon homing migration, three different analyses have recently been applied using Japanese chum salmon (*Oncorhynchus keta*) migrating from the Bering Sea to Japan and then to their natal river. The first is behavioral analysis on swimming speeds of homing chum salmon by means of a micro-data logger with a propeller, the second is endocrinological analysis on hormone profiles in the brain-pituitary-gonadal axis, and the third is olfactory analysis on discriminating ability of the natal river.

Swimming speeds in the oceanic phase can be one of the keys to understand the mechanism of chum salmon homing migration. We tagged a maturing chum salmon (fork length = 685 mm) which was considered to be of Japanese origin with a data logger (sampling intervals: speed and depth = 5 sec; temperature = 60 sec) in the central Bering Sea on July 9, 2000 (Fig. 1). This salmon was retrieved by a set net along the eastern Hokkaido coast 67 days after the release, and 51-day data were recorded. The fish usually swam in the surface water column and rarely stayed deeper than 50 m. The average swimming speed was 60–70 cm per sec, and horizontal rate calculated by an

Fig. 1. Map of sampling sites of Japanese chum salmon. 1 and 3, releasing and recapturing points for behavior analysis; 2 and 4-9, sampling point for hormone analysis; 10, sampling point for olfactory analysis



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empirical relationship between the attack angle and vertical rate was 42.3–47.7 km per day. The estimated horizontal rate indicates that chum salmon traveled 2,763 km in 67 days, which is almost equivalent to the distance between points of release and retrieve. It implies that chum salmon moved to the coastal area near the spawning ground almost straightly from the Bering Sea, partly helped by currents. Vertical profiles of ambient temperature sampled by salmon suggest that the fish passed through the Okhotsk Sea around mid-August. All through the recording period, chum salmon showed a clear foraging period in the daytime, which consisted of repeated short diving from the surface water column to the depth beyond the thermocline. It indicates that chum salmon traveled searching a prey patch during their oceanic migration. These results suggest that homing chum salmon migrated along the continental shelf of Kuril Islands.

Gonadtropin-releasing hormone molecules produced in the various brain regions are considered to be involved in many physiological functions of teleost life cycle. In order to clarify GnRH roles on salmon homing migration, measurements of two molecular types of GnRH, salmon GnRH (sGnRH) and chicken GnRH-II (cGnRH-II) in different brain regions, as well as gonadotropin (GTH) and steroid hormones were conducted using specific time-resolved fluoroimmunoassay (TR-FIA) systems (Yamada et al., 2002; Leonard et al., 2002). Maturing chum salmon were caught in nine points from the Bering Sea to the Chitose River. After decapitation, the brain was divided into six regions; olfactory bulb (OB), telencepharon (TC), diencephalon (DC), optic tectum (OT), cerebellum (CB), and medulla oblongata (MO). During spawning migration of chum salmon, sGnRH levels in OB, TC, and pituitary of both sexes were increased at the coastal sea to the branch point of the Chitose River from the Ishikari River. Moreover, sGnRH levels in the pituitary tended to increase at the same time of elevation in female pituitary GTH II and ovarian GTH I levels. cGnRH-II level in MO was increased at the pre-spawning ground in both sexes, and levels of OT were also increased in male. Both GnRH levels in DC showed no significant changes during spawning migration. GTH II levels in gonads were not detected though the sampling period. Serum steroid hormone levels showed similar profiles as previous observations (Ueda 1999); estradiol-17β in females and 11-ketotestosterone in males increased during vitellogenesis and spermatogenesis, respectively, and 17α,20β-dihydroxy-4-pregnen-3-one increased dramatically at the time of final gonadal maturation in both sexes. It is quite interesting to note that both sGnRH content in TC and serum testosterone level showed coincident peaks at the branch point of the Chitose River from the Ishikari River. Theses results confirm the previous findings that sGnRH plays a role on GTH secretion in the pituitary of chum salmon, and sGnRH and cGnRH-II might be involved in brain region-dependent roles on sexual maturation and behavior in salmonid fishes.

For upstream homing migration from the coastal area to the natal stream, the olfactory hypothesis which was proposed by Hasler and Wisby (1951) has been discussed in many behavioral and electrophysiological studies, but the odor substances of home stream are still unknown. We found that the response to artificial stream water based on the compositions of amino acids and salts closely resembled the response to the corresponding natural water (Shoji et al., 2000), and we carried out behavior experiments to test whether amino acids mixtures of the home stream have attractive effects on chum salmon upstream movement. Mature male chum salmon (mainly 4 year olds) were captured at the weir in the Osaru River, Hokkaido, Japan, in the late spawning season of 2002, transferred to the Toya Lake Station, Hokkaido University, and reared for several days before experiments. Behavior experiments were conduced in the two-choice test tank. The artificial home stream water was prepared by the amino acid and related substance composition of the Osaru River and dissolved in artificial freshwater. A total of 44 chum salmon was tested, and 28 fish (63.6%) showed upstream movement to one of the choice arm. Among those that moved, 24 fish (85.7%) were found in the arm running the artificial home stream water, and 4 fish (14.3%) were observed in the arm running the natural lake water. These results demonstrate clearly that the artificial home stream water reconstituted by the amino acid composition of home stream has attractive effects on the chum salmon upstream selective movement. We concluded that amino acids dissolved in the home stream water are home stream odorants, and the hypothesis that amino acids dissolved in stream waters are home stream substances for salmon homing is strongly supported by these results.

These different new approaches will help to understand mechanisms of salmon homing migration and eventually to evaluate the stock dynamics of salmon in the North Pacific Ocean and Bering Sea.

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