Applications of endocrinology to salmon culture: Hormonal induction of spawning of adults and hormone patterns during development of juveniles

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The many applications of endocrinology in fish culture can be categorized into two major types. One involves establishing the functions of hormones and measuring their activities during normal physiological processes. The other involves the application of hormones (or their synthetic agonists or antagonists) in order to control some aspect of the animal’s physiology. Two examples of these types of applications will be discussed. The changes in blood plasma concentrations of hormones during the parr-to-smolt transformation of juvenile salmon reveal a complex pattern of endocrine activities that may be used to predict the optimal time for transferring salmon from fresh- to seawater. The use of hormones to induce spawning of captive broodstock salmon in either fresh water or seawater is a good example of applications of hormones to facilitate broodstock husbandry.

The developmental period known as the parr-to-smolt transformation (smoltification) prepares the freshwater resident juvenile salmon for downstream migration and entry into the estuary and ocean. Smoltification is associated with a variety of morphological, biochemical, and behavioral changes in the fish. This developmental process appears to be influenced primarily by photoperiod and temperature, among other environmental factors. Control of smoltification is mediated at least in part through neuroendocrine and endocrine mechanisms. Histological studies have implicated involvement of the thyroid, pituitary, interrenal, pancreas, Corpuscles of Stannius, ultimobranchial, urohypophysis and catecholaminergic (head kidney) tissue. Application of radioimmunoassay to determine blood plasma concentration of hormones has verified a role for some of these glands and implicated others as possible mediators of smoltification. Increased activity of the thyroid during smoltification is associated with increases in plasma thyroxine (T4) and, depending on the species, triiodothyronine concentration. Plasma cortisol levels increase subsequent to or coincident with the increase in circulating T4. In some cases, plasma estradiol concentration has been shown to follow a pattern of increase and decrease similar to that of T4. Daytime levels of plasma melatonin appear to be constant throughout smoltification. Plasma levels of insulin increase in parr immediately prior to the beginning of smoltification. A similar increase in insulin-like growth factor I (IGF I) may also occur at this time. Plasma levels of norepinephrine and epinephrine become elevated near the end of smolt development. The large number of pituitary-dependent and independent hormones that change during smoltification suggests that there is a hypothalamic or general endocrine activation during juvenile development of salmon (Dickhoff and Sullivan 1987). The appropriate order or sequence of activation of the various endocrine glands during normal development remains to be established. Furthermore, the interactions of various hormones that change during smoltification need to be examined.

The natural process of spawning in teleost fish is accomplished through neuroendocrine and endocrine pathways. Environmental stimuli (photoperiod, temperature) are perceived by the brain which regulates the release of neuropeptides and catecholamines which in turn control the release of gonadotropic hormone (GtH) by the pituitary gland. Pituitary GtH released into the blood acts on the gonads to promote the release of gametes (spermiation and ovulation). Release of GtH by the pituitary is stimulated by the brain peptide, gonadotropin-releasing hormone (GnRH). In teleost fishes spawning can be induced by the injection of GtH or GnRH. A synthetic analogue of GnRH, desGly¹⁰, D-Ala³GnRH, (GnRHₐ), is particularly effective in inducing spawning of salmonid fish.
Salmonids normally spawn in fresh water, although some species may spawn in brackish water. Attempts to spawn salmonids maintained in seawater have yielded mixed results. Frequently maturing adults retained in seawater will die before spawning. If spawning does occur in seawater, the gametes are often not viable. There are several biological mechanisms that may be operating to inhibit spawning in seawater or be responsible for a reduction in gamete fertilizability or viability. Residence in seawater may block the activation of neuroendocrine and endocrine pathways that normally control spawning. Alternatively, prolonged seawater residence may cause ionic or osmotic imbalances in the blood or tissues and have direct adverse effects on the gonads. Experiments were carried out to test these possibilities (Dickhoff unpubl.). Four-year-old Atlantic salmon (Salmo salar) of the Gaspe stock were maintained in floating seawater netpens in Puget Sound near Manchester, Washington. Near the time of sexual maturation, two groups of fish were retained in seawater (29°/oo), two groups were transferred to fresh water, and a third set of two groups was transferred to floating netpens in which a layer of dilute seawater (17 to 19°/oo) was established. One group in each of the three environments was injected with GnRHa (10 µg/kg) on days 1 and 3. The control groups were injected with 0.9% saline. In comparison with controls, spawning was advanced in all groups injected with GnRHa. Prespawning mortality was high in the group maintained in full-strength seawater and injected with saline. The cumulative percent fertilization and survival to the eyed stage for gametes and embryos was similar in hormone- and saline-injected groups in fresh water and in dilute seawater for the hormone-injected group that was spawned within one week after injection.

Fertilization and survival of embryos were reduced in the groups in dilute seawater at day-10 after injection and in the group in full-strength seawater. These results indicate that spawning of salmonids in seawater can be induced by injection of GnRHa. Egg fertilizability and gamete viability may be reduced when adults are maintained in full-strength seawater or for a prolonged period in dilute seawater. The results support the hypothesis that in maturing salmonids in seawater the neuroendocrine pathway controlling spawning is inhibited by the central nervous system.

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