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Y. Nagahama
H. Ishizaki

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ENDOCRINE PHYSIOLOGY OF SALMON DEVELOPMENT AND SEAWATER ADAPTATION

Graham Young, Richard S. Nishioka and Howard A. Bern

Department of Zoology and Cancer Research Laboratory, University of California, Berkeley, CA 94720, U.S.A.

Hatchery rearing of anadromous salmonids improves the survival of young fish through the parr-smolt transformation, but this initial advantage is generally not reflected in their overall contribution to the fishery. The ability to withstand the critical transition into seawater (SW) and to grow in the ocean is a key event in the life cycle and one which may be amenable to manipulation before release. Understanding the physiology and endocrinology of salmonid development should lead to an increased contribution of hatchery-reared salmonids to the fishery. Current knowledge of the endocrine physiology of smoltification, based on the work of our laboratory and others, will be reviewed, with emphasis on the implications of recent advances for hatchery practices. In addition, new studies on larval development and growth will be described.

I. Smoltification and Seawater Adaptation

Thyroid hormones (TH) are generally believed to play major, although as yet incompletely defined roles in the control of smoltification. In all species studied to date, increased plasma thyroxine (T_4) levels parallel the numerous changes associated with smoltification. Administration of TH may induce some of these changes but results of attempts to increase SW adaptability and/or advance the timing of smoltification are equivocal. Plasma T_4 peaks on the new moon phase of the lunar cycle in several species of Pacific salmon and may serve to synchronize the various developmental events comprising smoltification. Basing hatchery release times on the lunar cycle led to a doubling of the contribution of hatchery-reared coho to the fishery. Alterations in 'water quality' induce changes in the T_4 pattern (Lin, Rivas, Grau). The role of cortisol is controversial. Plasma cortisol levels rise during smoltification concomitant with increased hypoosmoregulatory ability and changes in whole animal transepithelial potential (Iwata) and generally peak after the time of the T_4 surge. Recently, cortisol has been shown to induce increases in gill Na^+,K^+-ATPase levels both in intact and hypophysectomized coho salmon (Richman,

Björnsson, Yamauchi). Growth hormone (GH) increases during smoltification (Bolton) and GH administration enhances SW adaptability in several salmonids. GH administration to intact or hypophysectomized coho results in an elevation in gill Na^+,K^+-ATPase levels. In vitro studies indicate an important synergism of GH and cortisol on gill Na^+,K^+-ATPase (McCormick). Increased plasma levels of prolactin, generally prior to the T_4 surge, have been observed in coho and may function to reduce ion loss in FW from fish preadapting to SW (Prunet). A variety of metabolic changes occur during smoltification, and all the hormones discussed above increase lipolysis in coho parr (Sheridan).

II. Abnormal Smoltification

The critical nature of the timing of SW entry is exemplified by the inhibition of thyroid function after transfer of coho to SW at an inappropriate time. In extreme cases, growth virtually ceases and animals 'stunt' and eventually die. This phenomenon is not restricted to coho since stunting has recently been documented in Atlantic salmon (Björnsson). Stunts are largely hypoendocrine, but GH levels are four-fold higher than in normal counterparts (Bolton). Tissue GH binding is reduced (Fryer). Plasma ions and osmolarity are relatively normal in stunts but intracellular ion levels may be abnormal (Kerstetter). GH levels of stunts are reduced after transfer into FW, emphasizing that external salinity is an important factor in the development of this phenomenon. Understanding the ontogeny of stunting may lead to practical methods by which coho can be introduced into SW at an early age.

III. Larval Development and Thyroid Hormones

Several lines of evidence point to an important role of TH in larval development. Recent work analyzing whole body TH content shows the presence of substantial quantities of thyroid hormones in eggs, embryos and larvae of coho and chinook salmon (and other teleosts) (Kobuke, Specker, Greenblatt, Brown). The pattern of occurrence of these hormones suggests that they are initially of maternal origin and serve to provide the developing animal with TH before the larval thyroid develops. TH treatment of gravid females may improve larval survival, development and growth by augmenting the TH reservoir in eggs.

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