TELEOST EPIDERMAL MORPHOLOGICAL PLASTICITY: A POTENTIAL INDICATOR OF ENVIRONMENTAL QUALITY?

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Abstract
Seasonal changes, correlated with the reproductive cycle, occur in the epidermal morphology of some teleosts. Captivity and exposure of *Pleuronectes americanus* and *Salmo salar* to crude oil have subtle effects on such environmental changes. More extensive base-line studies on fish skin could provide a foundation for monitoring environmental quality.

Salmonid species eg *Salmo trutta* (Stoklosowa 1966; Pickering 1977) and *Salmo salar* (Burton *et al* 1985) exhibit profound seasonal changes in epidermal thickness and goblet cell frequency. Such changes have also been observed in the case of winter flounder (*Pleuronectes americanus*). Specimens sampled monthly from a wild population at the same location off the coast of Newfoundland display considerable thickening of the epidermis during the fall, and a remarkable thinning in the late spring in both males and females (Burton & Fletcher 1983). Epidermal thickening is particularly prominent on the pale blind side of males. The epidermal thinning occurs after spawning and is correlated with the decline in gonadosomatic index (GSI). Thickening of the epidermis occurs in the fall at the same time as gonad recrudescence and increasing GSI. Goblet cell frequencies vary from month to month, but particularly high frequencies are associated with the fall and with the prespawning period, these peaks being greater in the females. These highly dynamic characteristics of the teleost epidermis represent a high degree of morphological plasticity in the boundary between fish and environment and can result in significant sexual dimorphism.

There is increasing evidence that these seasonal changes in epidermal thickness are primarily regulated by seasonal fluctuations in plasmatic androgens associated with the reproductive cycle (Idler et al 1961; McBride & Van Overbeeke 1971; Yamasaki 1972; Pottinger & Pickering 1985a, 1985b) and treatment with 11-ketotestosterone can thicken the pale blind side of male winter flounder (Burton & Everard 1991a). Ball (1969), Blüm & Fiedler (1972) and Benjamin (1980) claim a role for prolactin in inducing mucigenesis and maintaining goblet cells in at least some teleosts.

The winter flounder population off Newfoundland includes a subset of non-reproductive post-mature fish in addition to subsets of sexually immature and reproductive fish (Burton, M.P.M. & Idler 1984). This non-reproductive post-mature state is related to nutritional status and hence food availability, and can be reversed (Burton, M.P.M. & Idler 1987). This subset is characterized by a poor condition factor (total body weight x 100/ total length^3) and by the failure of the gonads to mature in a given year. A subset like this can serve as a valuable, naturally occurring physiological model. During the prespawning period for reproductive flounder there is some thickening of the epidermis for non-reproductive adults, the ratio of blind side/ocular side thickness (B/O ratio) for the males being 1.5 in one study, whereas the greater thickening in the male reproductive fish resulted in a B/O ratio of 1.9, whilst it was only 1.1 in immature fish (Burton, D. & Burton, M.P.M. 1989). At the same time in non-reproductive adult females the epidermis was thinner than the reproductive females, but in both subsets the B/O ratio was 1.5 compared with 1.2 in immature females. In the reproductive females there was significant thickening of the blind side epidermis and an increase in B/O ratio from 1.2 to 1.7 during vitellogenic oocyte final maturation. Samples taken during the summer after spawning displayed thicker epidermis on the pale blind side than on the darker ocular side, a distinction not apparent in immature specimens. Although epidermal thinness is a characteristic of non-reproductive adult flounders, as compared with reproductive fish, the seasonal thickening of the blind side epidermis in the absence of gonadal maturation suggests that some seasonal steroidogenesis may still be occurring in these fish. This could be gonadal or extra-gonadal as in human skin (Julesz *et al* 1971). The seasonal character of the blind side epidermal thickening also implies that a pituitary gonadotropin regulating steroidogenesis is still functional, although in these fish with their low condition factor, recrudescence had not been started or maintained in the previous summer.

The seasonal changes in the teleost epidermis can also be influence by captivity. An experimental procedure was designed to compare the epidermis of winter flounder kept in stock tanks with that in samples from the wild population, from which the captive fish had been taken, at critical times during the reproductive cycle (Burton & Everard 1991b). The effect of short term captivity was greatest when post-spawned flounders were caught at a time when the epidermis was thinnest early in July. After six weeks in captivity these fish had a thick epidermis with high goblet cell frequencies compared with the wild population in mid-August when GSI values were still low. Also after more prolonged captivity, over a year, winter flounder epidermis develops a more or less complete superficial layer of mucus secreting cells. These are smaller than goblet cells and appear to be morphologically different from them under light microscopy. They may possibly differentiate from the surface cells of the epidermis as they were not observed in the deeper layers of this tissue. Currently, it is not known why these changes occur in the epidermis of captive fish. The thicker epidermis may result from lower levels of abrasive activity compared with the wild population in which individuals frequently bury themselves in the substratum. Such abrasive action may have a greater impact on the skin at a time when plasmatic androgen levels are low after spawning.

It would be anticipated that the epidermis, as the functional boundary between fish and aquatic environment, would be affected by environmental pollutants. Regardless of this obvious potential relationship little is known about the effects of pollutants on fish skin. The problem is exacerbated by variability within and between species and by the effects of normal environmental and seasonal factors. Knowledge of the effect of crude oil exposure on fish skin is largely limited to gross integumental lesions (Balouet & Blaudin-Laurencin 1980) and fin erosion (Desauncy 1974). However, before the development of such extreme conditions it is possible to detect more subtle microscopic changes in the skin. Hawkes (1977) recorded affects of exposure to crude oil in the mucus cells. Experiments on post-spawned winter flounder (Burton *et al* 1984) exposed to Venezuelan crude oil (30ml/270l) demonstrate that dissociation of epidermal tissue associated with this phase of the reproductive cycle and reduced by laboratory confinement, is even further reduced after exposure to the crude oil. Also, the seasonal decline in epidermal melanophore frequency associated with the thinning of the epidermis is not observed in flounders exposed to oil. In these flounder exposure to crude oil did not influence goblet cell frequency but alcian blue staining stained the 2-3 superficial layers of the epidermis indicating a mucigenic role for these cells. These superficial epidermal cells sometimes included small vesicles which were alcian blue positive. This observation is consistent with the view expressed by Whitear (1970) that a mucopolysaccharide cuticle is secreted by teleost superficial epidermal cells rather than by goblet cells. Pre-spawning male *Salmo salar* exposed under experimental conditions to water accommodated crude oil ($0.9/10^6$) for up to 28 days, without direct contact with oil, did not possess the same degree of pre-spawning epidermal thickening as in control fish (Burton *et al* 1985). Also, there was depression of goblet cell differentiation in these oil exposed fish. In the fish used in this study the plasmatic levels of testosterone and 11-ketotestosterone rose sharply over the 28 days in the controls, but levels were significantly lower in the oil-exposed fish (Truscott et al 1983). These results indicate that crude oil can have a systemic effect, the seasonal epidermal change being indirectly inhibited by suppression of plasmatic androgen levels.

These examples demonstrate the capacity of the teleost epidermis for morphological plasticity. It is also apparent that some changes may be a direct effect on the epidermis while other changes can be regulated through the endocrine system and environmentally related epidermis morphological plasticity may involve such systemic control in many instances, Abnormal development of integumentary secondary sexual characteristics and epidermal cellular activity have a potential for developing new indicators for environmental monitoring.

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