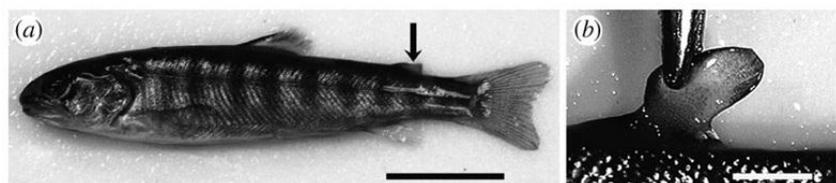


### **The salmon adipose fin; new evidence of a neural network implies functionality.**

In the watery world of fishes, salmon are some of the most familiar species to both scientists and layman alike. Due to their cultural, commercial and recreational importance they were some of the earliest fish to receive the focus of scientific inquiry and played a major role in the development of modern fish hatcheries. As the canning industries of the nineteenth century rose, leading to declining fish stocks throughout the twentieth century, billions of dollars were spent worldwide to better understand salmon in an effort to preserve healthy runs (Lichatowich 1999). With such a prominent role in our society, many would suspect that everything there is to know about these fish had already been discovered. It turns out far less may be known than we assumed.

The focus of recent studies has centered on a small seemingly unremarkable fin located between the more recognizable dorsal fin and the tail. This structure, referred to as the adipose fin, is present in all salmon and trout as well as a few other fish species (Fig. 1).

The assumption had long been made that this fin was an



**Figure 1.** The adipose fin of a juvenile salmon. (a) Arrow pointing to the adipose fin between the dorsal fin and tail. (b) Close-up view of the adipose fin. Reproduced from Buckland-Nicks et al. (2012).

evolutionary relic and possessed no real function, a condition referred to as vestigial. Numerous experiments dating back nearly a century have tested whether this fin has any effect on growth or survival. Most of these studies concluded that its presence provided no advantage in the

mobility or survival of salmon (Vander Haegen et al. 2005). Operating under this assumption, it has been common for fish hatcheries to remove the adipose fin of juvenile salmon prior to release as a means of distinguishing them from fish born in the wild. The absence of this fin also allows fishermen to identify hatchery fish, legal for retention, in species that would otherwise need to be released.

Only recently have scientists started to rethink their long standing beliefs about the adipose fin. Looking at how other fish like tuna are able to maximize their speed and swimming efficiency with analogous structures called finlets has led some to speculate that the adipose could have a similar function in salmon (Reimchen and Temple 2004). Others have suggested alternate reasons for the trait's persistence. As anatomical features with no benefit tend to disappear over evolutionary time, it has also been thought that this fin may serve as a selective characteristic in reproduction (Pettersson et al. 1999). Female preference of males with larger adipose fins during spawning could offer a reason why this trait remains in certain fishes.

With new ideas bubbling to the surface of such an old topic, a team of researchers from the University of British Columbia and St. Francis University set out to do what surprisingly no one had done in the past, fully understand the structure of the adipose fin in an attempt to better understand its possible function (Buckland-Nicks et al. 2012). This was accomplished through careful laboratory examination aided by the advantages of modern equipment. One test of particular interest focused on searching for and identifying possible nervous tissues that could indicate a role as a sensory organ.

This group of Canadian scientists obtained a sample of juvenile brown trout from the Fraser's Mill fish hatchery in St. Andrews, Nova Scotia. After euthanizing the fish, the adipose fins and tissue below were carefully removed and preserved. Some fins were left whole and

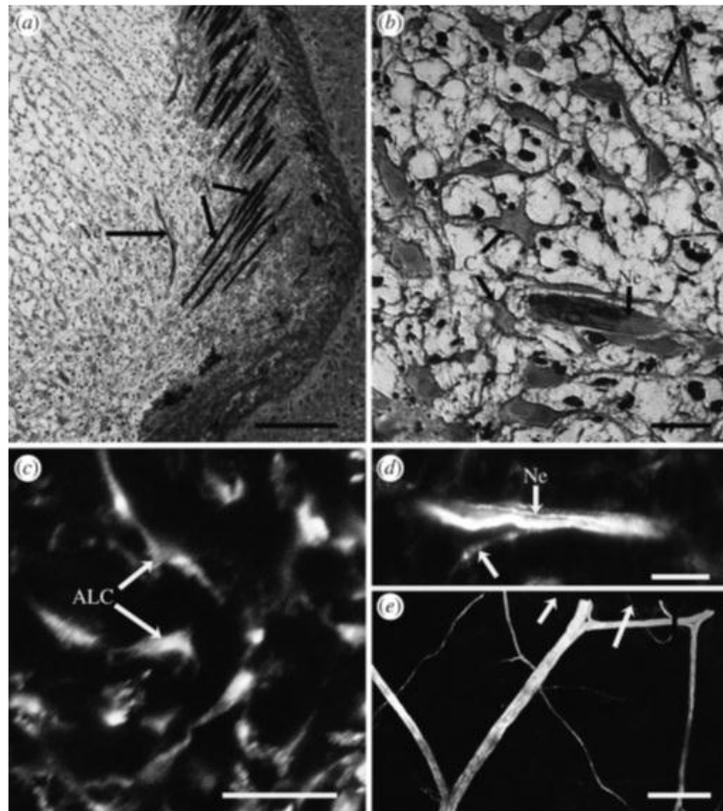
others were sliced into cross sections for further analysis. Another group of fins were treated with silver nitrate, a process commonly used to stain the nervous system. The specimens were then examined under an electron microscope and photographed to determine any results.

The initial observation of the specimens showed four distinct layers making up the structure of the adipose fin, the first three continuous with the skin of the body (Buckland-Nicks et al. 2012). The innermost space

was composed of loose connective tissues with collagen “cables” spanning opposite sides of the outer layers.

Unsurprisingly, no fatty adipose tissue as implied by the structure’s name was found. This terminology has persisted in its usage regardless of long proven studies showing otherwise (Weisel 1968). When the

samples that had received the silver nitrate staining were examined, the results were



**Figure 2.** Photographs of the microscopic structure of the adipose fin. (a) Cross section of adipose fin showing nerves (Ne) present near the supporting edge of the fin (A). (b) Enlarged portion of the inner fin layer showing a network of cells (ALC) associated with a nerve (Ne) near a collagen cable (CB). (c) Electron microscope photograph showing cellular network of stained inner fin. (d) Stained tissue showing a nerve (Ne) connected by cellular network (arrow). (e) Photograph courtesy of Dr. Roger Croll showing a nerve entering the cut edge of the adipose fin (arrows). Reproduced from Buckland-Nicks et al. (2012).

unexpected. The presence of nerves clearly associated with the collagen cables were observed in the inner layer of the fin (Buckland-Nicks et al. 2012). Nerves associated with other structural cells could also be seen forming a network within the innermost layer of the adipose fin (Fig. 2).

These nerves appear to converge at the edge of the fin which may indicate a role in environmental perception.

What makes the findings published in the resulting paper so outstanding is that for the first time unambiguous evidence has been presented that the adipose fin contains a structure composed of nerves. This presence strongly suggests that it may play an important role as a sensory organ (Buckland-Nicks et al. 2012). No muscles or supporting bones were found in the fin, hinting that its passive movement could stimulate nerves and provide information on environmental characteristics like turbulence and water flow. After many years of viewing the adipose fin as functionless, Buckland-Nicks and his colleagues (2012) have provided clear and undebatable evidence indicating the existence of a neural network.

As with many revelations, these findings have raised even more questions that deserve future exploration. Now that nerves have been shown to be present in the adipose fin, the next step should be defining which tissues play a direct role in this network (Buckland-Nicks et al. 2012). Once more is known it might be possible to attribute a specific function or advantage. This discovery could lend more credibility to previous studies observing possible sexual selection based on fin characteristics (Petersson et al. 1999).

While the work reflected in this paper focuses on nervous structure, it does not imply this is the sole purpose of the adipose fin and suggests broader exploration of functional possibilities (Buckland-Nicks et al. 2012). There may also be merit to earlier suggestions that the fin poses an advantage to swimming in swift moving water (Reimchen and Temple 2004). While most findings have rejected the idea that the presence of an adipose gives an advantage, many tests occurred in non-turbulent water (Vander Haegen et al. 2005). The exclusion of currents in experimentation could account for the lack of differentiation between adipose fin clipped and

non-clipped samples. Historically there have also been some results that disagree with this assessment. Research conducted by Saunders and Allen (1967) did show that growth was reduced in fast water fish that had received fin clipping. Whether these results were due to sensory ability or mechanical advantage should certainly be considered.

While further research is still needed, the ramifications of this discovery may warrant several changes in the academic and professional world moving forward. With evidence of nervous structure, it seems hard to continue claiming that the adipose fin is vestigial and without function. Textbooks reflecting the previous classification should be changed and an immediate attempt should be made to emphasize this new evidence in biological science education.

Perhaps the most important change would be a reevaluation of current aquaculture practices, how fish are raised in hatcheries for release into the wild. The knowledge that this fin could have a purpose and operate as a sensory organ should play heavily on the ethical considerations of its removal. Even if further examination found that fish could still survive and reproduce without the adipose, it would be best to find a different way to mark hatchery reared fish. When in doubt prudence should be exercised rather than continuing a potentially harmful practice.

This paper should serve as a reminder of our limited understanding of the world around us. We have not come close to piecing together the complexity of living organisms or the true nature of their environmental interactions. Remembering that lack of knowledge should not be equated to lack of function is an important lesson that extends beyond the topic of adipose fins. Perhaps the most inspiring point to be gained for up and coming scientists is that there is still plenty of work to be done. There remains the potential for new and groundbreaking discoveries, even in areas we thought of as a closed book.

## LITURATURE CITED

- Buckland-Nicks JA, Gillis M, Reimchen TE. 2012. Neural network detected in a presumed vestigial trait: ultrastructure of the salmonid adipose fin. *Proceedings of the Royal Society Biological Sciences*. 279(1728): 553-563.
- Lichatowich, JA. 1999. *Salmon without rivers*. Washington, D.C. Island Press.
- Petersson E, Jarvi T, Olsen H, Mayer I, Hedenskog M. 1999. Male-male competition and female choice in brown trout. *Animal Behaviour*. 57(4): 777-783.
- Reimchen TE, Temple NF. 2004. Hydrodynamic and phylogenetic aspects of the adipose fin in fishes. *Canadian Journal of Zoology*. 82(6): 910-916.
- Saunders A, Allen KR. 1967. Effects of tagging and of fin-clipping on the survival and growth of Atlantic salmon between smolt and adult stages. *Journal of the Fisheries Research Board of Canada*. 24(12): 2595-2611.
- Vander Haegen GE, Blankenship HL, Hoffmann A, Thompson DA. 2005. The effects of adipose fin clipping and coded wire tagging on the survival and growth of spring Chinook salmon. *North American Journal of Fisheries Management*. 25(3): 1161-1170.
- Weisel GF. 1968. The salmonid adipose fin. *Copeia*. 1968(3): 626-627.