CONSEQUENCES OF NESTBUILDING BEHAVIOUR
FOR OSMOREGULATION IN MALE THREE-SPINED
STICKLEBACKS

by

A. J. H. DE RUITER and S. E. WENDELAAR BONGA

(Department of Animal Physiology, University of Groningen,
P.O. Box 14, 9750 AA Haren, The Netherlands)

(With 6 Figures)

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During the last decades the complicated behaviour of three-spined
sticklebacks has not only attracted the attention of ethologists, but also of
many students of osmoregulation. The migratory behaviour, as shown
especially by the trachurus form of the three-spined stickleback, makes
high demands upon the osmoregulatory capacities of the fish during its
journey from freshwater to seawater and vice versa. Many investigators
have studied the physiological mechanisms of adaptation that enable
these fish to live in environments that are totally different in osmolality
and ion composition (Koch & Heuts, 1943; Lam, 1968; Wendelaar
Bonga, 1973, 1976; Wendelaar Bonga & Veenhuis, 1974a, b; see also
Wootton, 1976).

The nestbuilding behaviour displayed by male sticklebacks during the
reproductive period requires osmoregulatory adaptations as drastic as
seaward migration. However, whereas migration is shown by many
other fish, the nestbuilding behaviour of sticklebacks has consequences
for osmoregulation that are quite unique among the more than 20,000
species of teleosts. The materials selected for nestbuilding by male
sticklebacks are glued together with a mucous substance secreted by the
kidneys. To this end the kidneys are transformed, structurally and func-
tionally, from an important osmoregulatory organ into a mucus secreting
gland. This phenomenon offers the opportunity of studying the osmotic
and ionic homeostasis in a freshwater fish that lacks normal kidney func-
tions. Our studies have been concerned with the glandular transforma-
tion of the kidneys, the endocrine control of this process, and its conse-
quences for hydromineral control.

1) Present address: Department of Zoology, University of Nijmegen, The Netherlands.
Some principles of hydromineral regulation in freshwater fish

Ion concentrations in the blood and other body fluids are maintained at rather constant levels, which results in an osmolality of about 330 mOsmol/l in freshwater sticklebacks. Freshwater is strongly hypotonic compared to the body fluids (less than 5 mOsmol/l), and this results in osmotic water influx and loss of ions via the gills (Conte, 1969). The kidneys normally play an important role in the elimination of the water surplus, via excretion of large volumes of urine (Hickman & Trump, 1969). Due to the high ion-reabsorptive capacity of the kidney tubules, the elimination of the water can take place without substantial loss of ions (Hickman & Trump, 1969). Any loss of ions via urine or via diffusion through the gills are compensated by active uptake of ions from the food in the intestine and from the ambient water by the chloride cells in the gills (Conte, 1969; Bierther, 1970). Thus, in normal freshwater fish the kidneys, intestine and gills are vital organs for maintaining water and ion homeostasis. It is therefore surprising that male sticklebacks can live in freshwater with their kidneys transformed into mucus glands.

Structure and function of the normal stickleback kidney

The kidneys are located in the body cavity, basolaterally to the spinal column, and consist of numerous nephrons—coiled tubule-like structures—embedded in haematopoietic tissue. The nephrons are connected by short branches to the two ureters, which run laterally of the kidneys and terminate in the urinary bladder. A nephron consists of a renal corpuscle, and the attached nephronic tubule which consists of four segments.

The renal corpuscle consists of a Bowman's capsule with inside a tuft of bloodcapillaries, the glomerulus. In the three-spined stickleback the renal corpuscles are situated in small groups, mostly at the periphery of the kidney.

The nephronic tubules consist of a short neck-segment, which connects the Bowman's capsule to the remaining part of the tubule, and three main segments, namely the first and second proximal segments and the remaining collecting tubule, which opens into the ureters (Figs 1 and 2).

A glomerular filtrate is formed by means of ultrafiltration of the blood. This is processed into urine in the nephronic tubule segments, via reabsorption and secretion of substances such as ions, small proteins, sugars and amino acids. Reabsorption of ions, water and macromolecules takes place in the first proximal segment, while in the other segments mainly ions and water are reabsorbed.