

shows a trend in which the relative size of the aperture decreases northwards from Cornwall to the Isle of Man while the jugosity of the aperture (lip length) increases. However, the two most obvious trends involve PC5 (3.4 %) and PC6 (2.7 %). These include the aperture becoming relatively longer and narrower from Cornwall upto at least the Outer Hebrides, while the width of the second whorl becomes relatively larger with respect to columella length. Plotting these components against each other shows that Lewis/Harris shells form a very discrete group.

Comparison of this data with that from the south coast indicates that, with the exception of PC5, the corresponding Principal Components are strongly correlated with each other. However, the trends differ. Thus PC2 (28.2 %) and PC3 (15.3 %) indicate, respectively, that in the west the columella length and operculum area are both relatively larger with respect to lip length and apical angle, while the basal whorls are relatively larger with respect to lip length and columella length. There are no obvious trends in PC5 and PC6 but a plot of these against each other indicates that the shells from south east England form a fairly discrete group.

In summary, clines in shell shape have been demonstrated along both the west and south coasts, but each involves different aspects of shape. However, examination of PC2 in both analyses indicates a taller spire in west coast sites and a greater degree of aperture jugosity in south east England.

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New perspectives on sensitivity of littorinids to TBT pollution

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In a basic study of tributyltin (TBT) effects along the German North Sea coast between Emden and Cuxhaven we have analysed 11 *Littorina littorea* populations suffering from different TBT exposure (range of TBT body burden : 151-1289 µg as Sn/kg dry wt.). Especially in direct proximity to marinas and harbours TBT concentrations in edible winkles increase and females exhibit malformations of the pallial oviduct. Contrary to TBT induced imposex development (= "imposed sex", superimposition of male sex organs on females) in other prosobranch species (for review Fioroni *et al.*, 1991) this phenomenon was termed "intersex" and can be described by a scheme with 5 different stages. From stage 0 (normal female) to stage 1 (bursa copulatrix split ventrally), 2 (entire pallial oviduct split ventrally), 3 (prostate gland instead of the capsule/covering gland complex) and 4 (as stage 3 but with penis and sperm groove) a gradual transformation of the pallial oviduct into the corresponding male structures occurs.

It seems highly improbable that the reproductive performance of *Littorina littorea*

females is unaffected by these alterations. In stage 1 sperms are spilled off the gaping bursa copulatrix into the mantle cavity. At least the stages 2, 3 and 4 are sterilized because the formation of egg capsules is prevented either by the open structure of the pallial oviduct or by the absence of capsule and covering gland. Such curtailment of breeding activity would result in population decline. These observations can be verified by poor or no recruitment of juveniles before the TBT ban in England (Matthiessen *et al.*, 1991). Additionally, a diminution of the pallial organs of females (receptaculum seminis, albumen, capsule and covering gland) in highly TBT polluted populations is evident.

The intersex index (= ISI, calculated as the average intersex stage of a population) and the average prostate length of females demonstrate a significant and positive correlation to the TBT body burden of *Littorina littorea*. Both indices are most promising parameters for TBT biomonitoring. Obviously intersex development of edible winkles is induced at higher ambient TBT concentrations compared to the imposex phenomenon in other prosobranch species with threshold concentrations of ≤ 0.5 ng TBT as Sn/l (Gibbs *et al.*, 1987 ; Oehlmann *et al.*, 1992 ; Stroben *et al.*, 1992a, b).

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Probable extinction of prosobranch populations as result of TBT pollution in the Bay of Morlaix

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Tributyltin (TBT) induces imposex (superimposition of male sex organs on females) in prosobranch species. As its final point females of muricid gastropods are sterilized by an occlusion of the vagina (*Nucella lapillus* : Oehlmann *et al.*, 1991) or by an incomplete ontogenetic fusion of the pallial oviduct resulting in a splitted capsule gland and bursa copulatrix (*Ocenebra erinacea* : Oehlmann *et al.*, 1992). The blockade of the vagina causes an accumulation of abortive capsules in the pallial glands provoking their rupture and finally the death of the female. The vas deferens sequence (VDS) index allows an exact assessment of the imposex intensity and TBT exposure of a population ; values above 4.0 indicate that a portion of the females and values above 5.0 that all females are sterilized (Oehlmann *et al.*, 1991, 1992).

Between 1988 and 1993 more than 25,000 specimens belonging to 12 prosobranch species were analysed especially in the Bay of Morlaix. We found the highest TBT sensitivity in *Ocenebrina aciculata* (threshold concentration for female sterility ≤ 1.5 ng TBT-Sn/l), followed by *Nucella lapillus* (2.0 ng TBT-Sn/l) and *Ocenebra erinacea* (8.0 ng TBT-Sn/l).