Comparative morphology of the otolith of the triplefins (family: Tripterygiidae)

LAITH A. JAWAD

Upper Hutt, Wellington, New Zealand

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Abstract
Otolith morphology may provide useful information about the triplefin fish family Tripterygiidae. A comparative study of the otolith of 40 tripterygiid species was conducted to identify the most appropriate taxonomical characters that can separate the species and genera of the family Tripterygiidae. Among other otolith characters, it is possible to distinguish characters that clearly define a taxonomic group (genus or species), and other characters that are shared by several genera, but may be only useful to define certain species within a genus. Ontogenetic changes in the otolith of the triplefin fishes studied are evident. The otolith of the juvenile *Ucla xenogrammus* was the most similar to the adult otolith, while otolith of the juvenile *Blennodon dorsale* was the least similar to the adult otolith.

Keywords: Morphology, otoliths, SEM, triplefins, Tripterygiidae

Introduction
Otoliths or ‘ear stones’ are solid calcareous structures considered unique among vertebrates in the sense that they are not parts of the skeleton, but integral and specialized hard parts of the acoustic-lateralis system (Nolf 1985). They are enclosed in three compartments linked with the ear in teleost fishes (Popper et al. 1988). The saccular otolith (sagitta) is the largest and the utricular otolith (lapillus) is the smallest among the three (Paxton 2000), at least in most teleost families (in cyprinids the lapillus may be larger than the sagitta) (Schulz-Mirbach & Reichenbacher 2006).

The uniqueness of fish otoliths was first observed by Aristotle in the third century BC (Stinton 1975), their taxonomic utility was recognized by Cuvier (in Cuvier & Valenciennes 1836), and their value to palaeoichthyology was first acknowledged by Koken (1884). However, the use of otoliths as a taxonomic character has proliferated greatly, evidenced by the number of publications on otoliths of existing species (e.g. Hecht 1987), and fossil evidence extends back to the Devonian period (Nolf 1985).

Although the morphological features of otoliths are highly variable between species, ranging from the relatively simple disc shape of some flat fishes (Pleuronectidae) to the
irregular shape of others, a high level of species-specificity has for a long time been used to achieve various taxonomical objectives (e.g. Hecht 1987; Hunt 1992). Characteristics of populations can also be detected by the morphology of the otolith (Reichenbacher & Sienknecht 2001; Schulz-Mirbach et al. 2006).

Studies on otolith morphology of the family Tripterygiidae are very few. Chaine (1956) described the sagittal otolith of *Tripterygion tripteronotus* (Risso, 1810), using the synonym *T. nasus* (non Risso, 1826). Wirtz (1976) briefly described the otolith morphology of three existing members of the genus *Tripterygion* in the Mediterranean Sea (*T. tripteronotus*, *T. xanthosoma* Zander and Heymer, 1970, and *T. melanurus minor* Guichenot, 1850). He concluded that there are great similarities in structure between the three species, but there are also species-specific differences. Recently, Smale et al. (1995), in their otolith atlas of southern African fishes, described in detail the morphology of the saccular otolith of two triplefin fishes, *Cremnochorites capensis* Gilchrist and Thompson, 1908 and *Helgogramma obtusirostre* (Klunzinger 1871).

In New Zealand, otolith studies are scarce. Although Stinton (1957) described 11 new species of fish from the Tertiary period in New Zealand, his work did not include triplefin fish. Lalas (1983), on the other hand, published images of several unidentified tripterygiid fish species under the genus *Tripterygion* without providing a morphological description. The work of Schwarzhans (1980) on fish otoliths from the New Zealand Tertiary can be considered as the pilot work for palaeontologists in particular and ichthyologists in general. Later, Grenfell (1984) studied lower Miocene teleost otoliths from Parengarenga Harbour, New Zealand from a palaeontological perspective. Schwarzhans and Grenfell (2002) reported on the presence of otoliths of four triplefin fishes from early Nukumaruan sites of Hawkes Bay and Waipukurau. Thus, there is no work on record that deals solely with the systematics of Recent New Zealand tripterygiid otoliths.

In the present work, an attempt was made to describe the otolith morphological characters of the family Tripterygiidae collected mainly from New Zealand and from other areas such as Australia, Chile, South Africa, the Mediterranean Sea and North America. This work is intended as a contribution to ichthyology and might be considered a tool to resolve the identification problems of Tripterygiidae.

**Materials and methods**

Forty triplefin species belonging to 24 genera were obtained from New Zealand (several localities); Australia (Tasmania, Lizard Island, Avalon, Port Phillip Bay); South Africa (False Bay, Sodwana Bay); Chile (Quintero); USA (California: West Ventura); Italy (Pisa); and Spain (Ibiza: Portinax) (see Appendix 1). Only saccular otoliths were extracted from preserved specimens owing to the effect of formalin on otolith structure. These otoliths are located on the two sides of the mid-ventral ridge of the basioccipital (Ruck 1976). The otoliths were removed by turning the ventral side of the fish upward to allow removal of the lower jaw, the gills and the hypobranchial apparatus, and to expose the base of the skull. With a sharp scalpel, the otic capsules were separated and the otoliths gently removed with a pair of fine tweezers. Later, the otoliths were cleaned with 70% ethanol and stored dry in a small plastic tube. They were examined under a dissecting microscope to record the morphological characters on the mesial and lateral faces of the saccular otolith. In the systematic description of their otoliths, fish genera and species within genera are arranged alphabetically. The terminology of otolith morphology is based on Smale et al. (1995) (Figure 1). Width of the otolith is the distance between the dorsal and ventral margins,
described as deep (depth > otolith length), moderate (depth = otolith length), and slender (depth < half otolith length).

Results

The shape of the otolith in triplefins can be classified into five types: elliptic, obovate, oval, rectangular, and spindle-like (Table I; Appendix 2; Figures 1–75). It varies greatly depending on the relative size of the fish. Of the triplefins studied, 57.5% are spindle-shaped, 20% are elliptical, 17.5% are obovate and 2.5% are rectangular and oval.

The mesial surface, however, provides a wide range of ornamental sculptures that in most cases helps to differentiate taxa and may be considered among the characters that are important in solving systematic problems (Nolf 1993). The lateral surface texture is mainly smooth in most triplefins studied. However, in some species it is smooth with a shallow

Figure 1. (A) Diagram of the mesial surface of the left otoliths of *Forsterygion flavonigrum* illustrating various features which may be found on the otoliths and which are described in the text; (B) diagram of the mesial surface of the left otoliths of *Lepidoblennius haplodactylus* illustrating excisura.
Table I. Otolith characters of both adults and juvenile (important taxonomic characters).

| Species                                      | Shape | Depth | Lateral surface | Dorsal margin | Posterior margin | Shape of antirostrum |
|----------------------------------------------|-------|-------|-----------------|---------------|------------------|----------------------|
| *Acanthanectes rufus* Holleman and Buxton, 1993 (adult) (Figure 2) | 1     | 7     | 16, 17          | 18            | 23               | 32, 34, 35           |
| *Apopterygion oculus* Fricke and Roberts in Fricke, 1994 (juvenile) (Figure 3) | 2     | 8     | 10              | 20            | 26               | 37                   |
| *Apopterygion oculus* Fricke and Roberts in Fricke, 1994 (adult) (Figure 4) | 2     | 8     | 10              | 19            | 24               | 37                   |
| Bellapiscis lesleyae Hardy, 1987 (juvenile) (Figure 5) | 1     | 9     | 11, 17          | 20            | 24               | 35                   |
| Bellapiscis lesleyae Hardy, 1987 (adult) (Figure 6) | 2     | 9     | 11, 17          | 20            | 25               | 32, 36, 38           |
| Bellapiscis medius (Günther, 1861) (juvenile) (Figure 7) | 1     | 8     | 11, 17          | 20            | 24               | 35                   |
| Bellapiscis medius (Günther, 1861) (adult) (Figure 8) | 2     | 8     | 11, 17          | 20            | 25               | 30, 36, 38           |
| Blemoden dorsale (Clarke, 1879) (juvenile) (Figure 9) | 2     | 7     | 11, 17          | 18            | 24               | 35                   |
| Blemoden dorsale (Clarke, 1879) (adult) (Figures 10, 11) | 2     | 7     | 11, 17          | 20            | 23               | 32, 36, 39           |
| Ceratobregma acanthops (Whitley, 1964) (adult) (Figure 12) | 1     | 7     | 10, 17          | 21            | 26               | 36                   |
| Cremnochorites capensis (Gilchrist and Thompson, 1908) (adult) (Figure 13) | 2     | 7     | 13              | 20            | 26               | 37                   |
| Crocodilichthys gracilis Allen and Robertson, 1991 (adult) (Figure 14) | 1     | 7     | 12, 17          | 21            | 24               | 37                   |
| Cryptichthys jojettae Hardy, 1987b (juvenile) (Figure 15) | 2     | 7     | 11, 17          | 18            | 24               | 37                   |
| Cryptichthys jojettae Hardy, 1987b (adult) (Figure 16) | 2     | 7     | 11              | 18            | 24               | 37                   |
| Enneapterygius abeli (Klausewitz, 1960) (juvenile) (Figure 17) | 1     | 8     | 11, 17          | 22            | 31               | 35                   |
| Enneapterygius abeli (Klausewitz, 1960) (adult) (Figure 18) | 1     | 7     | 11, 17          | 18            | 23               | 32, 40               |
| Enneapterygius arroculare (Günther, 1873) (juvenile) (Figure 19) | 1     | 8     | 12, 17          | 20            | 23               | 37                   |
| Enneapterygius arroculare (Günther, 1873) (adult) (Figure 20) | 1     | 7     | 12, 17          | 18            | 24               | 37                   |
| Enneapterygius gracilis Fricke, 1994 (juvenile) (Figure 21) | 1     | 7     | 12, 17          | 18            | 31               | 37                   |
| Enneapterygius gracilis Fricke, 1994 (adult) (Figure 22) | 1     | 7     | 12, 17          | 18            | 24               | 37                   |
| Enneapterygius paucifasiatus Fricke, 1994 (adult) (Figure 23) | 1     | 7     | 12, 17          | 18            | 24               | 37                   |
| Enneapterygius rufopileus (Waite, 1904) (juvenile) (Figure 24) | 1     | 7     | 12, 17          | 18            | 26               | 37                   |
| Enneapterygius rufopileus (Waite, 1904) (adult) (Figure 25) | 1     | 7     | 12, 17          | 18            | 24               | 32                   |
| Enneapterygius ventermaculus Holleman, 1982 (adult) (Figure 26) | 1     | 7     | 12, 17          | 18            | 27               | 32, 34, 40           |
| Species | Shape | Depth | Lateral surface | Dorsal margin | Posterior margin | Shape of antirostrum |
|---------|-------|-------|-----------------|---------------|------------------|---------------------|
| *Forsterygion flavonigrum* Fricke and Roberts in Fricke, 1994 (juvenile) (Figure 27) | 4 | 9 | 10, 14 | 20 | 24 | 32, 38 |
| *Forsterygion flavonigrum* Fricke and Roberts in Fricke, 1994 (adult) (Figure 28) | 4 | 9 | 10, 14 | 20 | 24 | 32, 38 |
| *Forsterygion lapillum* Hardy, 1989a (juvenile) (Figure 29) | 3 | 9 | 10, 14 | 18 | 24 | 37 |
| *Forsterygion lapillum* Hardy, 1989a (adult) (Figure 30) | 3 | 9 | 10, 14 | 20 | 24 | 32, 34 |
| *Forsterygion malcolmi* Hardy, 1987a (juvenile) (Figure 31) | 3 | 7 | 11, 17 | 18 | 24 | 37 |
| *Forsterygion malcolmi* Hardy, 1987a (adult) (Figure 32) | 3 | 7 | 11, 17 | 20 | 28 | 32, 34, 38 |
| *Forsterygion varium* Forster in Bloch and Schneider, 1801 (juvenile) (Figure 33) | 3 | 7 | 10, 14 | 19 | 24 | 32 |
| *Forsterygion varium* Forster in Bloch and Schneider, 1801 (adult) (Figures 34, 35) | 3 | 7 | 10, 14 | 20 | 24 | 32 |
| *Gilloblennius abditus* Hardy, 1986 (juvenile) (Figure 36) | 2 | 7 | 10, 17 | 18 | 24 | 32, 34 |
| *Gilloblennius abditus* Hardy, 1986 (adult) (Figure 37) | 2 | 7 | 10, 17 | 20 | 24 | 33, 39 |
| *Gilloblennius tripennis* (Forster in Bloch and Schneider, 1801) (juvenile) (Figure 38) | 2 | 7 | 11, 17 | 20 | 23 | 33, 38 |
| *Gilloblennius tripennis* (Forster in Bloch and Schneider, 1801) (adult) (Figure 39) | 1 | 7 | 11, 17 | 20 | 26 | 33, 38 |
| *Grahamina capito* Jenyns, 1842 (juvenile) (Figure 40) | 3 | 7 | 10, 17 | 18 | 24 | 34, 36 |
| *Grahamina capito* Jenyns, 1842 (adult) (Figures 41, 42) | 3 | 7 | 10, 17 | 20 | 29 | 34, 36 |
| *Grahamina gymnota* (Scott, 1977) (juvenile) (Figure 43) | 3 | 7 | 10, 17 | 19 | 24 | 36 |
| *Grahamina gymnota* (Scott, 1977) (adult) (Figure 44) | 3 | 7 | 10, 17 | 20 | 28 | 34, 35 |
| *Grahamina nigripenne* (Valenciennes in Cuvier and Valenciennes, 1836) (juvenile) (Figure 45) | 3 | 7 | 10, 15 | 20 | 28 | 32, 34 |
| *Grahamina nigripenne* (Valenciennes in Cuvier and Valenciennes, 1836) (adult) (Figure 46) | 3 | 7 | 10, 15 | 20 | 28 | 32, 34 |
| *Helcogramma obtusirostre* (Klunzinger, 1871) (adult) (Figure 47) | 3 | 7 | 12, 17 | 18 | 31 | 37 |
| *Helcogramma springeri* Hansen, 1986 (juvenile) (Figure 48) | 1 | 7 | 11, 17 | 22 | 24 | 37 |
| *Helcogramma springeri* Hansen, 1986 (adult) (Figure 49) | 1 | 7 | 11, 17 | 22 | 31 | 37 |
| *Helcogrammoides cunninghami* (Smitt, 1898) (adult) (Figure 50) | 2 or 1 | 9 | 11, 17 | 20 | 24 | 32, 38 |
### Table I. (Continued).

| Species | Shape | Depth | Lateral surface | Dorsal margin | Posterior margin | Shape of anterostrum |
|---------|-------|-------|-----------------|---------------|------------------|---------------------|
| *Karalepis stewarti* Hardy, 1984 (juvenile) (Figure 51) | 2 | 7 | 10, 16, 17 | 19 | 23 | 37 |
| *Karalepis stewarti* Hardy, 1984 (adult) (Figure 52) | 1 | 7 | 10, 16, 17 | 20 | 28 | 33, 34, 38 |
| *Lepidoblennius haplopectylus* Steindachner, 1867 (juvenile) (Figure 53) | 1 | 8 | 10, 17 | 20 | 23 | 33, 36, 39 |
| *Lepidoblennius haplopectylus* Steindachner, 1867 (adult) (Figure 54) | 1 | 7 | 10, 17 | 20 | 24 | 33, 36, 39 |
| *Norfolkia clarkei* Morton, 1888 (juvenile) (Figure 55) | 1 | 7 | 11, 17 | 20 | 24 | 37 |
| *Norfolkia clarkei* (Morton, 1888) (adult) (Figure 56) | 1 | 7 | 11, 17 | 20 | 26, 30 | 37 |
| *Notoclinops caerulepunctus* Hardy, 1989 (juvenile) (Figure 57) | 1 | 9 | 11, 17 | 18 | 24, 29 | 37 |
| *Notoclinops caerulepunctus* Hardy, 1989 (adult) (Figure 58) | 1 | 9 | 11, 17 | 20 | 24 or 26 | 37 |
| *Notoclinops segmentatus* (McCulloch and Phillips, 1923) (juvenile) (Figure 59) | 1 | 7 | 11, 17 | 18 | 24 | 32, 38 |
| *Notoclinops segmentatus* (McCulloch and Phillips, 1923) (adult) (Figure 60) | 1 | 7 | 11, 17 | 20 | 24 | 32, 38 |
| *Notoclinops yaldwyni* Hardy, 1987d (juvenile) (Figure 61) | 2 | 7 | 11, 17 | 20 | 24 | 32, 34 |
| *Notoclinops yaldwyni* Hardy, 1987d (adult) (Figure 62) | 1 | 7 | 11, 17 | 20 | 24 | 32, 34 |
| *Notoclinus compressus* (Hutton, 1872) (juvenile) (Figure 63) | 4 | 7 | 12, 17 | 18 | 23 | 32, 34 |
| *Notoclinus compressus* (Hutton, 1872) (adult) (Figure 64) | 4 or 1 | 7 | 12, 17 | 18 | 23, 26 | 32, 34 |
| *Obliquichthys maryannae* Hardy, 1987 (juvenile) (Figure 65) | 3 | 9 | 10, 17 | 20 | 24 | 32, 34 |
| *Obliquichthys maryannae* Hardy, 1987 (adult) (Figure 66) | 3 | 9 | 10, 17 | 20 | 24 | 32, 38 |
| *Ruanoho decemdigitatus* (Clarke, 1879) (juvenile) (Figure 67) | 1 | 7 | 10, 17 | 19 | 24 | 32, 41 |
| *Ruanoho decemdigitatus* (Clarke, 1879) (adult) (Figure 68) | 1 | 7 | 10, 17 | 18 | 26 | 30, 34 |
| *Ruanoho whero* Hardy, 1986 (juvenile) (Figure 69) | 1 | 7 | 10, 17 | 18 | 24 | 30, 34 |
| *Ruanoho whero* Hardy, 1986 (adult) (Figure 70,71) | 1 | 7 | 10, 17 | 19 or 20 | 24 or 26 | 30, 34 |
| *Trianectes bucephalus* McCulloch and Waite, 1918 (adult) (Figure 72) | 1 | 7 | 11, 17 | 20 | 23 | 32, 34 |
| *Tripterygium tripteronotus* Risso, 1810 (adult) (Figure 73) | 5 | 7 | 12, 17 | 18 | 26 | 37 |
| *Ucla xenogrammus* Holleman, 1993 (juvenile) (Figure 74) | 1 | 7 | 11, 17 | 20 | 26 | 37 |
| *Ucla xenogrammus* Holleman, 1993 (adult) (Figure 75) | 1 | 7 | 11, 17 | 18 | 26 | 37 |
groove running across the ventral area (*Acanthanectes rufus* and *Karalepis stewarti*), irregular (*Apopterygion oculus* and *Cremnochorites capensis*), or with fine grooves radiating towards the ventral margin (*Grahamina nigripenne*).

The width of the triplefin otolith can be divided into deep, moderate, and shallow. Shallow otoliths are the most common among triplefin fishes. *Apopterygion oculus* and *Bellapiscis medius* are the only triplefins with a deep otolith. Six species were in the moderate category. The remaining species were shown to have a shallow otolith.

The shape of the dorsal margin (smooth, irregular, lobate) is characteristic within a group of related species or even among members of the same genus (see Table I; Appendix 2).

The ventral margin, on the other hand, can be divided into crenate, irregular, lobate, and smooth.

The posterior margin is usually not uniform and can be irregular, multi-lobate, pointed, rounded, or vertical. The rostrum has six forms: long, short, pointed, blunt, broad and rounded. On the other hand, the antirostrum may be absent or present. In the latter case, it has six forms: long, short, pointed, blunt, broad and rounded.

The sculptures on the mesial surface lie in an area called the sulcus, which is divided into the cauda and ostium. Anteriorly, and at the ventral side, the sulcus ends with the rostrum and dorsally with the antirostrum. The cauda and ostium can be short, long, broad, narrow, deep and shallow. In addition, an ostium may or may not lie along the rostrum. In most of the triplefin otoliths studied, the cauda is separated from the ostium by a constriction of the sulcus called an ostio-caudal differentiation. Excisura can be wide or narrow and may have a notch. If the sulcus does not reach the margin of the otolith there is no excisura, even though a notch may be present. The notch, if present, is described in the present study as shallow or deep, and the angle of the notch is known as acute or wide. The ostial rim appears to be either raised or not raised, with the former being the most common in the triplefin otolith.

In triplefin otoliths, the sulcus can be divided into three types according to shape, namely heterosulcoid, homosulcoid, and archaeosulcoid. On the other hand, the sulcus acusticus in triplefins is ostial where it opens on to the anterior (or dorsal) margin.

Developmental changes in the triplefin otolith are quite evident. The greatest intraspecific differences were found in a comparison of adult and juvenile *Blennodon dorsale* (Clarke 1879), where the otolith appeared to differ in 13 out of 17 characters. The least intraspecific differences were found in the otolith of juvenile *Ucla xenogrammus* Holleman, 1993, where it differs from the adult otolith in only one character. Differences involving four, seven, and eight characters were observed in five species and are considered the common case among the tripterygiid species studied.

The shape of the posterior margin was the character that showed differences in 20 species out of 30 species studied. On the other hand, excisura width showed differences in only three species.
Figures 2–19. (2) Acanthanectes rufus (adult), 28 mm SL. (3) Aporterygion oculus (juvenile), 37 mm SL. (4) A. oculus (adult), 48 mm SL. (5) Bellapiscis lesleyae (juvenile), 38 mm SL. (6) B. lesleyae (adult), 49 mm SL. (7) Bellapiscis medius (juvenile), 28 mm SL. (8) B. medius (adult), 66 mm SL. (9) Blennodon dorsale (juvenile), 25 mm SL. (10) B. dorsale (adult), 115 mm SL. (11) B. dorsale (adult), 135 mm SL. (12) Ceratobregma acanthops (adult), 23 mm SL. (13) Cremnochorites capensis (adult), 54 mm SL. (14) Crocodilichthys gracilis (adult), 31 mm SL. (15) Cryptichthys jojettae (juvenile), 22 mm SL. (16) C. jojettae (adult), 41 mm SL. (17) Enneapterygus abeli (juvenile), 18 mm SL. (18) E. abeli (adult), 23 mm SL. (19) Enneapterygus atrogulare (juvenile), 18 mm SL.
Figures 20–37. (20) *Enneapterygius atrogulare* (adult), 27 mm SL. (21) *Enneapterygius gracilis* (juvenile), 16 mm SL. (22) *E. gracilis* (adult), 21 mm SL. (23) *Enneapterygius paucifaciatus* (adult), 24 mm SL. (24) *Enneapterygius rufopileus* (juvenile), 28 mm SL. (25) *E. rufopileus* (adult), 39 mm SL. (26) *Enneapterygius ventermaculatus* (adult), 14 mm SL. (27) *Forsterygion flavonigrum* (juvenile), 26 mm SL. (28) *F. flavonigrum* (adult), 50 mm SL. (29) *Forsterygion lapillum* (juvenile), 24 mm SL. (30) *F. lapillum* (adult), 59 mm SL. (31) *Forsterygion malcolmi* (juvenile), 38.8 mm SL. (32) *F. malcolmi* (adult), 91 mm SL. (33) *Forsterygion varium* (juvenile), 37 mm SL. (34) *F. varium* (adult), 100 mm SL. (35) *F. varium* (adult), 110 mm SL. (36) *Gilloblennius abditus* (juvenile), 27 mm SL. (37) *G. abditus* (adult), 41 mm SL.
Figures 38–55. (38) Gilloblennius tripennis (juvenile), 67 mm SL. (39) G. tripennis (adult), 113 mm SL. (40) Grahamina capito (juvenile), 34.3 mm SL. (41) G. capito (juvenile), 35 mm SL. (42) G. capito (adult), 82.8 mm SL. (43) Grahamina gymnota (juvenile), 36 mm SL. (44) G. gymnota (adult), 85 mm SL. (45) Grahamina nigripenne (juvenile), 33 mm SL. (46) G. nigripenne (adult), 86 mm SL. (47) Helcogramma obtusirostre (adult), 38 mm SL. (48) Helcogramma springeri (juvenile), 24 mm SL. (49) H. springeri (adult), 32 mm SL. (50) Helcogrammoides cunninghami (adult), 24 mm SL. (51) Karalepis stewarti (juvenile), 36 mm SL. (52) K. stewarti (adult), 117 mm SL. (53) Lepidoblennius haplodactylus (juvenile), 36 mm SL. (54) L. haplodactylus (adult), 76 mm SL. (55) Norfolkia clarkei (juvenile), 35 mm SL.
Figures 56–75. (56) *Norfolkia clarkei* (adult), 57 mm SL. (57) *Notoclinops caeruleopunctus* (juvenile), 25 mm SL. (58) *N. caeruleopunctus* (adult), 38 mm SL. (59) *Notoclinops segmentatus* (juvenile), 15 mm SL. (60) *N. segmentatus* (adult), 47 mm SL. (61) *Notoclinops yaldwyni* (juvenile), 20 mm SL. (62) *N. yaldwyni* (adult), 51 mm SL. (63) *Notoclinus compressus* (juvenile), 54 mm SL. (64) *N. compressus* (adult), 72 mm SL. (65) *Obliquichthys maryannae* (juvenile), 27 mm SL. (66) *O. maryannae* (adult), 53 mm SL. (67) *Ruanoho decemdigitatus* (juvenile), 38 mm SL. (68) *R. decemdigitatus* (adult), 102 mm SL. (69) *Ruanoho whero* (juvenile), 30 mm SL. (70) *R. whero* (adult), 75 mm SL. (71) *R. whero* (adult), 77 mm SL. (72) *Trianeutes bucephalus* (adult), 67 mm SL. (73) *Tripterygion tripteronotus* (adult), 48 mm SL. (74) *Ucla xenogrammus* (juvenile), 23 mm SL. (75) *U. xenogrammus* (adult), 44 mm SL.
Interspecific variation in otolith morphology has been documented to be substantial (e.g. Chaine & Duvergier 1934; Nolf 1985; Reichenbacher 2000). However, this variation is dependent on the ontogenetic stage of the fish (Smale et al. 1995; Aguire & Lombarte 1999). There are some landmark morphological features of the saccular otoliths that are of help in taxonomic studies (Figure 1), such landmarks being documented in the works of several authors since the early 20th century (e.g. Chaine & Duvergier 1934; Nolf 1985, 1988). Because of their large size and degree of interspecific differences, teleost saccular otoliths are a widely used tool in comparative taxonomic studies.

This study of otolith morphology in the triplefins dealt with a wide range of otolith characters. From such characters, it is possible to select some that are useful in tripterygiid systematics. This study is considered preliminary because, of a total of 132 tripterygiid species (Eschmeyer 1990), only 30.3% have so far been examined. However, 24 of the 29 genera have been studied, so a reasonable survey was possible at this level.

During the present work it was possible to distinguish two groups of otolith features: (1) exclusive characters that clearly define a taxonomic group (genus or species); (2) characters that are shared by several genera, but that may be useful to define certain species within a genus.

Because the rectangular and oval otolith shapes are reported only for Notoclinus and Tripterygion triperonotus, respectively, these characters might be considered as synapomorphy for those taxa. Similarly, an elliptical shape is found in members of the genera Forsterygion, Grahamina, and Obliquichthys only. Thus, it is considered to be a synapomorphy for these genera and can separate them from the rest of the triplefin genera. The similarity in otolith shape between members of the genus Forsterygion and Obliquichthys maryannae supports the finding of Schwarzhans and Grenfell (2002) who reported similarities among Forsterygion varium, F. lapillum, F. flavonigrum, and Obliquichthys maryannae. Although the shape character of the otolith was variable to a certain extent, there were no genera with multiple shapes, except for the genus Gilloblennius, in which G. abditus has an obovate otolith and G. tripennis has a spindle-shaped otolith. However, the juvenile of the latter species has an obovate shape.

The depth of the triplefin otolith varies in different species, but their taxonomic significance is unclear. On the other hand, the deep otolith might be considered a distinctive character for the otolith of Apopterygion oculus and Bellapiscis medius.

The otolith ventral margin has different shapes in different species, but the taxonomic significance is unclear. On the other hand, the crenate shape is considered a distinctive character for Acanthanectes rufus. Smooth and irregular ventral margins were in the major triplefins studied. A lobate ventral margin is a character of Forsterygion malcolmii,
Helcogramma springeri, and Helcogrammoides cunninghami. Thus, it is considered a good taxonomic criterion for differentiating those species within their genera.

A variety of shapes for the posterior margin is also evident among the triplefin species studied (see Table I).

The shape of the sulcus acusticus is a variable character across triplefin species. Most of the species have a homosulcoid-type sulcus acusticus (see Table I). Clearly, the shape of the sulcus acusticus is shared by genera for which a close relationship has not been confirmed.

In the present work, the otolith antirostrum showed variation in size, shape, presence and absence. None of these characters successfully discriminated among the triplefins studied. On the other hand, a pointed or blunt antirostrum appeared to differentiate Lepidoblennius haplodactylus and members of the genus Bellapiscis, respectively.

Ostium, cauda, ostio-caudal differentiation, crista superior, crista inferior, dorsal depression, rostrum, excisura and ostial rim are not considered good taxonomic characters for discriminating among the triplefins that were studied.

As in other teleost fishes (Nolf 1985, Figure 8; Smale et al. 1995; Reichenbacher 2000, Figure 37), ontogenetic variations in triplefin otolith structure are evident. Juvenile otoliths showed some variation in morphology from that of adults. The otolith of juvenile Ucla xenogrammus was the most similar to the adult, but differs in the shape of the dorsal margin where there is a notch in the juvenile otolith. On the other hand, the otolith of juvenile Blennodon dorsale was the most variable and showed the least similarity to the adult otolith. It differs in 13 characters out of the 17 characters studied.

The degree of variability of characters among juvenile otoliths also differs between the species of triplefin studied. The shape of the posterior margin, for example, was the most variable character. It showed variation from the adult otolith in 20 species studied. On the other hand, characters such as shape of otolith, and ostial rim were the most conservative. The shape of the posterior margin is not considered as a good taxonomic character because of low variability among species, but high variability within species.

The above ontogenetic differences in otolith structure are important from the taxonomic point of view and should be considered in any such study based on otolith morphology. Young individuals of the same species might be classified as a different species on the basis of otolith shape.

It is difficult to write a key to separate the triplefin fish species based on the morphological characters of their otoliths. However, it was possible to separate certain genera and species. For example, Acanthanectes rufus (with rectangular otolith shape), Apopterygion oculus (with lobate dorsal margin), Blennodon dorsale (with irregular posterior margin and blunt antirostrum), members of the genus Forsterygion, Grahamina, and Obliquichthys (with elliptic otolith shape), Lepidoblennius haplodactylus (with pointed antirostrum), Notoclinus compressus (with rectangular otolith shape) and Tripterygion tripteronotus (with ovate otolith shape).

Among the 132 species of the triplefin family Tripterygiidae (Eschmeyer 1990), six species only have been used to study otolith morphology (Wirtz 1976; Smale et al. 1995) in previous studies. There is no otolith-based fossil record of triplefins (Schwarzhans 1980). The otolith morphology given for Cremnochorites capensis and Helcogramma obtusirostre by Smale et al. (1995) agrees with that given in the present work. Both descriptions agree regarding the main otolith structures. They differ in other otolith characters such as those depending on size. Smale et al. (1995) showed that the size of the fish has a great effect on the shape variation of the otolith. This is clear in the otolith specimens of Cremnochorites capensis and Helcogramma obtusirostre described by those authors.
**Tripterygon tripteronotus** is a Mediterranean triplefin whose otoliths were described for the first time by Chaine (1956), using the synonym *Tripterygion nasus*, and later by Wirtz (1976). Although the description of Wirtz (1976) was concise, the characters he mentioned for *Tripterygon tripteronotus* otolith agree with that of the present work.

The morphology of the saccular otoliths certainly contributes a major diagnostic feature in most teleostean fishes (e.g. Nolf 1993; Assis 2000). However, otoliths alone cannot be taken as a sufficient argument for modifying existing classifications. Otoliths can suggest affinities between groups that appear to be otherwise disparate and vice versa. These suggestions can be tested by osteological and other anatomical characters, which should confirm or refute the systematic value of otolith features.

It is well established that morphology of the saccular otoliths, the sagitta, is not only related to common ancestry, but also to the habitat where a particular species of fish lives (Schwarzhanz 1978; Nolf 1985, 1993) and to the anatomical specialization connected with sound perception (Nolf 1985, 1993; Popper & Platt 1993). There are, therefore, different degrees of morphological convergence among evolutionarily distant taxa and divergence among evolutionarily close ones (Nolf 1985, 1993). Nevertheless, it is clear that the characteristics of the otoliths can be of considerable relevance, in conjunction with other characters of the fish body, to increase the information available in studies of fish systematics and phylogeny.

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**References**

Aguire H, Lombarte A. 1999. Ecomorphological comparisons of sagittae in *Mullus barbatus* and *M. surmuletus*. Journal of Fish Biology 55:105–114.

Assis CAS. 2000. Estudo morfologico dos otolitos sagitta, astericus e lapillus de teleosteos (Actinopterygii, Teleostei) de Portugal Continental. Sua Aplicacao em estudos de filogenia, Sistematica e Ecologia [PhD thesis]. Lisbon: University of Lisbon.

Chaine J. 1956. Recherches sur le otoliths des poissons. Etude descriptive et comparative de la sagitta des teleostéens. Bulletin du Centre d’Études Recherches Scientifiques 1:159–275.

Chaine J, Duvergier J. 1934. Recherches sur les otoliths des poissons étude descriptive et comparative de la sagitta des teleostéens. Actes de la Société Linnéenne de Bordeaux 86:5–254.

Cuvier G, Valenciennes A. 1836. Histoire naturelle des poissons. Paris: Libraire de la Société Géologique de France.
Appendix 1. List of the material examined

All localities are in New Zealand, except for those where the country has been given. Specimens without registration number belong to the University of Auckland, New Zealand. The following abbreviations are used: AMSA, Australian Museum, Sydney,
Australia; NMNZ, Museum of New Zealand, Te Papa tongarewa, Wellington, New Zealand; SL, standard body length.

*Acanthanectes rufus* (*n=3*). 27–28 mm SL, South Africa, 1999.

*Apopterygion oculus* (*n=3*). 48 mm SL, Mernoo Bank, Chatham Rise, Tangaroa, 12 January 1979, NMNZ P. 25176; 37 mm SL, Foveaux Strait, Oyster dredge, no date, NMNZ P. 25335; 30 mm SL, Canterbury Bight, R/V *James Cook*, January 1974, NMNZ P. 17205.

*Bellapiscis lesleyae* (*n=6*). 2, 40–49 mm SL, Mathesons Bay, Hauraki Gulf, 27 January 1997; 2, 38–45 mm SL, Cape Rodney, Hauraki Gulf, 20 November 1997; 2, 44–47 mm SL, Stirling Point, 26 January 1998.

*Bellapiscis medius* (*n=16*). 6, 28–58 mm SL, Horseshoe Bay, Stewart Island, 3 January 1998; 10, 41–66 mm SL, Huia, Manukau Harbour, Auckland, 21 June 1998.

*Blennodon dorsale* (*n=7*). 2, 25–30 mm SL, Muriwai, 9 October 1999; 76 mm SL, Whatipu, Manukau Entrance, 8 April 2001; 4, 112–135 mm SL, First Point, Makara Beach, Wellington, 15 April 2001.

*Ceratobregma acanthops* (*n=6*). 6, 23–36 mm SL, Lizard Island, Australia, 24 December 1997.

*Cremnochorites capensis* (*n=4*). 4, 54–74 mm SL, False Bay, South Africa, January 1997.

*Crocodilichthys gracilis* (*n=20*). 20, 31–47 mm SL, West Ventura, California, USA, 1997.

*Cryptichthys jojettae* (*n=23*). 6, 26–39 mm SL, Breaker Bay, Wellington, 9 February 1998; 6, 30–41 mm SL, Mokohinau Islands, 16 April 1998; 11, 22–28 mm SL, Three Kings Islands, 2 March 1999.

*Enneapterygius abeli* (*n=6*). 6, 18–23 mm SL, Sodwana Bay, South Africa, 29 May 2001.

*Enneapterygius atrogulare* (*n=17*). 17, 18–27 mm SL, Lizard Island, Australia, 19 December 1997.

*Enneapterygius gracilis* (*n=9*). 9, 16–21 mm SL, Lizard Island, Australia, 19 December 1997.

*Enneapterygius pausifasciatus* (*n=5*). 5, 18–24 mm SL, Lizard Island, Australia, 23 December 1997.

*Enneapterygius rufopileus* (*n=7*). 7, 28–39 mm SL, Australia, 18 April 1997, UN.7710-014.

*Enneapterygius ventermaculus* (*n=7*). 7, 12–14 mm SL, Sodwana Bay, South Africa, 28 May 2001.
Forsterygion flavonigrum \((n=7)\). 2, 26–28 mm SL, Otago, 2 May 1998; 5, 45–50 mm SL, Ulva Islands, Stewart Island, 30 January 1998.

Forsterygion lapillum \((n=10)\). 1, 24 mm SL, Hen and Chicken Islands, Hauraki Gulf, 6 February 1997; 9, 46–59 mm SL, Ulva Islands, Stewart Island, February 1998.

Forsterygion malcomi \((n=13)\). 4, 38.8 mm SL, Stewart Island, 30 January 1998; 9, 42–91 mm SL, Mokohinau Islands, 18 February 1998.

Forsterygion varium \((n=10)\). 5, 37–100 mm SL, Ulva Island, Stewart Island, 1 February 1998; 5, 48–110 mm SL, Island Bay, Wellington, 7 February 1998.

Gilloblennius abditus \((n=5)\). 5, 27–41 mm SL, Kapiti Island, 6 March 1996, NMNZ P. 33278.

Gilloblennius tripennis \((n=3)\). 2, 93–113 mm SL, north end of Ringaringa Bay, Oban, Stewart Island, 7 March 1992, NMNZ P. 27627; 67 mm SL, Horoera Point, 23 January 1993, NMNZ P. 29990.

Grahamina capito \((n=12)\). 7, 34.1–82.8 mm SL, Island Bay, Wellington, 7 and 8 January 2000; 5, 57.3–73.3 mm SL, Seatoun Wharf, Wellington, 8 January 2000.

Grahamina gymnota \((n=23)\). 11, 36–85 mm SL, Queens Wharf, Wellington, 23 April 2000; 12, 43–56 mm SL, Orapiu Wharf, Waiheke Island, 29 and 30 December 1999, 1 January 2000.

Grahamina nigripenne \((n=25)\). 12, 33–86 mm SL, Whangateau Wharf, Whangateau Estuary, 13 December 1999; 10, 40–69 mm SL, Mill Greek, Halfmoon Bay, Stewart Island, 3 March 1992.

Helcogramma obtusirostre \((n=10)\). 10, 21–38 mm SL, Sodwana Bay, South Africa, 27 May 2001.

Helcogramma springeri \((n=20)\). 18, 24–32 mm SL, Lizard Island, Australia, 24 December 1997.

Helcogrammoides cunninghami \((n=1)\). 24 mm SL, Playa El Durazno, Quintero, Chile, 28 November 1999.

Karalepis stewarti \((n=37)\). 19, 36–117 mm SL, Three Kings Islands, 1 March 1999; 18, 41–102 mm SL, Mokohinau Islands, 21 January 1998.

Lepidoblennius haplodactylus \((n=30)\). 30, 36–76 mm SL, Avalon, Sydney, Australia, 23 April 1997.

Norfolkia clarkei \((n=24)\). 6, 35–57 mm SL, Port Phillip Bay, Victoria, Australia, 9 April 1997; 18, 42–50 mm SL, Port Phillip Bay, Victoria, Australia, 12 February 2000.
Notoclinops caerulepunctus (n=17). 5, 25–30 mm SL, Cathedral Rock, 20 January 1998; 12, 28–38 mm SL, Fanal Island, Hauraki Gulf, 20 January 1998.

Notoclinops segmenta (n=11). 3, 15–26 mm SL, Hen and Chicken Islands, Hauraki Gulf, 6 February 1997; 8, 34–47 mm SL, Horseshoe Bay, Pukoroi Bay, Stewart Island, 28 January 1998.

Notoclinops yaldwyni (n=13). 4, 20–47 mm SL, Mokohinau Islands, 20 January 1998; 9, 40–51 mm SL, Breaker Bay, Wellington, 9 February 1998.

Notoclinus compressus (n=8). 5, 64–72 mm SL, Manukau Bay, Owenga, Chatham Island, 4 February 1991; 3, 54–58 mm SL, Rurina Island, off Whale Island, eastern Bay of Plenty, 7–10 m, 2 June 1998.

Obliquichthys maryannae (n=26). 18, 27–47 mm SL, Three Kings Islands, 1 March 1999; 8, 44–53 mm SL, Kaikoura, 15 October 1997.

Ruanoho decemdigitatus (n=11). 38 mm SL, Island Bay, 7 February 1998; 10, 62–102 mm SL, Breaker Bay, 9 February 1998.

Ruanoho whero (n=21). 9, 57–77 mm SL, Ulva Islands, Stewart Island, 30 January 1998; 12, 30–56 mm SL, Mokohinua Islands, 19 January 1998.

Trianectes bucephalus (n=4). 4, 65–67 mm SL, Portsea Pier, Port Phillip Bay, Victoria, Australia, 12 April 1977, I.19777-003 (AMSA).

Tripterygion tripteronotus (n=7). 7, 38–48 mm SL, Portinax (Ibiza), Spain, July 2001.

Ucla xenogrammus (n=25). 25, 23–44 mm SL, Lizard Island, Australia, 14 December 1997.
## Appendix 2. Otolith characters of both adults and juvenile (less important taxonomic characters)

| Species | Character |
|---------|----------|
| **Acanthanectes rufus** Holleman and Buxton, 1993 (adult) (Figure 2) | 1 10 21, 22 25, 27, 29, 33, 35, 37, 39, 41 |
| **Apopterygion oculus** Fricke and Roberts in Fricke, 1994 (adult) (Figure 3) | 1 10 21, 22 25, 28, 29, 34, 36, 37, 39 |
| **Apopterygion oculus** Fricke and Roberts in Fricke, 1994 (juvenile) (Figure 4) | 1 10 21, 22 25, 28, 29, 32 33, 35, 38, 41 |
| **Bellapiscis lesleyae** Hardy, 1987 (juvenile) (Figure 5) | 1 11, 19 21, 22 25, 27, 29, 31 34, 35, 37 |
| **Bellapiscis lesleyae** Hardy, 1987 (adult) (Figure 6) | 1 11, 19 21, 22 25, 27, 29, 31 34, 35, 37 |
| **B. medius** (Günther, 1861) (juvenile) (Figure 7) | 2 10, 12 21, 22 25, 27, 29, 32 33, 35, 38, 41 |
| **Bellapiscis medius** (Günther, 1861) (adult) (Figure 8) | 2 10 21, 22 25, 27, 29, 32 33, 35, 37 |
| **Blennodon dorsale** Clarke, 1879 (juvenile) (Figure 9) | 1 9 21, 22 25, 27, 29, 32 33, 35, 37 |
| **Blennodon dorsale** Clarke, 1879 (adult) (Figures 10, 11) | 1 10 21, 22 26, 28, 29, 31 32, 35, 36, 38 |
| **Ceratobregma acanthops** (Whitley, 1964) (adult) (Figure 12) | 1 10 21, 23 25, 27, 29, 32 33, 35, 38 |
| **Cremnochorites capensis** (Gilchrist and Thompson, 1908) (adult) (Figure 13) | 3 10 21, 23 25, 27, 29, 32 33, 37 |
| **Crocodilichthys gracilis** Allen and Robertson, 1991 (adult) (Figure 14) | 3 9 21, 22 26, 27, 29, 30, 31 33, 35, 37, 40 |
| **Cryptichthys jojettae** Hardy, 1987b (juvenile) (Figure 15) | 3 9 21, 22 25, 28, 29, 32 34, 35, 38 |
| **Cryptichthys jojettae** Hardy, 1987b (adult) (Figure 16) | 3 9 21, 22 25, 28, 29, 32 34, 35, 38 |
### Forsterygion flavonigrum

| Species | Character | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---------|-----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Enneapterygius abeli (Klausewitz, 1960) (juvenile) (Figure 17) | 1 | 10 | 21, 24 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 48 | 53 | 59 | 64 | 67, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius abeli (Klausewitz, 1960) (adult) (Figure 18) | 1 | 9 | 21, 24 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 48 | 53 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius atrogulare Günther, 1873 (juvenile) (Figure 19) | 1 | 9 | 21, 23 | 26, 27, 33, 35, 29, 31 | 37 | 45 | 48 | 55 | 61 | 64 | 68, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius atrogulare Günther, 1873 (adult) (Figure 20) | 1 | 9 | 21, 23 | 26, 27, 33, 35, 29, 31 | 37 | 45 | 48 | 55 | 61 | 64 | 68, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius gracilis Fricke, 1994 (juvenile) (Figure 21) | 1 | 10 | 21, 23 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 48 | 55 | 63 | 64 | 67, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius gracilis Fricke, 1994 (adult) (Figure 22) | 1 | 9 | 21, 23 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 48 | 55 | 59 | 64 | 67, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius paucifasiatus Fricke, 1994 (adult) (Figure 23) | 1 | 9 | 24 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 50 | 55 | 59 | 64 | 67, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius rufopileus (Waite, 1904) (juvenile) (Figure 21) | 1 | 14 | 21, 24 | 26, 27, 34, 35, 30, 31 | 37 | 45 | 48 | 53 | 59 | 64 | 68, 69 | 76 | 82 | 85 | 90 |
| Enneapterygius rufopileus Waite, 1904 (adult) (Figure 25) | 1 | 9 | 21, 24 | 26, 27, 34, 35, 30, 31 | 37 | 45 | 48 | 55 | 61 | 64 | 67, 70 | 76 | 82 | 85 | 90 |
| Enneapterygius ventermaculus Hollema, 1982 (adult) (Figure 26) | 1 | 9 | 21, 24 | 26, 27, 34, 35, 29, 31 | 37 | 45 | 48 | 55 | 59 | 64 | 67, 70, 74 | 76 | 82 | 85 | 90 |
| Forsterygion flavonigrum Fricke and Roberts in Fricke, 1994 (juvenile) (Figure 27) | 3 | 14 | 21, 23 | 25, 27, 33, 35, 30, 31 | 37, 42 | 45 | 48 | 53 | 58 | 64 | 67, 69, 72 | 74 | 82 | 85 | 87 |
| Forsterygion flavonigrum Fricke and Roberts in Fricke, 1994 (adult) (Figure 28) | 3 | 9, 18 | 21, 23 | 25, 27, 33, 35, 30, 31 | 37, 42 | 45 | 48 | 53 | 58 | 64 | 67, 69, 72 | 74 | 82 | 85 | 87 |
| Forsterygion lapillum Hardy, 1989a 5, 7, 8 (juvenile) (Figure 29) | 9 | 21, 22 | 26, 27, 33, 35, 32, 37, 43 | 45 | 48 | 53 | 62 | 64 | 69, 72 | 76 | 82 | 85 | 86 |
| Forsterygion lapillum Hardy, 1989a 5, 7, 8 (adult) (Figure 30) | 9 | 21, 22 | 26, 27, 33, 35, 32, 37, 43 | 45 | 48 | 53 | 63 | 64 | 68, 70 | 76 | 82 | 85 | 86 |
| Forsterygion malcolmii Hardy, 1987a (juvenile) (Figure 31) | 3 | 10, 19 | 21, 23 | 26, 27, 34, 35, 29, 31 | 38 | 46 | 48 | 57 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 87 |
### Appendix 2. (Continued).

| Species | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forsterygion malcolmi Hardy, 1987a (adult) (Figure 32) | 3 | 13, 19 | 21, 23 | 26, 27, 34, 35 | 29, 31 | 37 | 46 | 48 | 57 | 59 | 64 | 68, 69, 70 | 76 | 82 | 85 | 87 |
| Forsterygion varium Forster in Bloch and Schneider, 1801 (juvenile) (Figure 33) | 3 | 10 | 21, 23 | 26, 27, 33, 35 | 29, 31 | 37, 44 | 46 | 48 | 57 | 59 or 63 | 64 | 67, 69, 72 | 76 | 82 | 85 | 86 |
| Forsterygion varium Forster in Bloch and Schneider, 1801 (adult) (Figures 34, 35) | 3 | 10 | 21, 23 | 26, 27, 33, 35 | 29, 31 | 37, 44 | 46 | 50 | 57 | 59 or 63 | 64 | 67, 69, 72 | 76 | 82 | 85 | 86 |
| Gilloblennius abditus Hardy, 1986 (juvenile) (Figure 36) | 1 | 10 | 21, 22 | 26, 27, 34, 35 | 30, 31 | 37 | 46 | 48 | 53 | 58 | 64 | 68, 69, 77 | 81 | 83 | 86 | 90 |
| Gilloblennius abditus Hardy, 1986 (adult) (Figure 37) | 1 | 9 | 21, 22 | 26, 27, 34, 35 | 29, 31 | 37 | 46 | 48 | 55 | 59 | 64 | 67, 69, 73 | 77 | 79 | 84 | 90 |
| Gilloblennius tripennis (Forster in Bloch and Schneider, 1801) (juvenile) (Figure 38) | 3 | 10 | 21, 22 | 26, 27, 34, 35 | 30, 32 | 37 | 45 | 48 | 53 | 58 | 64 | 68, 69, 73 | 76 | 82 | 85 | 86 |
| Gilloblennius tripennis (Forster in Bloch and Schneider, 1801) (adult) (Figure 39) | 3 | 10 | 21, 22 | 26, 27, 34, 35 | 30, 31 | 37 | 45 | 51 | 55 | 58 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
| Grahamina capito Jenyns, 1842 (juvenile) (Figure 40) | 1 | 14 | 21, 22 | 27, 25, 33, 35 | 30, 31 | 37 | 45 | 49 | 54 | 59 | 64 | 67, 69, 73 | 76 | 82 | 85 | 88 |
| Grahamina capito Jenyns, 1842 (adult) (Figures 41, 42) | 1 | 10 | 21, 22 | 26, 27, 34, 35 | 29, 31 | 37 | 45 | 49 | 54 | 59 | 64 | 67, 69, 73 | 76 | 82 | 85 | 86 |
| Grahamina gymnota (Scott, 1977) (juvenile) (Figure 43) | 3 | 10 | 21, 23 | 26, 27, 34, 35 | 29, 31 | 37 | 45 | 48 | 53 | 63 | 64 | 67, 69, 73 | 76 | 82 | 85 | 89 |
| Grahamina gymnota (Scott, 1977) (adult) (Figure 44) | 3 | 10 | 21, 23 | 26, 27, 34, 35 | 29, 31 | 37 | 45 | 48 | 53 | 63 | 64 | 68, 69, 73 | 76 | 82 | 85 | 90 |
| Grahamina nigripenne (Valenciennes in Cuvier and Valenciennes, 1836) (juvenile) (Figure 45) | 3 | 11 | 21, 23 | 26, 27, 34, 35 | 29, 31 | 37 | 46 | 49 | 54 | 58 | 64 | 67, 69, 73 | 76 | 82 | 85 | 86 |
| Grahamina nigripenne (Valenciennes in Cuvier and Valenciennes, 1836) (adult) (Figure 46) | 3 | 10 | 21, 23 | 26, 27, 34, 35 | 29, 31 | 37 | 46 | 49 | 54 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
### Appendix 2. (Continued).

| Species                                      | Character | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|----------------------------------------------|-----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Helcogramma obtusirostre (Klunzinger, 1871)  |           | 1 | 9 | 21, 22 | 26, 27, 34, 35, 39, 31 | 46 | 50 | 55 | 59 | 64 | 67, 73 | 76 | 82 | 85 | 86 |
| Helcogramma springeri Hansen, 1986 (juvenile) |           | 1 | 14 | 21, 22 | 26, 27, 34, 35, 39, 31 | 46 | 49 | 54 | 59 | 64 | 68, 69, 70 | 76 | 82 | 85 | 86 |
| Helcogramma springeri Hansen, 1986 (adult)   |           | 1 | 17 | 21, 22 | 26, 27, 34, 35, 39, 31 | 47 | 50 | 55 | 59 | 64 | 68, 69, 70 | 76 | 82 | 85 | 86 |
| Helcogrammoides cunninghami (Smitt, 1898)    |           | 3 | 20 | 21, 22 | 25, 27, 34, 35, 39, 31 | 45 | 50 | 53 | 59 | 64 | 67, 69, 73 | 76 | 82 | 85 | 86 |
| Karalepis stewarti Hardy, 1984 (juvenile)    |           | 3 | 10 | 21, 22 | 26, 27, 34, 35, 39, 31 | 46 | 49 | 54 | 59 | 64 | 68, 69, 78 | 76 | 80 | 84 | 86 |
| Karalepis stewarti Hardy, 1984 (adult)      |           | 3 | 10, 19 | 21, 22 | 26, 27, 34, 35, 39, 31 | 46 | 49 | 54 | 59 | 64 | 67, 69, 78 | 76 | 80 | 84 | 86 |
| Lepidoblennius haplodactylus Steindachner, 1867 (juvenile) | | 3 | 10 | 21, 24 | 26, 27, 34, 35, 39, 31 | 46 | 51 | 56 | 59 | 64 | 67, 69, 70, 75 | 77 | 79 | 83 | 86 |
| Lepidoblennius haplodactylus Steindachner, 1867 (adult) | | 3 | 10 | 21, 24 | 26, 27, 34, 35, 39, 31 | 46 | 51 | 56 | 59 | 64 | 67, 69, 70, 75 | 77 | 79 | 83 | 86 |
| Norfolkia clarkei (Morton, 1888) (juvenile)  |           | 1 | 10 | 21, 23 | 26, 27, 34, 35, 39, 31, 32 | 46 | 49 | 54 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
| Norfolkia clarkei (Morton, 1888) (adult)    |           | 1 | 10 | 21, 23 | 26, 27, 34, 35, 39, 31, 32 | 46 | 48 | 56 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
| Notoclinops caerulepunctus Hardy, 1989 (juvenile) | | 1 | 9 | 21, 23 | 25, 27, 34, 35, 39, 31, 32 | 46 | 48 | 54 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
| Notoclinops caerulepunctus Hardy, 1989 (adult) | | 1 | 11 | 21, 23 | 25, 30, 34, 35, 39, 31, 32 | 45 | 50 | 53 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
| Notoclinops segmentatus (McCulloch and Phillips, 1923) (juvenile) | | 1 | 9 | 21, 23 | 25, 27, 34, 36, 39, 31, 32 | 46 | 50 | 55 | 59 | 64 | 67, 69, 70 | 76 | 82 | 85 | 90 |
| Notoclinops segmentatus (McCulloch and Phillips, 1923) (adult) | | 1 | 10, 15 | 21, 23 | 25, 27, 34, 36, 39, 31, 32 | 46 | 49 | 53 | 58 | 64 | 67, 69, 70 | 76 | 82 | 85 | 86 |
### Appendix 2. (Continued).

| Species                                           | Character                                      | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---------------------------------------------------|------------------------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Notoclinops yaldwyni* Hardy, 1987d (juvenile)    | (Figure 61)                                    | 1 | 16| 21, 23 | 25, 27 | 33, 35 | 46 | 48 | 54 | 59 | 64 | 68, 69 | 76 | 82 | 85 | 86 |
| *Notoclinops yaldwyni* Hardy, 1987d (adult)      | (Figure 62)                                    | 1 | 10| 21, 23 | 25, 27 | 34, 35 | 46 | 49 | 54 | 58 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Notoclinus compressus* (Hutton, 1872) (juvenile) | (Figure 63)                                    | 1 | 10| 21, 22 | 25, 27 | 34, 35 | 46 | 50 | 56 | 58 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Notoclinus compressus* (Hutton, 1872) (adult)   | (Figure 64)                                    | 1 | 10| 21, 22 | 25, 27 | 33, 35 | 46 | 52 | 56 | 58 | 64 | 68, 69 | 76 | 82 | 85 | 86 |
| *Obliquichthys maryannae* Hardy, 1987 (juvenile) | (Figure 65)                                    | 1 | 4 | 10 | 21, 23 | 26, 27 | 33, 35 | 45 | 48 | 55 | 59 | 65 | 67, 69 | 76 | 81 | 83 | 86 |
| *Obliquichthys maryannae* Hardy, 1987 (adult)    | (Figure 66)                                    | 1 | 4 | 10 | 21, 23 | 25, 27 | 33, 35 | 45 | 48 | 55 | 59 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Ruanoho decemdigitatus* (Clarke, 1879) (juvenile)| (Figure 67)                                   | 3 | 6 | 20 | 21, 22 | 25, 27 | 34, 37 | 46 | 48 | 55 | 60 | 64 | 67, 69 | 76 | 81 | 83 | 90 |
| *Ruanoho decemdigitatus* (Clarke, 1879) (adult) | (Figure 68)                                   | 3 | 6 | 10 | 21, 22 | 25, 27 | 34, 37 | 46 | 52 or 50 | 56 | 60 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Ruanoho whero* Hardy, 1986 (juvenile)           | (Figure 69)                                    | 3 | 6 | 11 | 21, 22 | 25, 27 | 34, 35 | 46 | 50 | 56 | 63 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Ruanoho whero* Hardy, 1986 (adult)              | (Figure 70, 71)                                | 3 | 6 | 9, 11 | 21, 22 | 25, 27 | 34, 35 | 46 | 50 | 56 | 63 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
| *Trianeutes bucephalus* McCulloch and Waite, 1918| (adult)                                       | 1 | 10| 21, 22 | 26, 27 | 34, 36 | 29, 31 | 37, 42 | 46 | 51 | 56 | 59 | 64 | 67, 69 | 76 | 82 | 85 | 73 |
| *Tripterygium triperonotus* Risso, 1810 (adult)   | (Figure 72)                                    | 3 | 9 | 19 | 21, 22 | 26, 27 | 34, 35 | 29, 32 | 37 | 45 | 52 | 56 | 59 | 64 | 67, 69 | 76 | 82 | 85 | 86 |
Characters: (A) Mesial surface: 1, flat; 2, flat anteriorly; 3, convex; 4, convex posteriorly; 5, slightly convex; 6, convex dorsoventrally; 7, slightly concave; 8, slightly concave posteriorly. (B) Ventral margin: 9, smooth; 10, irregular; 11, slightly irregular; 12, irregular anteriorly; 13, irregular posteriorly; 14, wavy; 15, wavy anteriorly; 16, slightly wavy; 17, lobate; 18, fine lobate posteriorly; 19, lobate anteriorly; 20, slightly lobate. (C) Sulcus acusticus: 21, ostial; 22, heterosulcoid; 23, homosulcoid; 24, archaesulcoid. (D) Ostium: 25, short; 26, long; 27, broad; 28, narrow; 29, lies along rostrum; 30, not lies along rostrum; 31, deep; 32, shallow. (E) Cauda: 33, short; 34, long; 35, broad; 36, narrow; 37, deep; 38, shallow; 39, straight; 40, curved; 41, rounded; 42, with steep wall dorsally; 43, with steep wall dorsally and ventrally; 44, with straight downward inclination. (F) Ostio-caudal differentiation: 45, absent; 46, present; 47, poorly developed. (G) Crista superior: 48, absent; 49, present; 50, poorly developed; 51, developed; 52, well developed. (H) Crista inferior: 53, absent; 54, present; 55, poorly developed; 56, well developed; 57, developed. (I) Dorsal depression: 58, present; 59, absent; 60, slightly depressed; 61, slightly depressed over neck; 62, slightly depressed over ostium; 63, depressed posteriorly. (J) Ventral depression: 64, absent; 65, present; 66, present posteriorly. (K) Rostrum: 67, long; 68, short; 69, broad; 70, pointed; 71, broadly pointed; 72, blunt; 73, rounded; 74, slightly curved; 75, with line of small holes. (L) Excisura: 76, absent; 77, wide; 78, moderate. (M) Excisural angle: 79, wide; 80, narrow; 81, acute; 82, absent. (N) Excisural notch: 83, shallow; 84, deep; 85, absent. (O) Ostial rim: 86, raised; 87, raised between rostrum and antirostrum; 88, slightly raised; 89, raised anterior to antirostrum; 90, not raised.