

Comparative osteology of the family Tripterygiidae (Teleostei: Blenniiformes)

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This paper presents the results of a comparative study of five osteological complexes, the infraorbital bones, branchial arches, urohyal bone, interdigitation of the median fins, and the caudal fin skeleton, of some members of the fish family Tripterygiidae. Osteological characters that may prove valuable for taxonomic purposes are described, and on the basis of the material handled, their use to separate species within the family is discussed. Several formulae were developed for the distribution of the osteological complexes of the dorsal fin, dorsal and ventral caudal procurent ray distribution, and caudal fin in the different tripterygiid species studied.

Keywords: Branchial arches, caudal fin skeleton, comparative osteology, infraorbital bones, urohyal bone, Tripterygiidae

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INTRODUCTION

The earliest systematic studies of the family Tripterygiidae that used morphological characters date back to Bloch & Schneider (1801), Valenciennes in Cuvier & Valenciennes (1836) and Jenyns (1841), who worked on *Forsterygion capito*, and to the work of Clarke (1879) on *Blennodon dorsalis* and *Ruanoho decemdigitatus* and Rüppell (1835–1838) who worked on *Enneapterygius pusillus*. None of these studies included osteological characters. The first comprehensive osteological studies of the Tripterygiidae were revisions of the family (Rosenblatt, 1959) and the genus *Enneanectes* (Rosenblatt, 1960). Ruck's (1976) study of the osteology of the striped triplefin *Forsterygion varium* is considered the most comprehensive work on tripterygiid osteology to date. Later, Holleman (1979) and Clark (1980) reported on the osteology of some triplefins from South Africa and the Red Sea, respectively. During the 1980s, several works were published on a number of tripterygiid species. However, the osteological information is given within systematic descriptions of the species and not in a comparative form (Holleman, 1982; Hardy, 1984, 1986, 1987a, b, c, d, 1989a, b; Hansen, 1986). This also applies to studies published in the 1990s and later (Oliveira *et al.*, 1992; Holleman, 1991, 1993; Fricke & Roberts, 1993; Holleman & Buxton, 1993; Fricke, 1994, 1997, 2009; Castillo & Pequeño, 1998).

The aims of the present paper are: (1) to describe the morphology of the infraorbital bones, branchial arches, urohyal bone and caudal fin skeleton; (2) to develop a formula for the interdigitation of the dorsal and anal fin pterygiophores with the neural and haemal spines of the vertebral column; (3) to develop a formula for the distribution of the dorsal and ventral procurent rays; (4) to develop a formula

for the distribution of the caudal fin rays; (5) to demonstrate the usefulness of these structures in the diagnosis of the species of triplefins selected for this study. This study should form the basis for further work on osteological characters and their use in taxonomic and phylogenetic investigations.

MATERIALS AND METHODS

The materials examined include all species of triplefins from New Zealand and cover a wide range of genera. Out of the total of 173 valid species belonging to 29 genera of Tripterygiidae (Eschmeyer *et al.*, 2017), 39 species belonging to 29 genera were examined and documented in the present work (see Appendix 1). Collection abbreviations follow Fricke & Eschmeyer (2016); references follow Fricke (2016). The higher classification follows Nelson *et al.* (2016). Specimens were cleared in aqueous 1% KOH and were double-stained for bone and cartilage, employing the methods of Dingerkus & Uhler (1977) and Taylor & Van Dyke (1985) with modifications. Specimens were stored in 100% glycerine. Figures were drawn using a camera lucida fitted on a Wild M-8 dissecting microscope. The osteological terminology generally follows Springer (1968). The penultimate and antepenultimate vertebrae are referred to as the second preural (PU₂) and third preural (PU₃) vertebrae respectively (Rosen & Patterson, 1969; Rosen, 1973).

The dorsal fin formula (Table 1) was adopted, with some modification, from the gobioid formula of Birdsong (1975) and Birdsong *et al.* (1988). The formula was designed to facilitate comparison of the arrangement and relationships of the spinous dorsal fin pterygiophores with the underlying vertebrae. In this formula, (i) a Roman numeral indicates the number of pterygiophores anterior to the neural spine of the first vertebra; (ii) the letter (N), represents the neural spine of the first vertebra. If there is a pterygiophore in front of this spine, then it is marked by (1) or, if absent, (o) precedes the letter (N); (iii) the digits, separated by hyphens, represent

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Table 1. First dorsal fin interdigitation formula. N = neural spine of the 1st vertebra.

Species	Formula
<i>Acanthanectes rufus</i>	III-1N-0-0-1 ⁽²⁶⁾
<i>Apopterygion oculus</i>	II-1N-0-0-0-0-1 ⁽³⁰⁾
<i>Axoclinus lucillae</i>	I-N-1-1-0-1 ⁽¹²⁾
<i>Bellapiscis lesleyae</i>	I-1N-0-1-0-1 ⁽³³⁾
<i>Bellapiscis medius</i>	II-1N-0-1-0-1 ⁽³⁰⁾
<i>Blennodon dorsale</i>	I-1N-0-1 ⁽³⁷⁾
<i>Brachynectes fasciatus</i>	I-1N-0-0-0-1 ⁽²³⁾
<i>Ceratobregma acanthops</i>	I-1N-0-0-1-0-1 ⁽²⁷⁾
<i>Cremonochorites capensis</i>	III-1No-1-0-0-1 ⁽³⁰⁾
<i>Crocodilichthys gracilis</i>	II-1N-0-1-0-1 ⁽³⁰⁾
<i>Cryptichthys jojettae</i>	II-1N-0-1-0-1 ⁽²⁶⁾
<i>Enneanectes altivelis</i>	II-N-0-1 ⁽⁹⁾ -1-1 ⁽¹¹⁾
<i>Enneanectes carinalis</i>	II-1-N-0-1 ⁽¹⁰⁾ -0-1 ⁽⁹⁾
<i>Enneanectes reticulatus</i>	III-N-0-1 ⁽¹²⁾ -0-1 ⁽¹⁰⁾
<i>Enneapterygius abeli</i>	II-1N-0-0-1 ⁽²⁵⁾
<i>Enneapterygius ventermaculus</i>	I-1N-0-0-1 ⁽²⁹⁾
<i>Gilloblennius abditus</i>	I-1N-0-0-1 ⁽²⁶⁾
<i>Gilloblennius tripennis</i>	II-1N-0-0-0-1 ⁽²⁹⁾
<i>Helcogramma rharhabe</i>	I-1N-0-0-1 ⁽²⁵⁾
<i>Helcogramma springeri</i>	I-1N-0-0-1 ⁽²⁶⁾
<i>Helcogrammoides chilensis</i>	I-1N-0-0-0-1 ⁽²⁵⁾
<i>Helcogrammoides cunninghami</i>	I-1N-0-0-1 ⁽²⁸⁾
<i>Karalepis stewarti</i>	II-1N-0-1-0-1 ⁽²⁰⁾
<i>Lepidoblennius haplodactylus</i>	I-1N-0-0-1-0-1 ⁽²⁶⁾
<i>Lepidoblennius marmoratus</i>	I-1N-0-0-1-0-1 ⁽²⁸⁾
<i>Lepidonectes corallicola</i>	I-0-N-1 ⁽²⁵⁾
<i>Norfolkia brachylepis</i>	III-N-0-0-1-0-1 ⁽¹¹⁾ -1-1 ⁽³⁾ -1-1 ⁽⁸⁾
<i>Notoclinops caerulepunctus</i>	III-1N-0-0-0-1 ⁽³¹⁾
<i>Notoclinops segmentatus</i>	I-1N-0-1-1 ⁽²³⁾
<i>Notoclinops yaldwyni</i>	III-N10-0-0-1 ⁽³¹⁾
<i>Notoclinus compressus</i>	III-1N-1-0-1 ⁽²⁹⁾
<i>Notoclinus fenestratus</i>	III-1N-0-0-1 ⁽²⁴⁾
<i>Ruanoho decemdigitatus</i>	III-1N-0-0-0-1 ⁽³⁴⁾
<i>Ruanoho whero</i>	III-1N-0-0-0-1 ⁽³²⁾
<i>Springerichthys kulbickii</i>	I-1N-0-0-0-0-1 ⁽²⁵⁾
<i>Trianectes bucephalus</i>	II-1N-0-0-1 ⁽²⁸⁾
<i>Trinorfolkia clarkei</i>	I-1N-0-0-1 ⁽²⁷⁾
<i>Tripterygion tartessicum</i>	I-1N-0-0-0-0-1 ⁽²⁹⁾
<i>Ucla xenogrammus</i>	II-1N-0-0-1-0-1 ⁽²⁶⁾

the series of interneural spaces found behind the neural spine of the first vertebra (the number indicates the number of pterygiophores present in the spaces). The superscript number in parentheses represents the total number of neural spines with corresponding pterygiophores to the end of the vertebral column, e.g. II-1-N-0-1⁽¹⁰⁾-0-1⁽⁹⁾.

The anal fin formula (Table 2) was designed to facilitate comparison of the arrangement and relationships of the spinous anal fin pterygiophores with the haemal spines of vertebrae. In this formula, (i) a Roman numeral in brackets on the left of the letter H indicates number of pterygiophores anterior to the haemal spine of the first caudal; (ii) the letter (H) represents the haemal spine of the first caudal vertebra. If insertion place is empty then (o) precedes the letter (H); (iii) the digits, separated by hyphens, represent the series of interhaemal spaces found behind the haemal spine of the first caudal vertebra (the number indicates the number of pterygiophores present in the spaces). The superscript number represents the total number of haemal spines with corresponding pterygiophores to the end of the anal fin, e.g. 2-H-2-0-2-1⁽¹³⁾.

Table 2. The formula of the interdigitation of the haemal pterygiophores with the haemal spines of the anal fin of the family Tripterygiidae.

Species	Formula
<i>Acanthanectes rufus</i>	1-H-1 ⁽¹⁹⁾
<i>Apopterygion oculus</i>	2-H-1 ⁽²⁷⁾
<i>Axoclinus lucillae</i>	
<i>Bellapiscis lesleyae</i>	2-H-1 ⁽¹⁸⁾
<i>Bellapiscis medius</i>	2-H-1 ⁽²⁰⁾
<i>Blennodon dorsale</i>	2-H-1 ⁽²⁴⁾
<i>Brachynectes fasciatus</i>	3-H-1 ⁽²⁰⁾
<i>Ceratobregma acanthops</i>	1-H-1 ⁽²¹⁾
<i>Cremonochorites capensis</i>	3-H-1 ⁽¹⁷⁾
<i>Crocodilichthys gracilis</i>	
<i>Cryptichthys jojettae</i>	1-H-1 ⁽¹⁸⁾
<i>Enneanectes altivelis</i>	2-H-1 ⁽¹⁷⁾
<i>Enneanectes carinalis</i>	2-H-2-0-2-1 ⁽¹³⁾
<i>Enneanectes reticulatus</i>	2-H-1 ⁽¹⁷⁾
<i>Enneapterygius abeli</i>	0-H-1 ⁽¹⁸⁾
<i>Enneapterygius ventermaculus</i>	0-H-1 ⁽¹⁶⁾
<i>Forsterygion capito</i>	5-H-2-1 ⁽²¹⁾
<i>Forsterygion gymnota</i>	5-H-1 ⁽²³⁾
<i>Forsterygion lapillum</i>	5-H-1 ⁽²⁸⁾
<i>Forsterygion malcomi</i>	5-H-1 ⁽²⁶⁾
<i>Forsterygion maryanne</i>	5-H-1 ⁽²⁷⁾
<i>Forsterygion nigripenne</i>	5-H-1 ⁽¹⁹⁾
<i>Forsterygion flavonigrum</i>	5-H-1 ⁽²²⁾
<i>Forsterygion varium</i>	5-H-1 ⁽²⁴⁾
<i>Gilloblennius abditus</i>	3-H-1 ⁽¹⁹⁾
<i>Gilloblennius tripennis</i>	3-H-1 ⁽²¹⁾
<i>Helcogramma rharhabe</i>	2-H-1 ⁽²²⁾
<i>Helcogramma springeri</i>	2-H-1 ⁽²¹⁾
<i>Helcogrammoides cunninghami</i>	0-H-1 ⁽²¹⁾
<i>Helcogrammoides chilensis</i>	0-H-1 ⁽²²⁾
<i>Karalepis stewarti</i>	3-H-1 ⁽²¹⁾
<i>Lepidoblennius haplodactylus</i>	1-H-1 ⁽²⁰⁾
<i>Lepidoblennius marmoratus</i>	1-H-1 ⁽²²⁾
<i>Lepidonectes corallicola</i>	0-H-1 ⁽¹⁷⁾
<i>Matanui bathytaton</i>	3-H-1 ⁽²⁴⁾
<i>Matanui profundum</i>	3-H-1 ⁽²³⁾
<i>Norfolkia brachylepis</i>	4-H-1 ⁽¹⁶⁾
<i>Notoclinops caerulepunctus</i>	2-H-1 ⁽²³⁾
<i>Notoclinops segmentatus</i>	2-H-1 ⁽²⁴⁾
<i>Notoclinops yaldwyni</i>	2-H-1 ⁽²⁵⁾
<i>Notoclinus compressus</i>	0-H-2-1 ⁽¹⁷⁾
<i>Notoclinus fenestratus</i>	0-H-1-1 ⁽¹⁷⁾
<i>Ruanoho decemdigitatus</i>	3-H-1-1 ⁽²⁵⁾
<i>Ruanoho whero</i>	3-H-1-1 ⁽²³⁾
<i>Springerichthys kulbickii</i>	2-H-1-1 ⁽¹⁹⁾
<i>Trianectes bucephalus</i>	3-H-1-1 ⁽²⁰⁾
<i>Trinorfolkia clarkei</i>	0-H-1-1 ⁽²³⁾
<i>Tripterygion tartessicum</i>	2-H-2-1 ⁽²⁰⁾
<i>Ucla xenogrammus</i>	0-H-2-1 ⁽¹⁹⁾

The formula for the distribution of the dorsal procurrent rays is shown in Table 3. This formula is designed to facilitate comparison of the arrangement and relationships of the procurrent rays with the underlying caudal skeleton elements. The formula lists, in order, (i) an Arabic numerical that indicates the number of procurrent rays between the neural spines of the 3rd and 2nd preural vertebra; (ii) the letters (NSPU₃ & NSPU₂) represent the neural spines of the 3rd and 2nd preural vertebra; (iii) the Roman numerals in brackets represent the number of procurrent rays in front of the neural spine of the 3rd or the 2nd preural vertebra; (iv) the Arabic numerals in brackets represent the number of

Table 3. Formula for the distribution of the dorsal procurrent rays. NSPU₃, neural spine of the 3rd preural vertebra; NSPU₂, neural spine of the 2nd preural vertebra; E₁, 1st epural bone; E₂, 2nd epural bone; H₅, 5th hypural bone; UL, upper lobe. Roman numerical represents procurrent rays opposite the bone.

Species	Formula	Total number of procurrent rays
<i>Acanthanectes rufus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(2)E ₁ (o)(o)E ₂ (I)(1)H ₅ (I)(o)UL	5
<i>Apopterygion oculus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(2)E ₁ (II)(o)E ₂ (II)(1)H ₅ (I)(o)UL	6
<i>Axoclinus lucillae</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)E ₁ (III)(o)E ₂ (II)(1)H ₅ (I)	7
<i>Bellapiscis lesleyae</i>	oNSPU ₃ (o)(o)NSPU ₂ (I)(o)E ₁ (II)(o)E ₂ (II)(o)H ₅ (I)(1)UL	7
<i>Bellapiscis medius</i>	1NSPU ₃ (I)(o)NSPU ₂ (o)(o)E ₁ (I)(o)(o)E ₂ (I)(1)H ₅ (I)(2)UL	8
<i>Blennodon dorsale</i>	oNSPU ₃ (I)(2)NSPU ₂ (I)(o)E ₁ (o)(o)E ₂ (o)(3)H ₅ (o)(2)UL	9
<i>Brachynectes fasciatus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (o)(o)E ₂ (II)(1)H ₅ (I)(1)UL	5
<i>Ceratobregma acanthops</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(2)E ₁ (II)(1)E ₂ (II)(o)H ₅ (I)(o)UL	8
<i>Cremnochorites capensis</i>	oNSPU ₃ (I)(o)NSPU ₂ (I)(o)(o)E ₁ (o)(o)E ₂ (III)(o)H ₅ (I)(o)UL	6
<i>Crocodilichthys gracilis</i>	1NSPU ₃ (I)(o)NSPU ₂ (o)(o)E ₁ (III)(o)E ₂ (II)(1)H ₅ (I)(o)UL	9
<i>Cryptichthys jojettae</i>	oNSPU ₃ (II)(o)NSPU ₂ (o)(o)E ₁ (III)(o)E ₂ (II)(2)H ₅ (I)(o)UL	10
<i>Enneanectes altivelis</i>	oNSPU ₃ (o)NSPU ₂ (o)E ₁ (II)(o)E ₂ (II)(1)H ₅ (I)UL	7
<i>Enneanectes carminalis</i>	oNSPU ₃ (I)NSPU ₂ (II)(1)E ₁ &2(II)(1)H ₅ (I)UL	8
<i>Enneanectes reticulatus</i>	oNSPU ₃ (o)NSPU ₂ (o)E ₁ (II)(1)E ₂ (I)(1)H ₅ (1)UL	6
<i>Enneapterygius abeli</i>	oNSPU ₃ (I)(o)NSPU ₂ (II)(o)E ₁ (o)(3)E ₂ (o)(o)H ₅ (I)(o)UL	7
<i>Enneapterygius ventermaculus</i>	oNSPU ₃ (o)(o)NSPU ₂ (I)(o)E ₁ (o)(4)E ₂ (o)(o)H ₅ (I)(o)UL	6
<i>Gilloblennius abditus</i>	oNSPU ₃ (o)(2)NSPU ₂ (I)(o)E ₁ (o)(2)E ₂ (o)(1)H ₅ (I)(o)UL	7
<i>Gilloblennius tripennis</i>	oNSPU ₃ (o)(1)NSPU ₂ (II)(o)E ₁ (o)(3)E ₂ (o)(o)H ₅ (I)(o)UL	7
<i>Helcogramma rharhabe</i>	3NSPU ₃ (I)(o)NSPU ₂ (I)(o)E ₁ (I)(o)E ₂ (II)(o)H ₅ (I)(o)UL	9
<i>Helcogramma springeri</i>	oNSPU ₃ (III)(o)NSPU ₂ (I)(o)E ₁ (III)(o)E ₂ (I)(o)H ₅ (I)(o)UL	9
<i>Helcogrammoides chilensis</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(IV)E ₁ (I)(o)E ₂ (II)(1)H ₅ (I)(o)UL	9
<i>Helcogrammoides cunninghami</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (o)(o)E ₂ (III)(o)H ₅ (I)(o)UL	4
<i>Karalepis stewarti</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(III)E ₁ (I)(o)E ₂ (III)(1)H ₅ (I)(o)UL	9
<i>Lepidoblennius abditus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(1)E ₁ (I)(1)E ₂ (I)(1)H ₅ (I)(o)UL	6
<i>Lepidoblennius marmoratus</i>	oNSPU ₃ (I)(1)NSPU ₂ (o)(1)E ₁ (o)(IV)E ₂ (II)(o)H ₅ (1)(o)UL	8
<i>Lepidonectes corallicola</i>	1NSPU ₃ (I)(1)NSPU ₂ (o)E ₁ (o)E ₂ (o)(1)H ₅ (1)(o)UL	5
<i>Norfolkia brachylepis</i>	1NSPU ₃ (o)NSPU ₂ (1)E ₁ (I)(1)E ₂ (I)(2)	6
<i>Notoclinops caerulepunctus</i>	oNSPU ₃ (o)(o)NSPU ₂ (1)(o)E ₁ (III)(o)E ₂ (II)(1)H ₅ (o)(o)UL(I)	8
<i>Notoclinops segmentatus</i>	oNSPU ₃ (I)(1)NSPU ₂ (I)(o)E ₁ (II)(o)E ₂ (II)(1)H ₅ (I)(o)UL	9
<i>Notoclinops yaldwyni</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (I)(o)E ₂ (III)(1)H ₅ (o)(o)UL	5
<i>Notoclinus compressus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (o)(2)E ₂ (o)(1)H ₅ (II)(o)UL	5
<i>Notoclinus fenestratus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (I)(o)E ₂ (I)(o)H ₅ (I)(o)UL(II)	5
<i>Ruanoho decemdigitatus</i>	1NSPU ₃ (I)(1)NSPU ₂ (o)(o)E ₁ (o)(5)E ₂ (o)(o)H ₅ (I)(o)UL	8
<i>Ruanoho wheno</i>	oNSPU ₃ (III)(o)NSPU ₂ (o)(o)E ₁ (o)(4)E ₂ (o)(1)H ₅ (I)(o)UL	9
<i>Springerichthys kulbickii</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(3)E ₁ (I)(1)E ₂ (I)(1)H ₅ (I)(o)UL	8
<i>Trianectes bucephalus</i>	oNSPU ₃ (o)(o)NSPU ₂ (I)(o)E ₁ (I)(1)E ₂ (I)(1)H ₅ (o)(o)UL	5
<i>Trinorfolkia clarkei</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (I)(o)E ₂ (III)(o)H ₅ (II)(o)UL	6
<i>Tripterygion tripteronotus</i>	oNSPU ₃ (o)(o)NSPU ₂ (o)(o)E ₁ (I)(1)E ₂ (II)(o)H ₅ (I)(o)UL	5
<i>Ucla xenogrammus</i>	oNSPU ₃ (o)(o)NSPU ₂ (IV)(o)E ₁ (III)(o)E ₂ (II)(1)H ₅ (o)(o)UL	10

procurrent rays between the neural spines of the 3rd and 2nd preural vertebrae; (v) the Roman numerals in brackets between (NSPU₂) and the 1st epural (E₁) represent the number of procurrent rays opposite (NSPU₂) and (E₁); (vi) the Arabic numerals in brackets between (E₁) and (E₂) represent the number of procurrent rays between (E₁) and (E₂); (viii) the Roman numerals in brackets after (E₂) represent the number of procurrent rays in front of (E₂); (ix) and the Arabic numeral in brackets after (E₂) represent the number of procurrent rays falling after (E₂). Wherever (o) is present, it means no procurrent ray is found. The formula for the distribution of the ventral procurrent (Table 4) rays is exactly the same as that of the distribution of the dorsal procurrent rays, except for using HSPU 1, 2 and 3 denoting haemal spine of the 1st, 2nd and 3rd preural vertebrae.

The caudal fin formula (Table 5) was derived following Fricke (1983a), who used it to describe the caudal fin structure of callionymid and draconettid fishes. Some modification was required to comply with the caudal fin structure of

tripterygiids. Originally, the formula lists four types of fin rays; in the present study, the modified formula lists only two types of fin rays that are present in the caudal fin of the tripterygiids. Upper and lower procurrent ray formula are not included. In this formula: (i) the first small Roman numeral indicates the number of unbranched segmented soft rays in the upper lobe; (ii) Arabic numerals indicate the number of segmented branched soft rays in the upper lobe; (iii) dashed line between the two sets of numerals is present to separate the counts of the two lobes; (iv) the small Roman numeral indicates the presence of unbranched soft rays in the lower lobe; and (v) Arabic numerals indicate number of segmented branched soft rays in the lower lobe.

Bone size was defined according to the shape of the different bones studied. For basihyal and hypobranchial bones, a long bone is one with length (L) = width (W), and a short bone as having L < W. For ceratobranchial bones, a bone is 'broad' when the width of the middle part of the bone (W₁) = width of the medial or lateral ends (W₂), or 'narrow' when W₁ < W₂. For the epibranchial bones,

Table 4. Formula for the distribution of the ventral procurent rays. HSPU₃, haemal spine of the 3rd preural vertebra; HSPU₂, haemal spine of the 2nd preural vertebra; PH, parahypural bone; LL, lower lobe. Roman numerical represents procurent rays opposite the bone.

Species	Formula	Total number of procurent rays
<i>Acanthanectes rufus</i>	oHSPU ₃ (o)(2)HSPU ₂ (II)(o)PH(o)(o)LL	4
<i>Apopterygion oculus</i>	oHSPU ₃ (o)(1)HSPU ₂ (II)(1)PH(o)(o)LL	4
<i>Axoclinus lucillae</i>	oHSPU ₃ (o)(1)HSPU ₂ (V)(o)PH(I)(o)LL	7
<i>Bellapiscis lesleyae</i>	oHSPU ₃ (o)(3)HSPU ₂ (III)(1)PH(o)(o)LL	7
<i>Bellapiscis medius</i>	oHSPU ₃ (o)(2)HSPU ₂ (IV)(1)PH(o)(o)LL	7
<i>Blennodon dorsale</i>	oHSPU ₃ (o)(4)HSPU ₂ (V)(o)PH(I)(o)LL	10
<i>Brachynectes fasciatus</i>	oHSPU ₃ (o)(o)HSPU ₂ (II)(1)PH(o)(o)LL	3
<i>Ceratobregma acanthops</i>	oHSPU ₃ (o)(4)HSPU ₂ (III)(o)PH(o)(o)LL	7
<i>Cremonochorites capensis</i>	oHSPU ₃ (o)(2)HSPU ₂ (III)(o)PH(o)(o)LL	5
<i>Crocodilichthys gracilis</i>	oHSPU ₃ (I)(o)HSPU ₂ (V)(o)PH(o)(o)LL	6
<i>Cryptichthys jojettae</i>	oHSPU ₃ (o)(4)HSPU ₂ (III)(1)PH(o)(o)LL	8
<i>Enneanectes altivelis</i>	oHSPU ₃ (II)(3)HSPU ₂ (III)(o)PH(o)(o)LL	8
<i>Enneanectes carminalis</i>	oHSPU ₃ (IV)(o)HSPU ₂ (II)(o)PH(II)(1)LL	9
<i>Enneanectes reticulatus</i>	oHSPU ₃ (IV)(o)HSPU ₂ (o)(o)PH(o)(2)LL	6
<i>Enneapterygius abeli</i>	oHSPU ₃ (III)(o)HSPU ₂ (III)(o)PH(o)(o)LL	6
<i>Enneapterygius ventermaculus</i>	oHSPU ₃ (o)(o)HSPU ₂ (VI)(o)PH(o)(o)LL	6
<i>Gilloblennius abditus</i>	oHSPU ₃ (o)(2)HSPU ₂ (III)(1)PH(o)(o)LL	6
<i>Gilloblennius tripennis</i>	oHSPU ₃ (III)(1)HSPU ₂ (I)(1)PH(o)(o)LL	6
<i>Helcogramma rharhabe</i>	oHSPU ₃ (o)(2)HSPU ₂ (VI)(o)PH(o)(o)LL	8
<i>Helcogramma springeri</i>	oHSPU ₃ (II)(2)HSPU ₂ (IV)(o)PH(o)(o)LL	8
<i>Helcogrammoides chilensis</i>	oHSPU ₃ (o)(5)HSPU ₂ (III)(o)PH(o)(o)LL	8
<i>Helcogrammoides cunninghami</i>	oHSPU ₃ (o)(o)HSPU ₂ (II)(1)PH(o)(o)LL	3
<i>Karalepis stewarti</i>	oHSPU ₃ (II)(2)HSPU ₂ (III)(1)PH(o)(o)LL	8
<i>Lepidoblennius haplodactylus</i>	oHSPU ₃ (o)(o)HSPU ₂ (V)(o)PH(o)(o)LL	5
<i>Lepidoblennius marmoratus</i>	oHSPU ₃ (o)(2)HSPU ₂ (IV)(1)PH(o)(o)LL	7
<i>Lepidonectes corallicola</i>	oHSPU ₃ (II)(1)HSPU ₂ (I)(1)PH(o)(o)LL	5
<i>Norfolkia brachylepis</i>	oHSPU ₃ (o)(2)HSPU ₂ (V)(1)PH(o)(1)LL	9
<i>Notoclinops caerulepunctus</i>	oHSPU ₃ (o)(o)HSPU ₂ (V)(o)PH(II)(o)LL	7
<i>Notoclinops segmentatus</i>	1HSPU ₃ (I)(o)HSPU ₂ (VI)(o)PH(o)(o)LL	8
<i>Notoclinops yaldwyni</i>	oHSPU ₃ (I)(2)HSPU ₂ (V)(o)PH(o)(o)LL	8
<i>Notoclinus compressus</i>	oHSPU ₃ (o)(o)HSPU ₂ (II)(3)PH(o)(o)LL	5
<i>Notoclinus fenestratus</i>	oHSPU ₃ (o)(o)HSPU ₂ (II)(1)PH(o)(1)LL	4
<i>Ruanoho decemdigitatus</i>	oHSPU ₃ (I)(o)HSPU ₂ (VI)(o)PH(o)(o)LL(I)	8
<i>Ruanoho whero</i>	oHSPU ₃ (o)(1)HSPU ₂ (V)(1)PH(o)(o)LL	7
<i>Springerichthys kulbicki</i>	oHSPU ₃ (o)(5)HSPU ₂ (II)(o)PH(o)(o)LL	7
<i>Trianectes bucephalus</i>	oHSPU ₃ (o)(2)HSPU ₂ (II)(1)PH(o)(o)LL	5
<i>Trinorfolkia clarkei</i>	oHSPU ₃ (o)(o)HSPU ₂ (III)(o)PH(o)(o)LL	3
<i>Tripterygion tripteronotus</i>	oHSPU ₃ (o)(3)HSPU ₂ (III)(1)PH(o)(o)LL	7
<i>Ucla xenogrammus</i>	oHSPU ₃ (o)(3)HSPU ₂ (VI)(o)PH(o)(o)LL	9

'broad' is when the width of the middle part of the bone (W_1) > width of the medial or lateral ends (W_2), and 'narrow' is when $W_1 = W_2$. For the fifth hypural, a long and narrow bone is defined as: length (L) = $2 \times$ width (W), and short and broad bone is defined as: $L \leq W$. For the upper and lower hypural plates, a broad bone is defined as: length (L) = height (H); narrow as: $L > H \geq \frac{1}{2} L$; and very narrow as: $H > \frac{1}{2} L$.

For the parhypural bone, a long bone is defined as: length (L) > length of the lower hypural plate (L_1); short as: $L < L_1$; broad as: width (W) = $\frac{1}{3} \times$ width of the lower hypural plate (W_1); and narrow as: $W < \frac{1}{3} W_1$. For epural bones, a long bone is one with: Length (L) = length of the upper hypural plate (L_1); short as $L < L_1$; broad as: width (W) = $\frac{1}{2} \times$ width of the upper hypural plate (W_1); and narrow as: $W > \frac{1}{2} W_1$. For the neural spine of PU₂, a long spine is defined as: length of the spine (L) = length of the epural (L_1); short as: $L < L_1$; broad as: width of the spine (W) > width of the epural (W_1); and narrow as: $W < W_1$. For the haemal spine of PU₂, a long spine is defined as: length of the spine = length of the lower hypural plate (L_1); short as: $L < L_1$;

broad as width of the spine (W) = $\frac{1}{2}$ width of the lower hypural plate (W_1); and narrow as: $W < W_1$.

The osteology of the members of the *Forsterygion* has already been published (Jawad, 2008) and is not discussed here.

RESULTS AND DISCUSSION

A few authors have successfully used osteological characters to diagnose tripterygiid species, for example Hardy (1984, 1986, 1987a, b, c, d, 1989a, b), and to some extent Fricke & Roberts (1993). Holleman (1982, 1991, 1993), used osteological characters in generic descriptions and to infer relationships.

This osteological study of triplefins illustrates the wide range of bone characters present in members of this family. This study of triplefin osteology is considered comprehensive because it covers all the valid triplefin genera except for the genus *Matanui*, for which the osteology of its two species, *M. bathytaton* and *M. profundum* was described by Jawad & Clements (2004), and out of a total of 171 species described,

Table 5. Caudal fin rays distribution formula. Lower case Roman numerical represents number of unsegmented rays.

Species	Formula
<i>Acanthanectes rufus</i>	i,6-5,ii
<i>Apopterygion oculus</i>	ii,5-4,ii
<i>Axoclinus lucillae</i>	i,6-6,i
<i>Bellapiscis lesleyae</i>	ii,5-4,ii
<i>Bellapiscis medius</i>	ii,5-4,ii
<i>Blennodon dorsale</i>	ii,5-4,ii
<i>Brachynectes fasciatus</i>	i,5-4,ii
<i>Ceratobregma acanthops</i>	ii,5-4,ii
<i>Cremonochorites capensis</i>	ii,5-4,ii
<i>Crocodylichthys gracilis</i>	i,6-5,ii
<i>Cryptichthys jojettae</i>	ii,5-4,ii
<i>Enneanectes altivelis</i>	ii,4-5,ii
<i>Enneanectes carminalis</i>	ii,4-4,ii
<i>Enneanectes reticulatus</i>	ii,5-5,ii
<i>Enneapterygius abeli</i>	ii,5-3,iii
<i>Enneapterygius ventermaculus</i>	ii,5-4,ii
<i>Gilloblennius abditus</i>	ii,5-4,ii
<i>Gilloblennius tripennis</i>	i,6-5,i
<i>Helcogramma rharhabe</i>	ii,5-4,ii
<i>Helcogramma springeri</i>	ii,5-4,ii
<i>Helcogrammoides chilensis</i>	ii,5-4,ii
<i>Helcogrammoides cunninghami</i>	ii,5-5,i
<i>Karalepis stewarti</i>	ii,5-4,ii
<i>Lepidoblennius haplodactylus</i>	ii,5-5,i
<i>Lepidoblennius marmoratus</i>	ii,5-4,ii
<i>Lepidonectes corallicola</i>	ii,5-5,ii
<i>Norfolkia brachylepis</i>	ii,4-4,ii
<i>Notoclinops caerulepunctus</i>	i,6-5,ii
<i>Notoclinops segmentatus</i>	i,5-5,ii
<i>Notoclinops yaldwyni</i>	ii,5-4,iii
<i>Notoclinus compressus</i>	i,4-3,i
<i>Notoclinus fenestratus</i>	i,4-3,ii
<i>Ruanoho decemdigitatus</i>	ii,5-5,i
<i>Ruanoho whereo</i>	i,6-5,i
<i>Springerichthys kulbickii</i>	i,6-5,i
<i>Trianectes bucephalus</i>	i,6-5,i
<i>Triorfolkia clarkei</i>	ii,5-5,i
<i>Tripterygion tartessicum</i>	ii,5-4,ii
<i>Ucla xenogrammus</i>	ii,5-4,ii

only 22.8% of the known species have been examined. It was possible to distinguish exclusive characters that are confined to particular taxa.

Infraorbital bones (Figures 1 & 2)

The infraorbitals are a series of bones around the ventral curvature of the eye. They extend from the lateral ethmoid to the sphenotic bone (Springer, 1968; Ruck, 1976). The infraorbitals carry part of the cephalic lateralis system and the canal may be either an entirely open trough, as in *Enneapterygius*, or partially closed (Holleman, 1979).

There are four or five infraorbital bones in tripterygiids. The majority of the studied triplefin species (26 out of 39 species) have four bones. The anteriormost bone, the lachrymal, is the largest and the posteriormost bone, the 5th infraorbital bone is the smallest (when it is present) in most of the species studied. The shape of the lachrymal can be classified into six types: elongated, triangular, squarish, rectangular, club-shaped and irregular.

The lachrymal usually has three cup-shaped articulations (dorsal, anterior and posterior) on the mesial surface, which articulate with the lateral ethmoid. The dorsal process is long but broad, and is a common character among the studied triplefins. The posterior process is short and broad in most of the studied species. The anterior process varies in shape between long, short, broad and narrow and in some cases it is undeveloped. The ocular surface of the lachrymal and the other interorbital bones is mainly smooth.

The infraorbital bones other than the lachrymal are not usually tapered toward the anterior end and the size of these bones varies widely. In a few species the posterior infraorbital bones are larger than the anterior ones, whereas in others, the anterior bones are larger.

Within certain genera the shape of this bone appears to be distinctive. An irregular lachrymal was reported only for *Lepidoblennius haplodactylus*, and might be considered characteristic for this species. The squarish lacrymal of *Notoclinops yaldwyni* seems to diagnose this species and serves to separate it from the other two species of the genus studied. The highly variable shape of the three processes of the lachrymal bone and its ocular surface did not contribute much to the diagnosis of triplefin species.

Branchial arches (Figures 3 – 6)

The branchial arches consist of four median basibranchials, three paired hypobranchials, five paired ceratobranchials, four paired epibranchials and one pair of infrapharyngobranchials. The branchial bones are divided into two groups; the lower branchial arch elements include the basibranchials, the hypobranchials, and the ceratobranchials and a single bone the basihyal. The upper branchial arch elements include the epibranchials and infrapharyngobranchials.

A single bone bearing the upper pharyngeal tooth plate (Springer, 1968), and the infrapharyngobranchial bone (Hardy, 1986, 1987a, b, c) is attached to the second, third and fourth epibranchials. This single bone probably represents the second through fourth pharyngobranchials (Springer, 1968) and is suspended from the cranium. The fifth ceratobranchial bone is a single tooth-bearing bone representing the fifth branchial arch.

The shape of the basihyal in triplefins can be classified into six types: rectangular, club-shape, elongated, plunger-shape, triangular, and squarish, with the rectangular shape being the most common and squarish and triangular shapes being rare. Long and short are equally common characters for the length of the basihyal bone. Out of the 39 examined species of triplefins, only 19 have a short basihyal bone. Although the basihyal of most studied triplefins is not constricted, the results show the presence of a constriction at one of three locations: the anterior, the middle or the posterior part of this bone.

The branchial arches are highly variable in shape. In the lower branchial arch elements, there are several shapes of the basihyal bone that could be diagnostic for certain species within some genera (e.g. *Bellapiscis lesleyae*, *Bellapiscis medius*, *Gilloblennius abditus*, *Gilloblennius tripennis*). This is also true for the character and position of constrictions on this bone e.g. *Notoclinops caerulepunctus*. The size of the basihyal is not a good diagnostic character for certain species of triplefins (e.g. *Helcogramma springeri*, *Notoclinops yaldwyni*).

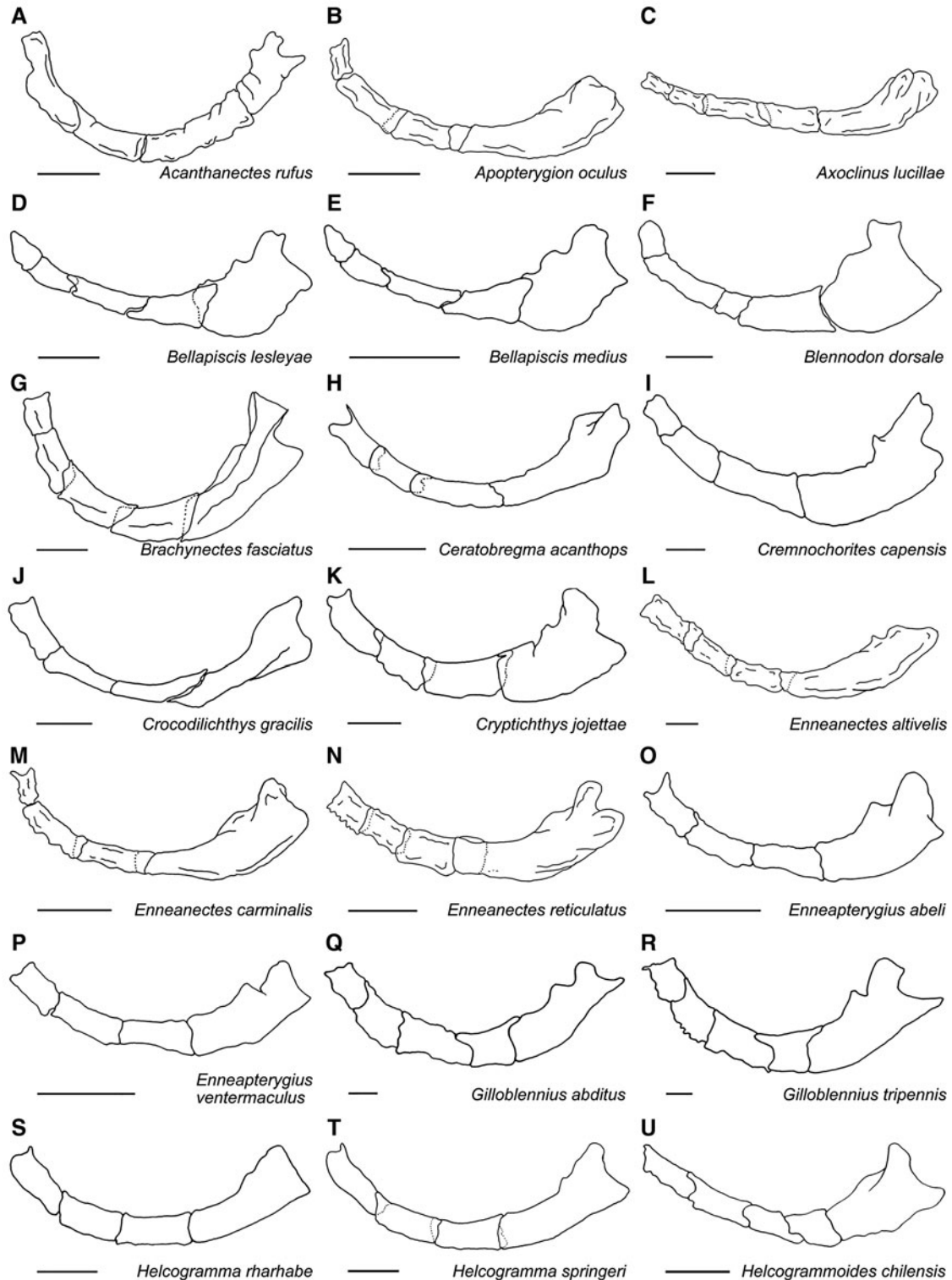


Fig. 1. Infraorbital bones (mesial surface) of: A, *Acanthanectes rufus*; B, *Apopterygion oculus*; C, *Axoclinus lucillae*; D, *Bellapiscis lesleyae*; E, *Bellapiscis medius*; F, *Blennodon dorsalis*; G, *Brachynectes fasciatus*; H, *Ceratobregma acanthops*; I, *Cremnochorites capensis*; J, *Crocodilichthys gracilis*; K, *Cryptichthys joettae*; L, *Enneanectes altivelis*; M, *Enneanectes carminalis*; N, *Enneanectes reticulatus*; O, *Enneapterygius abeli*; P, *Enneapterygius ventermaculus*; Q, *Gilloblennius abditus*; R, *Gilloblennius tripennis*; S, *Helcogramma rharhabe*; T, *Helcogramma springeri*; U, *Helcogrammoides chilensis*. Anterior bones at right, posterior at left. Scale bar = 1 mm.

The general shape of the basibranchial bones, the shape of their anterior margin and posterior end show wide variation in the studied triplefins. In some species these bones have a unique overall shape that, along with the form of their anterior

and posterior margins, helps separate them from the rest of the studied species (e.g. the diamond and trapezium shapes of the first basibranchial bone of *Lepidoblennius marmoratus* and *Brachynectes fasciatus*). The posterior end of the first

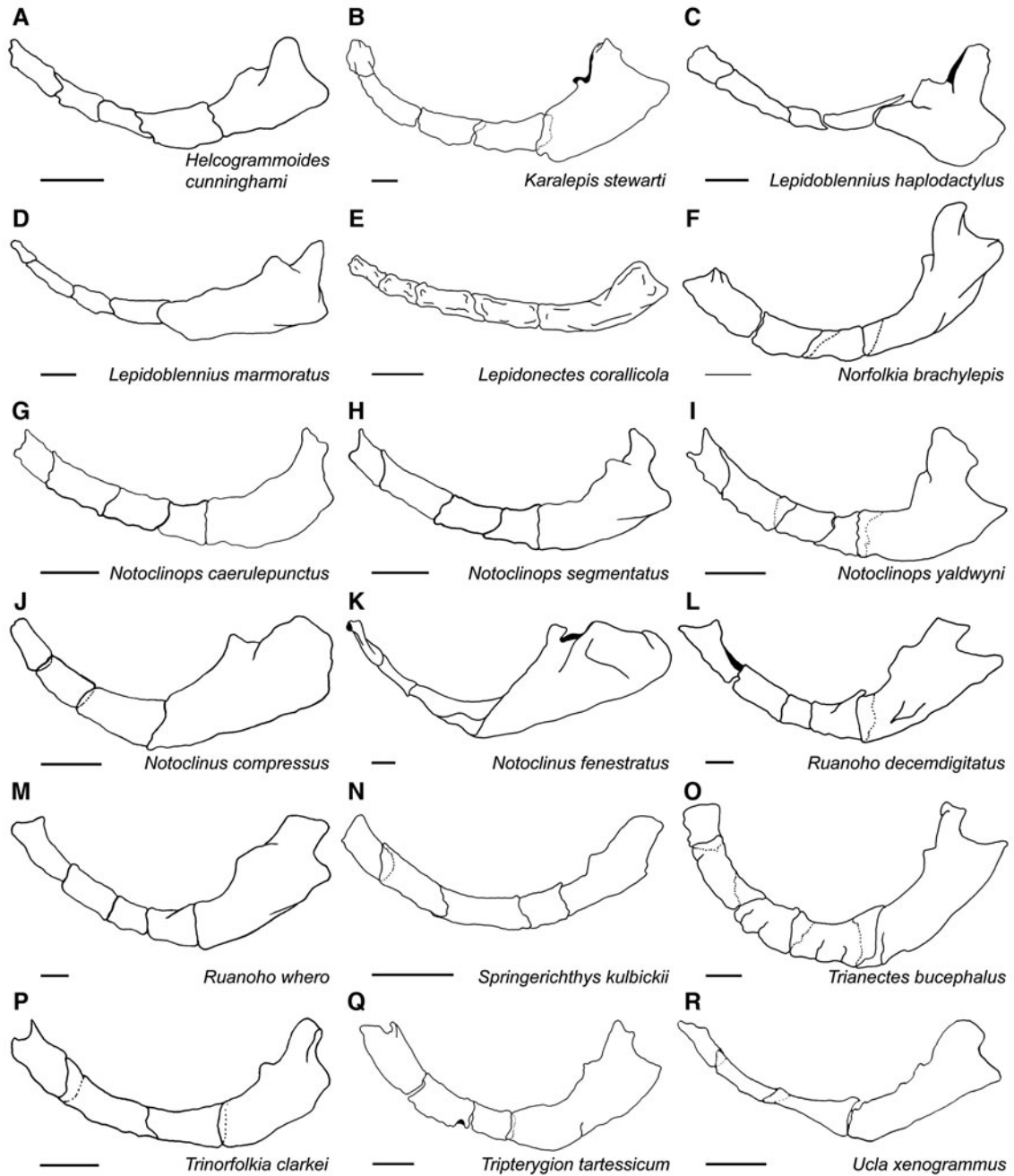


Fig. 2. Infraorbital bones (mesial surface) of: A, *Helcogrammoides cunninghami*; B, *Karalepis stewarti*; C, *Lepidoblennius haplodactylus*; D, *Lepidoblennius marmoratus*; E, *Lepidonectes corallicola*; F, *Norfolkia brachylepis*; G, *Notoclinops caerulepunctus*; H, *Notoclinops segmentatus*; I, *Notoclinops yaldwyni*; J, *Notoclinus compressus*; K, *Notoclinus fenestratus*; L, *Ruanoho decemdigitatus*; M, *Ruanoho whereo*; N, *Springerichthys kulbickii*; O, *Trianectes bucephalus*; P, *Trinorfolkia clarkei*; Q, *Tripterygion tartessicum*; R, *Ucla xenogrammus*. Anterior bones at right, posterior at left. Scale bar = 1 mm.

basibranchial is irregular and pointed as in *Cryptichthys jojettae* and *Trianectes bucephalus*. All these character states can be considered unique to *Lepidoblennius marmoratus*, *Brachynectes fasciatus*, *Cryptichthys jojettae* and *Trianectes bucephalus*.

The basibranchials are a series of four bones. The first basibranchial is the largest and the fourth is the smallest and is cartilaginous. In triplefins, the shape of the first basibranchial can be of nine types: squarish, rounded, rectangular, triangular, oval, Club head, irregular, semi-circular, and diamond-shaped or trapezoid. The squarish form is the most common. The anterior edge of this bone is rounded, truncate, irregular

or pointed. The posterior edge is straight, rounded, convex, irregular, or pointed, with straight-edged being the most common, and the irregular and pointed being rare. The second basibranchial is usually an elongate bone, but might be also squarish, rounded, rectangular or bow-tie. The anterior and posterior edges of this bone can be divided into five common types according to their shape: straight, rounded, irregular, sloped and pointed.

The shape of the third basibranchial can be classified into 10 types: elongate, triangular, chisel-shaped, club-shaped, irregular, dagger-shaped, diamond-shaped, oval-shaped, rectangular-shaped and pin-shaped, with the elongate shape

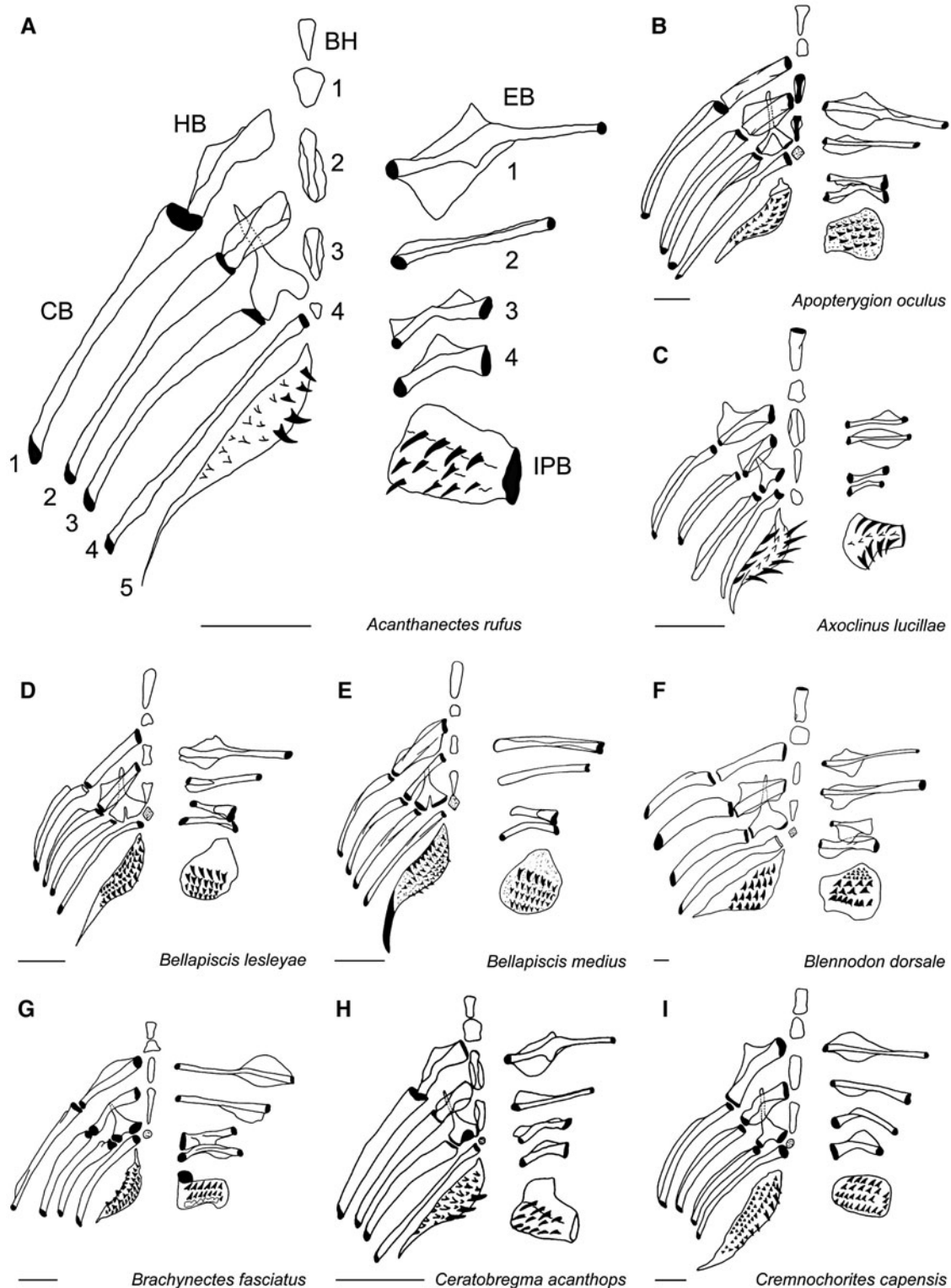


Fig. 3. Branchial arches (with the gill rakers removed) of: A, *Acanthanectes rufus*; B, *Apopterygion oculus*; C, *Axoclinus lucillae*; D, *Bellapiscis lesleyae*; E, *Bellapiscis medius*; F, *Blennodon dorsale*; G, *Brachynectes fasciatus*; H, *Ceratobregma acanthops*; I, *Cremnochorites capensis*. BB, basibranchial (3 ossified, 1 cartilaginous – shown stippled); CB, ceratobranchials (5); EB, epibranchials (4); HB, hypobranchial (3); IPB, infrapharyngobranchial plate. Scale bar = 1 mm.

being the most common. The anterior and posterior edges of this bone have two shared shapes, rounded and sharp which are considered as common shapes for those two edges respectively. Other shapes of anterior edge such as straight, pointed, irregular, concave and sloped were also observed in the studied triplefins.

The fourth basibranchial bone can be divided into three types according to its shape: diamond-shaped, triangular-shaped, semicircular-shaped and rounded in shape, with diamond being the most common. In most studied triplefins, this bone usually extends to the third basibranchial bone.

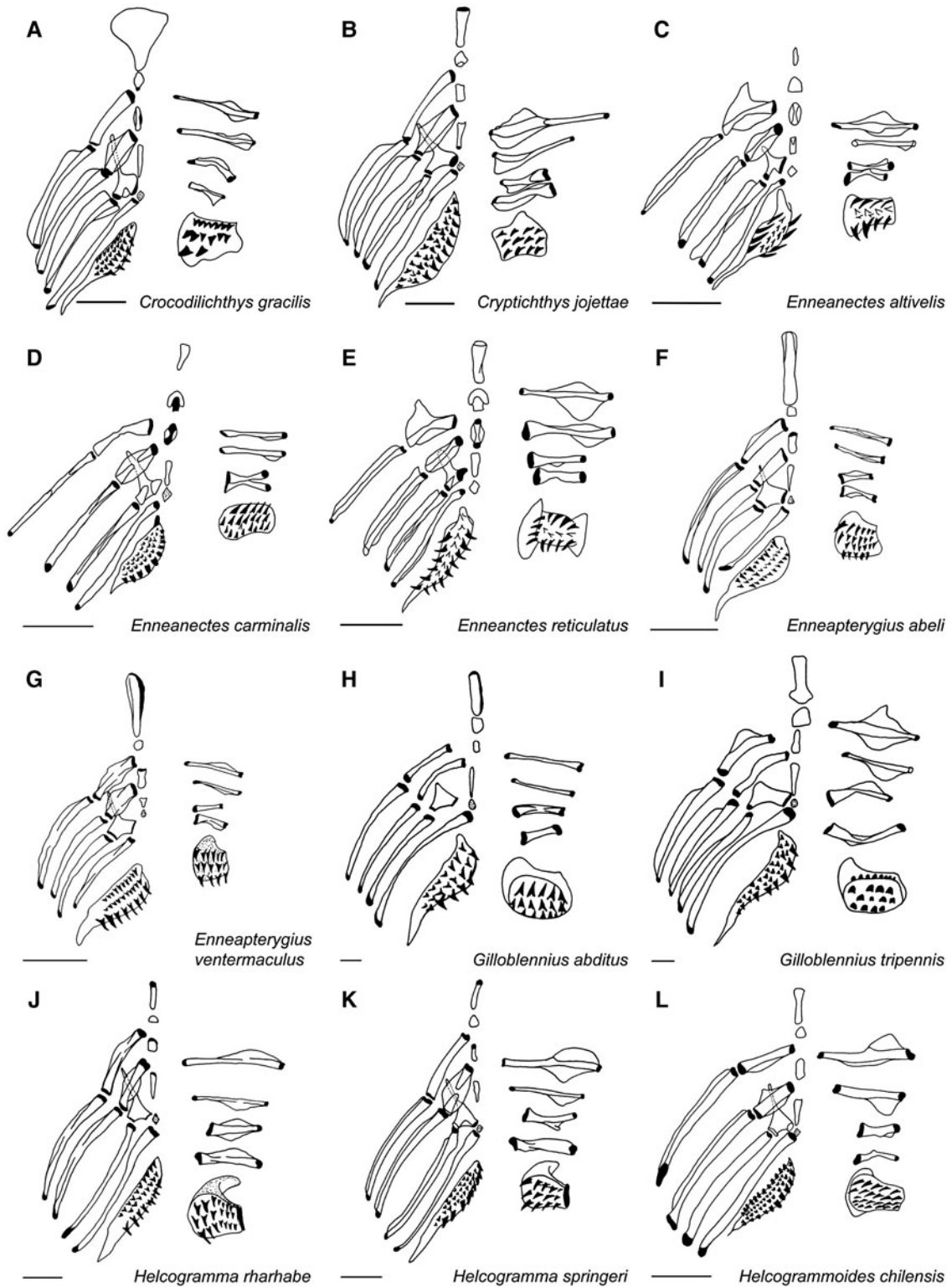


Fig. 4. Branchial arches (with gill rakers removed) of: A, *Crocodilichthys gracilis*; B, *Cryptichthys jojettae*; C, *Enneanectes altivelis*; D, *Enneanectes carinalis*; E, *Enneanectes reticulatus*; F, *Enneapterygius abeli*; G, *Enneapterygius ventermaculus*; H, *Gilloblennius abditus*; I, *Gilloblennius tripennis*; J, *Helcogramma rharhabe*; K, *Helcogramma springeri*; L, *Helcogrammoides chilensis*; Scale bar = 1 mm.

The overall shape of the third and fourth basibranchial bones shows a wide variation that does not allow separation of the studied triplefin species. Similar results were obtained by Choat & Randall (1986) and Bellwood (1994) on another teleost family, Scaridae.

The hypobranchial bones are mainly broad, tubular, curved and twisted except for the third hypobranchial, which is funnel-shaped with a long anterior extension. Other shapes such as irregular, waisted, twisted are also observed for the first and second hypobranchial bones.

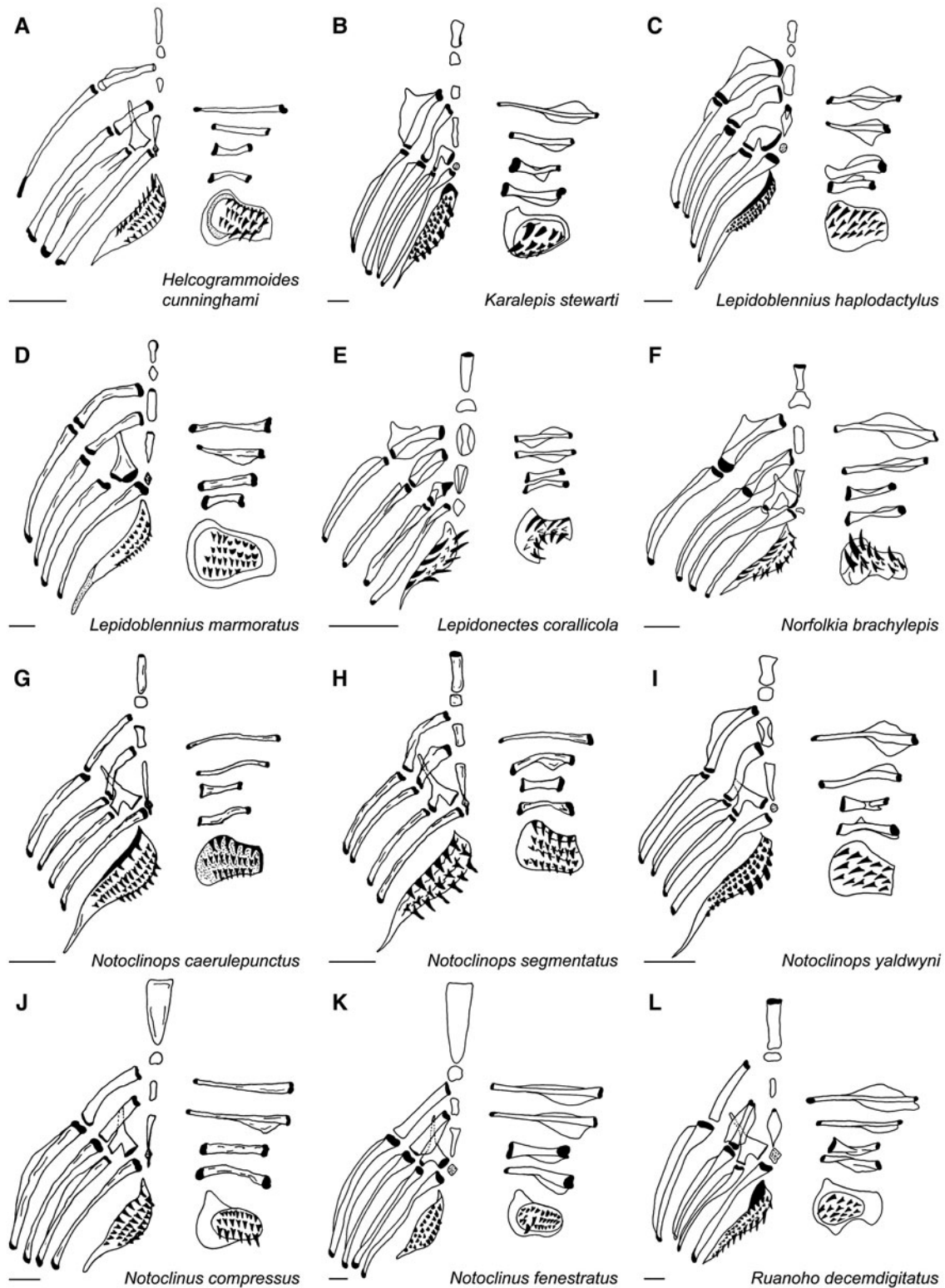


Fig. 5. Branchial arches (with gill rakers removed) of: A, *Helcogrammoides cunninghami*; B, *Karalepis stewarti*; C, *Lepidoblennius haplodactylus*; D, *Lepidoblennius marmoratus*; E, *Lepidonectes corallicola*; F, *Norfolkia brachylepis*; G, *Notoclinops caerulepunctus*; H, *Notoclinops segmentatus*; I, *Notoclinops yaldwyni*; J, *Notoclinus compressus*; K, *Notoclinus fenestratus*; L, *Ruanoho decemdigitatus*; Scale bar = 1 mm.

The median and lateral ends of those bones are mainly broad. The posterior process that includes these two conjoined processes is large, separated with a shallow gap between them; the anterior of the bone extends beyond the second hypobranchial bone.

The first and second hypobranchials show variations in their overall morphology and the shape of the medial and lateral ends among the studied triplefins. The shape of the second hypobranchial has shown much variation that invalidates any process of species separation. Most studied

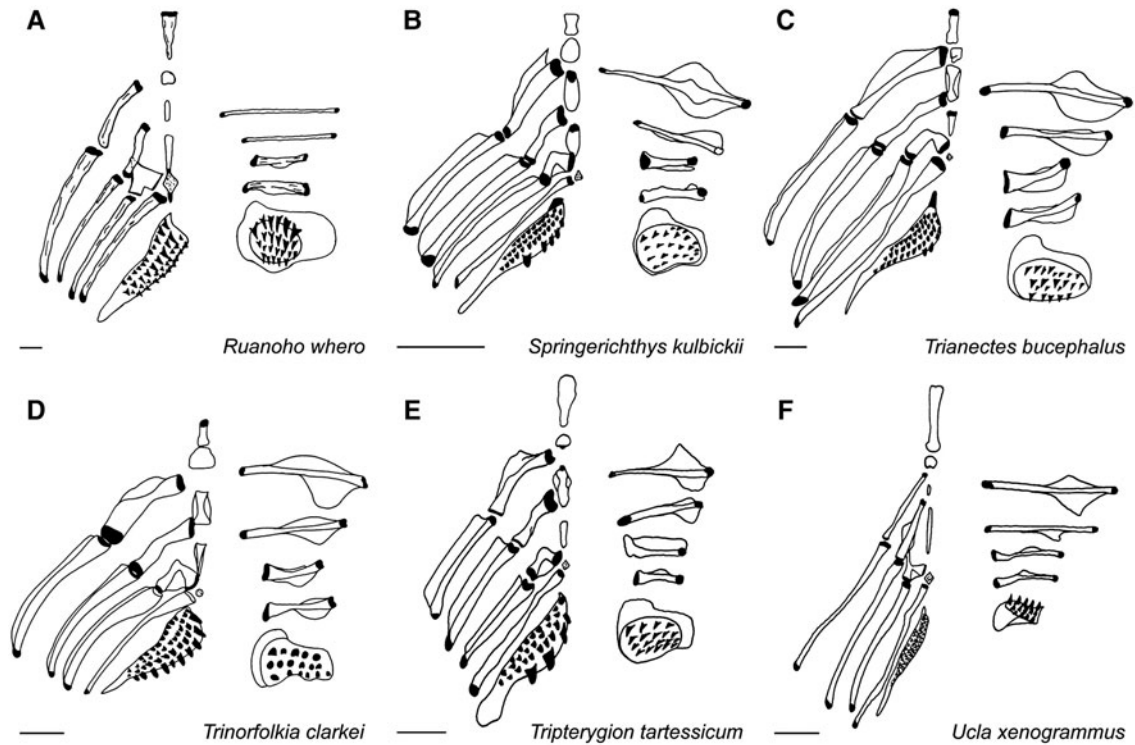


Fig. 6. Branchial arches (with gill rakers removed) of: A, *Ruanoho whero*; B, *Springerichthys kulbickii*; C, *Trianectes bucephalus*; D, *Trinorfolkia clarkei*; E, *Tripterygion tartessicum*; F, *Ucla xenogrammus*. Scale bar = 1 mm.

triplefins have either a tubular or twisted shape. Curved and zig-zag shapes are found only in *Brachynectes fasciatus* and *Ruanoho whero*, respectively. These characters states are good criteria to diagnose these two taxa within their genera.

The third hypobranchial bone has a shape that is different from those of the first two hypobranchials. This bone has an inverted Y-shape with particular variations in the length and thickness of its arms. The overall shape of this bone shows a range of variation that precluded its use for separating the triplefins investigated, except for *Lepidoblennius marmoratus* in which the arms of this bone were not clearly separated. Also, for *Norfolkia brachylepis* and *Enneanectes carminalis*, the two arms are connected with bony growth.

Another characteristic of this bone is its relationship with the 2nd hypobranchial bone. In the studied triplefins this bone usually lies over the second hypobranchial toward the anterior side of the fish. In *Acanthanectes rufus*, this bone extends further anteriorly and past the 2nd hypobranchial bone. In *Bellapiscis medius*, *Brachynectes fasciatus*, *Lepidoblennius haplodactylus*, *L. marmoratus*, *Notoclinops yaldwyni*, *Trianectes bucephalus*, *Enneanectes reticulatus*, *Axoclinus lucillae*, *Norfolkia brachylepis* and *Tripterygion tartessicum* this bone reaches the second hypobranchial, but does not extend beyond its anterior edge. In *Gilloblennius tripennis*, *Karalepis stewarti*, *Lepidonectes corallicola* and *Springerichthys kulbickii*, this bone does not reach the second hypobranchial, due to the absence of the anterior process of the third hypobranchial bone in these species. Anterior extension of the third hypobranchial reaching to but not extending beyond the anterior edge of the second hypobranchial bone is considered a good diagnostic character for those taxa that possess it. The length of the gap between the two posterior processes of the third hypobranchial

bone and whether those processes are separated or not showed an ambiguous distribution in the studied triplefins.

The ceratobranchial bones are elongate, except for the fifth, and slightly curved. Variations in the shape of these bones in the studied species include twisted, curved, wavy and constricted bones. The case of the fourth ceratobranchial reaching the fourth basibranchial is present in *Lepidoblennius marmoratus* and other taxa. The middle section of all ceratobranchials is narrow. The fifth ceratobranchial bone is pointed plate in some species and posteriorly broad. There are generally 3 or 4 rows of teeth, but 5 or 6 rows were observed in the *Trianectes bucephalus* and the *Bellapiscis medius*, respectively. In general, the teeth of the fifth ceratobranchial are long, curved, and pointed. Variation from the general shape is evident, as some triplefins have a few very large teeth and others are equipped with very small teeth.

On the medial curvature of each ceratobranchial bone, there is usually an anterior row of gill rakers. In some species they are found on both anterior and posterior sides and in only a few cases they are found on the posterior side only. The shape and size of the gill rakers shows some variation among the studied species of tripterygiids. In the majority of the species studied, the gill rakers are short. They are long in *Acanthanectes rufus*, *Blennodon dorsalis*, *Ceratobregma acanthops*, *Enneapterygius ventermaculus*, *Helcogramma rharhabe*, *H. springeri*, *Karalepis stewarti*, *Notoclinus compressus*, *N. fenestratus* and *Tripterygion tartessicum*. An opposite arrangement of gill rakers, where each pair of gill rakers faces each other, is the common pattern among triplefins; however, some species show an alternate arrangement, where each couple of gill rakers are not facing each other (*Acanthanectes rufus*, *Gilloblennius abditus*, *Helcogramma rharhabe* and *Ucla xenogrammus*).

The shape of the ceratobranchial bones is relatively uniform within the studied species of triplefins. They are usually narrow and elongate bones, except for a few species that have a curved first ceratobranchial. The medial and lateral ends of the ceratobranchials are usually flared at both the anterior and posterior ends.

The shape and size of the teeth cannot be used to diagnose species. The teeth are arranged in 3 or 4 rows, but in *Trianectes bucephalus* and *Bellapiscis medius*, 5 and 6 rows were observed, respectively. They seem to be unique to these two taxa.

The studied tripterygiid species show a considerable variation in the form and arrangement of the gill rakers, and the position of the teeth on the ceratiobranchials. Both long and short pairs of gill rakers are found in this study, with short gill rakers being the common condition. For *Lepidoblennius haplodactylus*, a mixture of long and short gill rakers was observed. This character might be considered a good criterion to characterize this species. The arrangement of the gill rakers is either alternate, where gill rakers are not facing each other, or opposite, where each couple of gill rakers is facing each other. The majority of the studied triplefins were shown to have their gill rakers arranged opposite each other. The alternate arrangement might be considered a distinctive character for the following taxa: *Acanthanectes rufus*, *Enneapterygius abeli*, *Gilloblennius abditus*, *Helcogramma rharhabe* and *Ucla xenogrammus*.

The epibranchial bones are mainly elongate, narrow, and straight except for the fourth epibranchial bone which is short, broad and curved. Other less common shapes such as twisted, wavy, waisted, triangular were also observed. The median end of the first and second epibranchials is mainly tubular, while that of the third and fourth is broad. Presence or absence of flanges on the medial end varies between triplefins. Usually, this end lacks flanges, but certain species show the presence of flanges on either anterior, posterior, or both sides of the medial end. When flanges are present at both anterior and posterior sides, those at the anterior sides are larger.

The shape of the four epibranchial bones shows wide variation. Hardy (1986) and Holleman (1993) documented variation in the shape of these bones in some triplefin species. The shape of these bones varies in the following species: *Springerichthys kulbickii* (twisted first and second epibranchial); *Notoclinops yaldwyni* (twisted first and wavy fourth epibranchial); *Blennodon dorsalis* (triangular third epibranchial); *Notoclinops caerulepunctus* (S-shape fourth epibranchial); and *Lepidoblennius haplodactylus* (wavy fourth epibranchial).

The medial and lateral ends of the first and second epibranchials are elongate and narrow while those of the third and fourth epibranchials are broad and short. These ends have flanges on the anterior, middle and posterior sides of the bone, and on both anterior and posterior at the same time. Absence of flanges is also reported for both the medial and lateral ends of different epibranchials of different triplefins. In certain cases the position of the flanges at the medial or lateral ends of the epibranchials is a good criterion to diagnose these species within genera. For example, the first epibranchial of the following species lack flanges: *Apopterygion oculus*, *Blennodon dorsalis*, *Ceratobregma acanthops*, *Cremonchorites capensis* and *Cryptichthys jojettae*. For the second epibranchial bone and on the medial end of the second epibranchial the following species have flanges: *Ceratobregma acanthops* (anterior side only); *Apopterygion oculus* and *Blennodon dorsalis*

(anterior and posterior sides). For the third epibranchial bone, the following species have flanges: *Enneapterygius abeli*, *Blennodon dorsalis*, *Helcogramma springeri* (medial end, posterior side only); *Ceratobregma acanthops*, *Cryptichthys jojettae*, *Gilloblennius tripennis* (medial end, anterior side only); *Trianectes bucephalus* (lateral end, anterior and posterior sides). For the fourth epibranchial, the following species have flanges: *Trinorfolkia clarkei* (lateral end, anterior and posterior sides); *Cremonchorites capensis* and *Ruanoho decemdigitatus* (lateral side, anterior side only); *Ceratobregma acanthops* (medial, anterior side); and *Gilloblennius tripennis* (medial, anterior and posterior sides).

There is a single gill raker at the base of the 1st epibranchial in bone in certain triplefin species such as *Blennodon dorsalis*, *Cremonchorites capensis*, *Cryptichthys jojettae*, *Gilloblennius abditus*, *Lepidoblennius haplodactylus*, *L. marmoratus* and *Springerichthys kulbickii*. *Notoclinus fenestratus* and *Trinorfolkia clarkei* have 2 and 3 gill rakers respectively. The infrapharyngobranchial bone (IPBB) is usually rectangular or rounded in shape. Squarish shape has also been observed in this study. The ventral surface of the IPBB is equipped with 2 to 6 rows of long, curved and pointed teeth, although in *L. marmoratus* the teeth are rounded and papilliform.

The IPBB of *Bellapiscis lesleyae*, *Karalepis stewarti*, *Notoclinops yaldwyni* and *Blennodon dorsalis* is rounded, while it is squarish in *Gilloblennius tripennis* and oval in *Cremonchorites capensis* and may be considered as distinctive for those species. The number of rows of teeth found on the ventral side of IPBB is either 3 or 4. Two and 6 rows of teeth were found only in *Brachynectes fasciatus* and *Blennodon dorsalis* respectively. This character can be used to separate these two species.

The teeth on the IPBB are usually long, curved and pointed. However, in certain species of triplefins, one or two rows are equipped with very large or very small teeth or a mixture of the two.

Urohyal bone (Figures 7 & 8)

The lateral and ventral side of this bone is variable in shape in the triplefins studied here, but is usually cup-shaped, heart-shaped or triangular. Lateral processes are broad and rounded and are present in most species, except for *Helcogrammoides chilensis*, *Lepidoblennius haplodactylus* and *Cremonchorites capensis*. The anterior margin can be divided into six types according to its shape: concave, convex, raised, wavy, straight and tubular with concave being the most common, followed by the convex shape. Sides are rounded or straight, other conditions such as asymmetrical, wavy and irregular are also seen. The posterior end is a broad extension and can be either tubular or pointed in shape. The tubular shape is the most common among triplefins. A very fine, thread-like posterior end is observed in *Helcogramma springeri*. In certain triplefin species, the ventral surface of this bone bears a keel-like structure. In the lateral view, the shape of the anterior margin is mainly straight. Other shapes are also seen, such as wavy, sloped, convex, pointed and concave. The lateral view of the urohyal bone is characterized as having a beak-like structure. Curved, straight and irregular were also seen in the studied triplefins. The posterior end has one, two or three processes. These processes are narrow, broad, curved or mixtures of these. A broad process is the most common condition. A

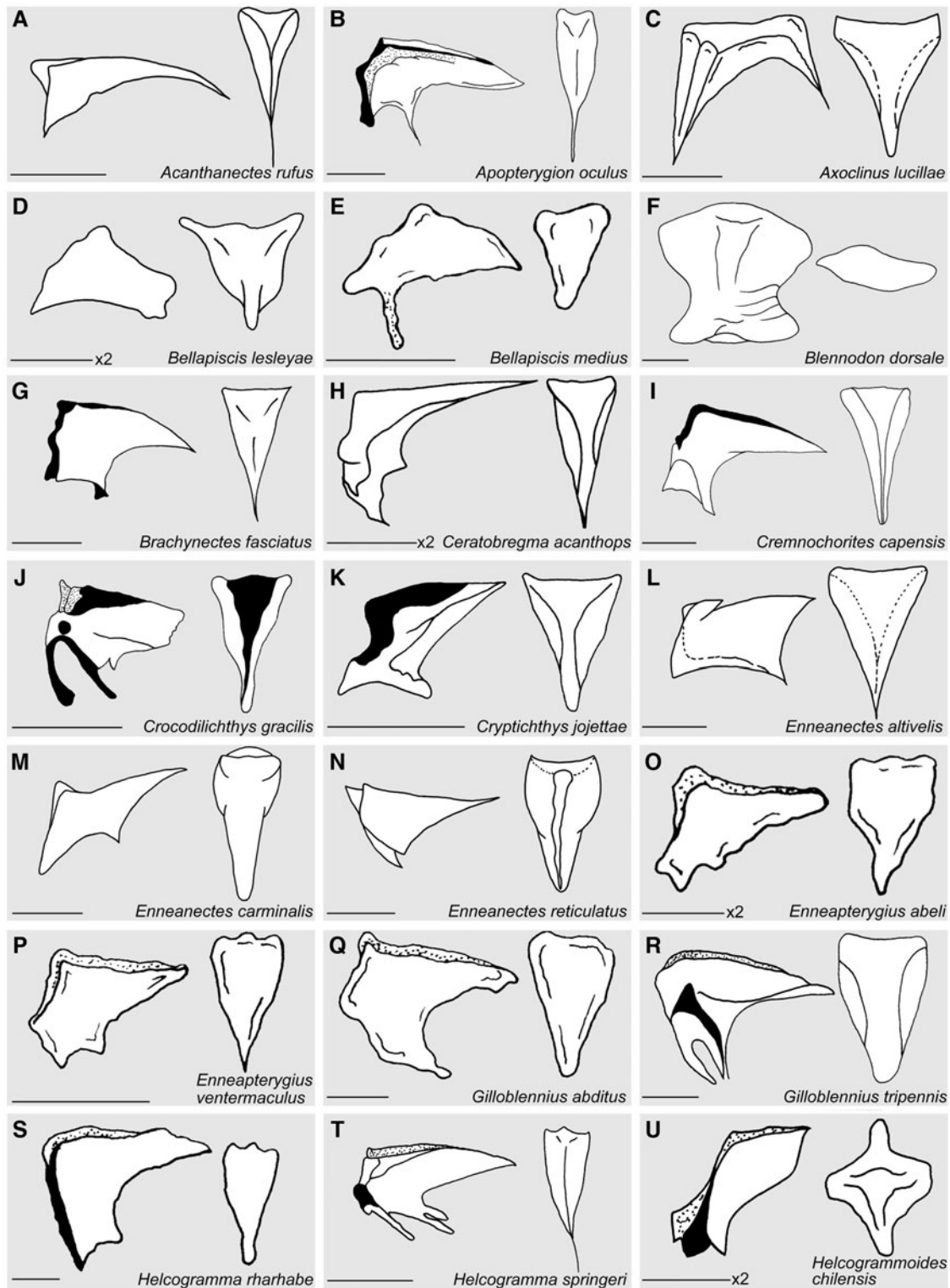


Fig. 7. Urohyal bone of: A, *Acanthanectes rufus*; B, *Apopterygion oculus*; C, *Axoclinus lucillae*; D, *Bellapiscis lesleyae*; E, *Bellapiscis medius*; F, *Blennodon dorsale*; G, *Brachynectes fasciatus*; H, *Ceratobregma acanthops*; I, *Cremnochorites capensis*; J, *Crocodilichthys gracilis*; K, *Cryptichthys jojettae*; L, *Enneanectes altivelis*; M, *Enneanectes carminalis*; N, *Enneanectes reticulatus*; O, *Enneapterygius abeli*; P, *Enneapterygius ventermaculus*; Q, *Gilloblennius abditus*; R, *Gilloblennius tripennis*; S, *Helcogramma rharhabe*; T, *Helcogramma springeri*; U, *Helcogrammoides chilensis*; Left figure, lateral view; right figure, ventral view. Scale bar = 1 mm.

mixture of narrow, broad, and narrow, curved processes was seen in a number of species.

The shape of the urohyal bone in the ventral and lateral view shows a wide range of variation that renders it of little use as a

diagnostic character. However, in certain species the urohyal has a shape in ventral view that makes the species distinctive from the rest of the tripterygiid fishes studied. The lateral wing in the ventral view is present, except for *Helcogrammoides*

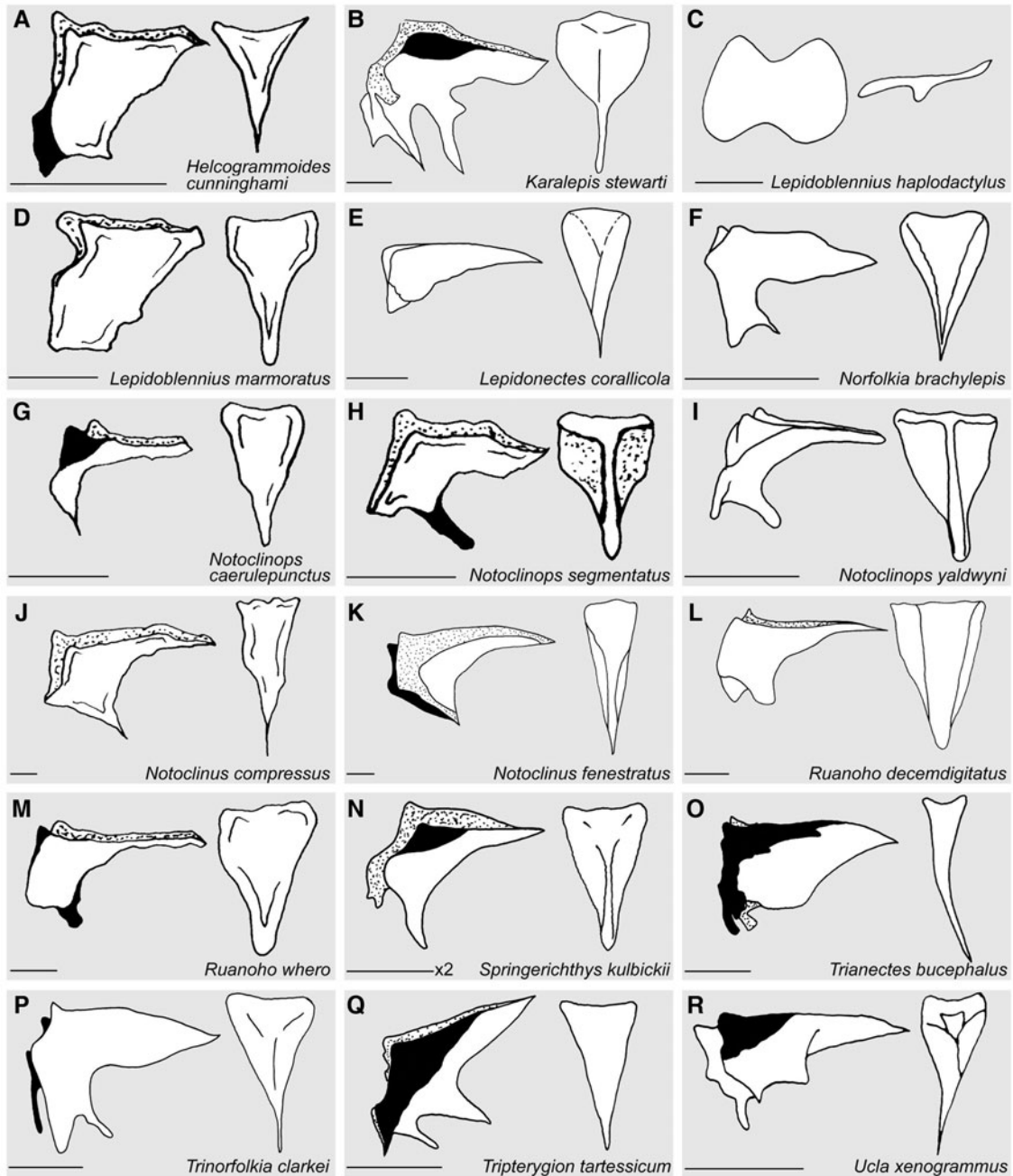


Fig. 8. Urohyal bone of: A, *Helcogrammoides cunninghami*; B, *Karalepis stewarti*; C, *Lepidoblennius haplodactylus*; D, *Lepidoblennius marmoratus*; E, *Lepidonectes corallicola*; F, *Norfolkia brachylepis*; G, *Notoclinops caerulepunctus*; H, *Notoclinops segmentatus*; I, *Notoclinops yaldwyni*; J, *Notoclinus compressus*; K, *Notoclinus fenestratus*; L, *Ruanoho decemdigitatus*; M, *Ruanoho whero*; N, *Springerichthys kulbickii*; O, *Trianectes bucephalus*; P, *Trinorfolkia clarkei*; Q, *Tripterygion tartessicum*; R, *Ucla xenogrammus*. Scale bar = 1 mm.

chilensis, *Lepidoblennius haplodactylus* and *Cremnochorites capensis*. The anterior margin in the ventral view is either concave or convex. Other shapes were also observed in the studied triplefins, straight, wavy and tubular. *Helcogrammoides chilensis* was the only triplefin seen with a tubular anterior margin to the urostyle when viewed ventrally. This character can be used to separate this species from the rest of the studied species. The sides, in the ventral view, appear mainly curved or straight, but wavy and tubular shapes were also observed, indicating variation in this character. The posterior end of the urohyal is usually tubular and pointed.

Of the morphological characters of the urohyal, the shape of its anterior margin and its sides, when viewed laterally, are useful diagnostic characters. Only in *Ucla xenogrammus* does the posterior end viewed laterally have three processes, a character that distinguishes this species from the other studied triplefins.

Supraneural and haemal spine insertion with pterygiophore of dorsal and anal fins

The Tripterygiidae are characterized by well-defined, separate dorsal fins: the two anterior ones have spines only, and the

third has just soft rays. The areas dividing these fins are formed by the loss of spines and pterygiophores, usually between the first and second fins, and sometimes between the second and third fins.

The spinous dorsal-fin pterygiophore formula shows a wide variation among the studied species of triplefins (Table 1). There are 1 to 3 pterygiophores anterior to the neural spine of the first vertebra. Most of the species examined (18) have 1 pterygiophore, 10 species have 2, and 10 species have 3.

The space between the posterior end of the second dorsal fin and the anterior end of the third dorsal fin is usually filled with 1 pterygiophore. No pterygiophore is present at this position in *Acanthanectes rufus*, *Gilloblennius tripennis*, *Notoclinops yaldwyni*, *Ruanoho decemdigitatus*, *Ruanoho where* and *Trianectes bucephalus*, and can be considered as a unique character state that can be used to characterize those species.

In all species examined there are very small, remnant pterygiophores posterior to the pterygiophore supporting the last dorsal- and anal-fin rays. In *Crocodilichthys gracilis* and *Helcogramma rharhabe*, the first ray of the third dorsal-fin is supported by 2 pterygiophores. The anal fin of triplefins usually has 1 or 2 spines. In a few genera, such as *Blenodon dorsalis*, *Cryptichthys jojettae*, *Gilloblennius abditus*, *Helcogrammoides chilensis*, *H. cunninghami* and *Lepidoblennius haplodactylus* there is no anal-fin spine.

Where there are 2 anal-fin spines, the first is supported by its own pterygiophore, while the pterygiophore that supports the second spine also supports the first ray. Where there is a single spine, its pterygiophore also supports the first ray (*Bellapiscis lesleyae*, *Enneapterygius abeli*, *E. ventermaculus*, *Helcogramma rharhabe*, *H. springeri*, *Notoclinops segmentatus*, *Notoclinus compressus*, *N. fenestratus*, *Tripterygion tartessicum*, *Ucla xenogrammus*, *Bellapiscis medius*, *Brachynectes fasciatus* and *Karalepis stewarti*). In *Springerichthys kulbickii* the 2 anal spines are supported by a single pterygiophore.

Springer (1993) documented the presence of a number of free pterygiophores (not supporting spines) between the second and third dorsal fins. He suggested that up to four of the pterygiophores immediately anterior to the first segmented ray lack spines. In the present study usually only 1 spine was found as lost, but in some species there are 1 or 3 spines. In *Cryptichthys gracilis*, *Helcogrammoides cunninghami* and *Notoclinus fenestratus*, there are 2 free pterygiophores between the second and third dorsal fins. However, no such loss appears in other species such as *Acanthanectes rufus*, *Gilloblennius tripennis*, *Notoclinops yaldwyni*, *Ruanoho decemdigitatus*, *R. where* and *Trianectes bucephalus*.

In tripterygiids the pterygiophores of the spinous dorsal fin have been reduced to single elements, probably through the fusion of the medial and distal segments. In the first dorsal fin, the anteriormost pterygiophores may be crowded over the head, and thus difficult to associate with a particular vertebra. The base of each dorsal spine is opposite the dorsal surface of its supporting pterygiophore. This mode of interdigitation appears to be universal among tripterygiids. With this arrangement there is usually 1 pterygiophore opposite the neural spine of the 1st vertebra (Springer, 1993).

The pattern of the interdigitation of the pterygiophores supporting the second and third dorsal fins with the neural spines of the vertebrae seems to be useful for taxonomic purposes. In most of the studied species, the pterygiophore that

supports the first spine of the second dorsal fin inserts anterior to the neural spine of the fourth and fifth vertebrae. In *Crocodilichthys gracilis*, *Enneapterygius abeli* and *E. ventermaculus*, it inserts anterior to the neural spine of the third vertebra. Insertion anterior to the neural spine of the sixth vertebra was observed in *Acanthanectes rufus*, *Apopterygion oculus*, *Helcogramma springeri*, *Notoclinops yaldwyni* and *Tripterygion tartessicum*. The interdigitation of the third dorsal fin shows wider variation than the interdigitation of the second dorsal fin. Usually, the pterygiophore supporting the first segmented ray of the third dorsal fin inserts anterior to the neural spine of the 19th, 22nd or 23rd vertebrae. Deviation from this sequence is evident when the pterygiophore occurs anterior to the neural spine of the 16th vertebra (*Brachynectes fasciatus*), the 18th vertebra (*Enneapterygius ventermaculus*, *Helcogrammoides chilensis*, *Notoclinus compressus*), the 20th vertebra (*Trinorfolkia clarkei*, *Ruanoho where*), the 21st vertebra (*Lepidoblennius haplodactylus*, *Notoclinus fenestratus*, *Springerichthys kulbickii*), the 24th vertebra (*Ceratobregma acanthops*) and the 27th vertebra (*Blenodon dorsalis*).

In the Tripterygiidae the segmented rays of the 3rd dorsal and anal fins are usually unbranched. Branched segmented rays in *Cremnochorites capensis* and *Crocodilichthys gracilis* have only been observed in large specimens. This branching in both fins is also reported in some specimens of *Ruanoho decemdigitatus*. In *R. decemdigitatus* this character is considered, at present, as an individual variation because this species is known from only a few specimens. Springer (1993) suggested that the unbranched rays in the dorsal and anal fins appear as a specialized character at several levels in the family Tripterygiidae and suggested that such specialization be considered as a unique character for the family as a whole.

The presence of a fully developed last dorsal-fin spine has been debated. Hardy (1986) found that 5% of his specimens of *Ruanoho decemdigitatus* and *R. where* were shown to have a fully developed last dorsal-fin spine. Springer (1993) argued that he never encountered any specimens of triplefin species with a fully developed dorsal-fin spine. The results of the present study support Springer's (1993) finding in the absence of a fully developed dorsal-fin spine. The results of Hardy (1986) could be an uncommon reversal to a primitive state, hence, a specialization of *Ruanoho* (Springer, 1993).

Although the osteology of the skull of the triplefin species was not included in this study, the septal bone was noted to be present in all species in consideration. Springer (1993) suspected that the septal bone would not be present in all triplefin genera, but the results of the present study show its presence in all tripterygiid fish species.

In the present work, the dorsal-fin formula proved useful in separating the genera and species of Tripterygiidae. The differences between species lie in the following: (1) number of pterygiophores opposite the neural spine of the first vertebra; (2) the number of vacant interneural spaces behind the neural spine of the first vertebra; and (3) the number of continuous pterygiophore insertions. The first character separated *Bellapiscis lesleyae*, *Helcogrammoides chilensis* and *Springerichthys kulbickii*, all of which have 1 pterygiophore opposite the neural spine of the first vertebra. The second character is diagnostic of *Notoclinus compressus* on the basis of a pterygiophore insertion in the first empty interneural space behind the neural spine of the first vertebra. The third character divided the studied

triplefins into three groups according to the number of the continuous insertions of pterygiophores. These groups are: GI (20–25 insertions); GII (26–30 insertions); and GIII (31–37 insertions). Most studied triplefins fall into GI and GII. Only six species (*Bellapiscis lesleyae*, *Blennodon dorsalis*, *Notoclinops caerulepunctus*, *N. yaldwyni*, *Ruanoho whero* and *R. decemdigitatus*) were shown to have over 30 insertions by which they can be easily characterized.

Differences in the support of the rays and spines of the third dorsal fin and anal fin by pterygiophores are another useful character for separating the studied triplefins. In *Crocodilichthys gracilis* and *Helcogramma rharhabe*, the first ray of the third dorsal fin is supported by 2 pterygiophores, an unusual condition for this fin ray support compared with the other studied triplefins. In *Bellapiscis lesleyae*, *Enneapterygius* spp., *Helcogramma* spp., *Notoclinops segmentatus*, *Notoclinus* spp., *Tripterygion tartessicum* and *Ucla xenogrammus*, the first spine and first segmented ray of the anal fin are supported by the same pterygiophore. Another condition that is unique to taxa in which two spines are present in the anal fin involves the second spine and the first segmented ray sharing the same pterygiophore. This condition is evident in *Bellapiscis medius* and *Brachynectes fasciatus*.

The absence of spines from the anal fin is considered as a valuable taxonomic character of *Blennodon dorsalis*, *Cryptichthys jojettae* and the two species of the genus *Helcogrammoides* as well as in *Gilloblennius abditus* and *Lepidoblennius haplodactylus*.

Caudal fin skeleton (Figures 9–12)

All bones in the caudal fin skeleton are directly or indirectly associated with the last 'compound centrum' of the vertebral column. The compound centrum is the result of the fusion of the ural centra and first preural centrum (Nybelin, 1963).

In the family Tripterygiidae the caudal fin skeleton is composed of the second preural centrum (PU₂), urostyle, hypurals, parhypural and epurals. The second preural centrum is located in front of the urostyle, bearing mainly long, broad neural and haemal spines. The neural spine is a curved bone with pointed tip reaching the dorsal edge of the fish's body. The haemal spine is a straight bone with a rounded tip reaching or not reaching the posterior edge of the caudal fin skeleton.

The urostyle is fused to third and fourth hypurals in all studied triplefins. The hypurals are plate-like bones, the lower plate is comprised of the first and second hypurals while the upper plate comprises the third and fourth hypurals.

The fifth hypural bone is autogenous. This bone is usually short and narrow, although a considerable number of studied species of triplefins have long, very short, or broad fifth hypural bones. In *Helcogramma rharhabe* and *Notoclinops segmentatus*, this bone was found to be cartilaginous.

The parhypural is a plate-like bone lying below the urostyle, fused to it and autogenous to the lower hypural plate. It is usually long and broad, but not reaching the posterior end of the lower hypural plate. A few triplefin species have a short, narrow parhypural reaching the posterior end of the lower hypural plate.

The epurals are two blade-like bones located above the urostyle. Epurals are usually long, broad and straight with rounded tips. They also have the same length and are generally fused together. Short epurals are found in a few triplefin

species. They usually do not reach the dorsal edge of the fish body in *Ceratobregma acanthops* and *Cryptichthys jojettae* only. They differ in length with the posterior longer than the anterior in *Cremnochorites capensis*, and in *Trianectes bucephalus* with the anterior longer than the posterior.

The procurrent rays are unsegmented and spine-like. The posteriormost dorsal procurrent ray is opposite the fifth hypural bone and sometimes it is counted as a principal caudal fin ray in blennies (Springer & Gomon, 1975). However, it is counted as a procurrent ray in studied tripterygiids in the present work because it resembles the anterior procurrent rays (short, segmented, spine-like with a smooth rather than knob-like base), rather than the long and segmented rays on the upper and lower hypural plates. Clark (1980) and McDowall (2001) followed the same usage and terminology for the posteriormost procurrent rays for Tripterygiidae and Galaxiidae respectively.

Comparative observations have shown that the number of dorsal and ventral procurrent rays varies from 4 to 10, and 3 to 9, respectively. Four dorsal procurrent rays were recorded in *Helcogrammoides cunninghami*, while 10 dorsal procurrent rays were recorded from *Ucla xenogrammus*.

The dorsal procurrent rays' distribution shows variation among the studied triplefins. Usually, there are no procurrent rays in the spaces anterior to NSPU₃, but only in *Helcogramma rharhabe* there are 3 and there is 1 in five triplefin species (Table 3).

In most of the triplefins studied, there is no procurrent ray in the position opposite NSPU₃. There are 2 rays in *Cryptichthys jojettae* and 3 in *Helcogramma springeri* and *Ruanoho whero*. The presence of 1 ray is found in 11 species (Table 3).

The position between NSPU₃ and NSPU₂ is usually free of procurrent rays, but in *B. dorsalis* and *Gilloblennius abditus* there are 2 rays and 1 ray is found in five triplefin species (Table 3).

There are either 1, 2 or 4 procurrent rays opposite NSPU₂. There are 8 species with 1 ray, four species with 2 rays and the presence of 4 rays is found in *Helcogrammoides chilensis* and *Ucla xenogrammus* (Table 3).

There are three species with 1 and 2 procurrent rays inbetween NSPU₂ and E, while *Springerichthys kulbickii* is the only species with 3 rays. This character could separate this species from the rest of the triplefins studied.

The position opposite E₁ is usually free of procurrent ray, but 11 species have 1 ray, seven species have 2 rays and six species have 3 rays. *Lepidoblennius marmoratus* is the only species with 4 procurrent rays in this position. This character can categorize this species.

The number of procurrent rays present between E₁ and E₂ ranges from 1–5. There are seven species with 1 ray, two species with 2 and 3 rays, three species with 4 rays and only *Ruanoho decemdigitatus* had 5 rays. This character can separate this species from the rest of the triplefins studied.

Number of procurrent rays opposite E₂ was 1 in 10 species, 2 in 15 species and 3 in five species. The number of procurrent rays present between E₂ and HU₅ did not exceed 3. There are 21 species with 1 ray in this position; 2 and 3 rays are found in only *Cryptichthys jojettae* and *B. dorsalis* respectively. This character can be considered a good taxonomic criterion to diagnose these two species.

Of 39 species studied, only 29 species were found to have procurrent rays opposite HU₅. Of this number, 27 species

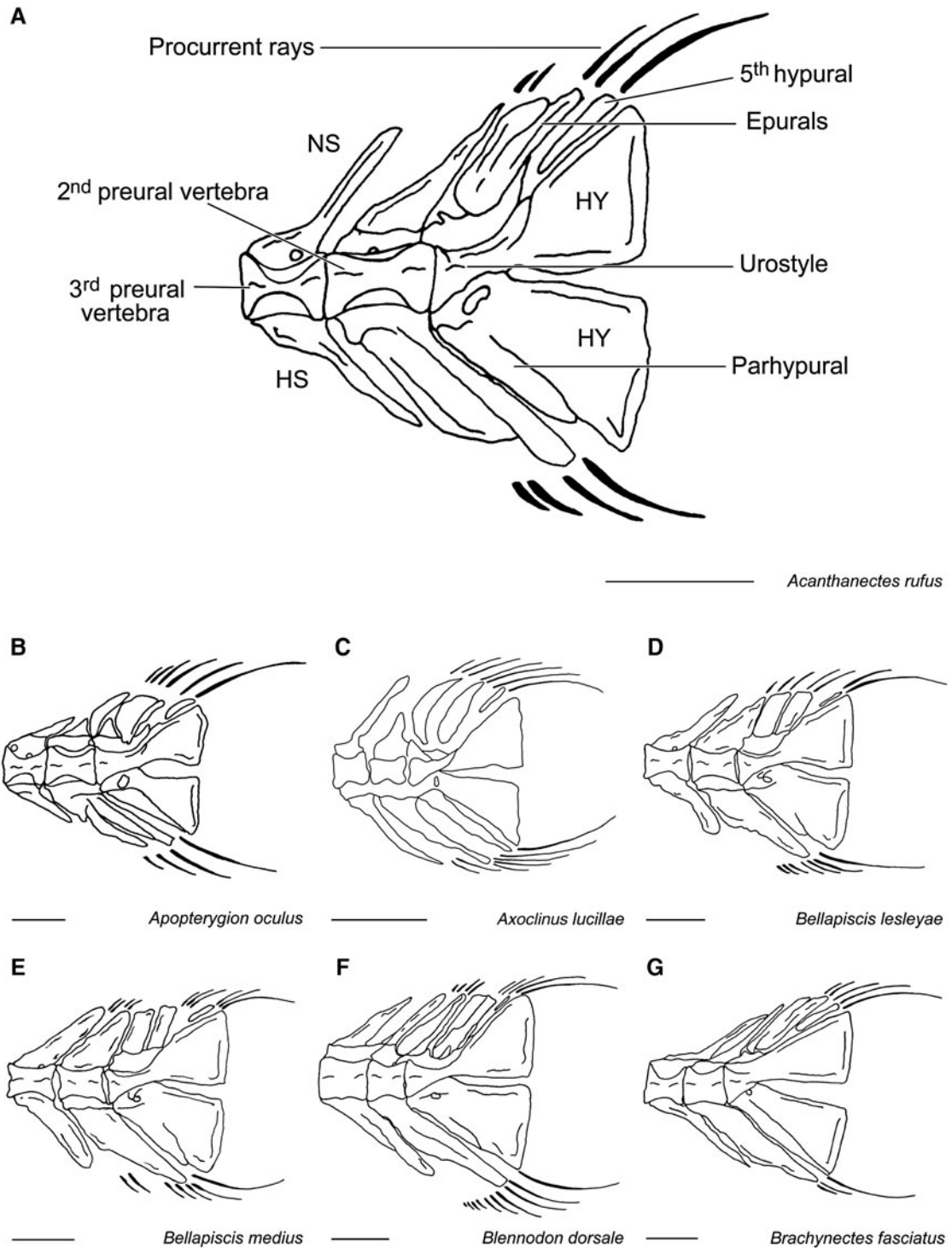


Fig. 9. Caudal skeleton of: A, *Acanthanectes rufus*; B, *Apopterygion oculus*; C, *Axoclinus lucillae*; D, *Bellapiscis lesleyae*; E, *Bellapiscis medius*; F, *Blennodon dorsalis*; G, *Brachynectes fasciatus*; H, NS, neural spine; HS, haemal spine; HY, hypural. Scale bar = 1 mm.

have 1 ray and only *Notoclinus compressus* and *Trinorfolkia clarkei* have 2 rays in this position.

The species *Brachynectes fasciatus*, *Bellapiscis lesleyae* and *Enneanectes reticulatus* can be separated from the rest of the triplefins studied by the presence of 1 procurrent ray between E2 and HU5. On the other hand, *Blennodon dorsalis* and *Bellapiscis medius* can be distinguished by the presence of 2 rays in this position. *Notoclinops caerulepunctus* and *Notoclinus fenestratus* can be separated from the remaining

species of the genera *Notoclinops* and *Notoclinus* in having 1 and 2 procurrent rays opposite UL.

Three ventral procurrent rays are found in *Brachynectes fasciatus*, *Lepidoblennius marmoratus* and *Helcogrammoides cunninghami*, while nine ventral procurrent rays were seen in *Blennodon dorsalis*, *Notoclinops segmentatus* and *Ucla xenogrammus*.

Notoclinops segmentatus can be separated from the other species of the genus *Notoclinops* in having 1 ventral

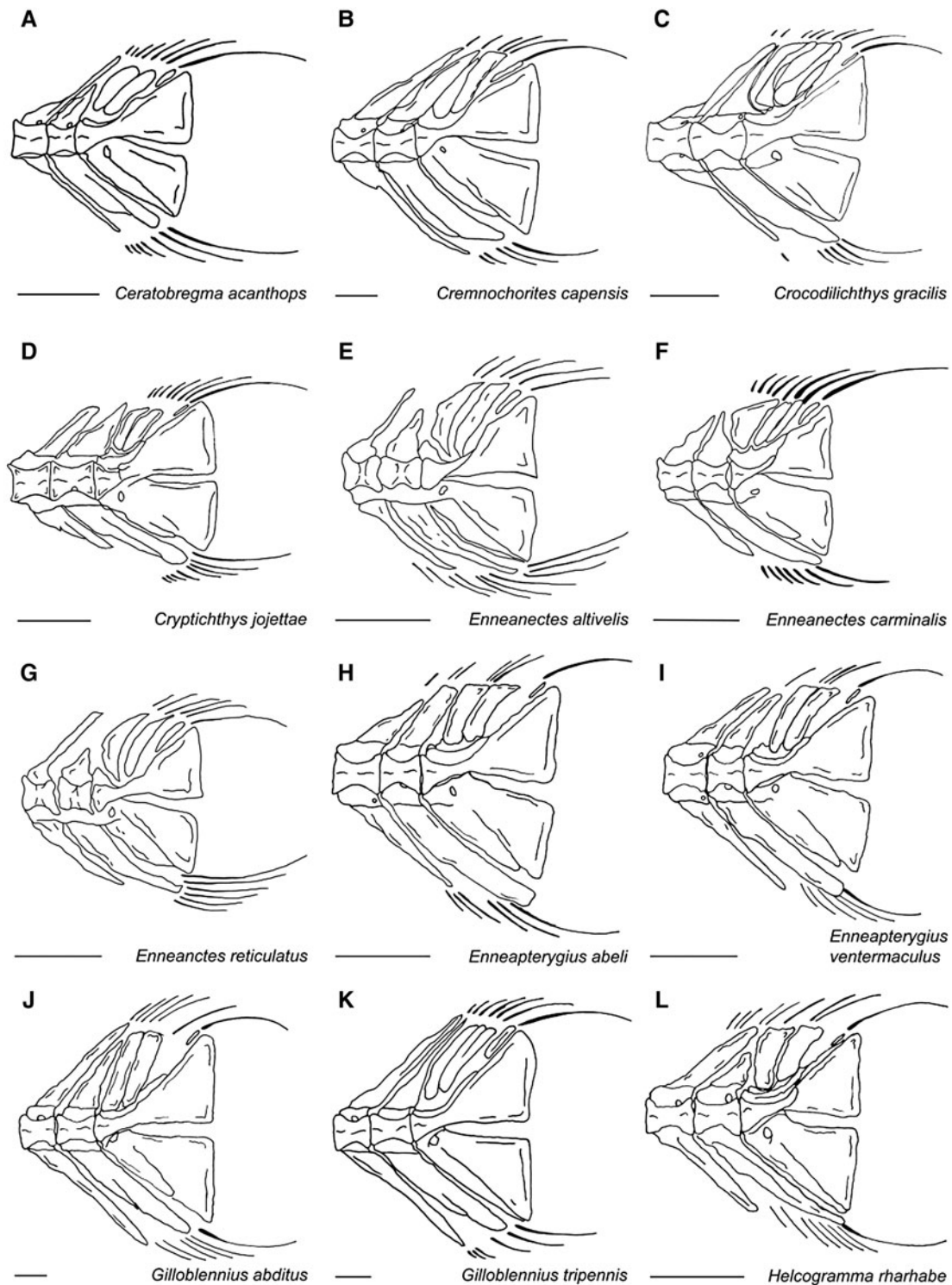


Fig. 10. Caudal skeleton of: A, *Ceratobregma acanthops*; B, *Cremnochorites capensis*; C, *Crocodilichthys gracilis*; D, *Cryptichthys jojettae*; E, *Enneanectes altivelis*; F, *Enneanectes carminalis*; G, *Enneanectes reticulatus*; H, *Enneapterygius abeli*; I, *Enneapterygius ventermaculus*; J, *Gilloblennius abditus*; K, *Gilloblennius tripennis*; L, *Helcogramma rharhabe*. Scale bar = 1 mm.

procurrent ray anterior to HPU₃. This is the only species of triplefin fish found to have a ray in this position.

The number of ventral procurrent rays opposite HPU₃ ranges from 1 to 4. There are six species with 1 ray and three species with 2 rays. *Enneapterygius abeli* and *Gilloblennius tripennis* are characterized in having 3 rays and only *Enneanectes carminalis*

has 4 rays in this position. Such a character found in different genera is not considered useful to characterize species.

Of 39 triplefin species studied, 25 species were found to have ventral procurrent rays between HPU₃ and HPU₂. These rays were distributed between species as follows: five species with 1 ray, 11 species with 2, four species with 3,

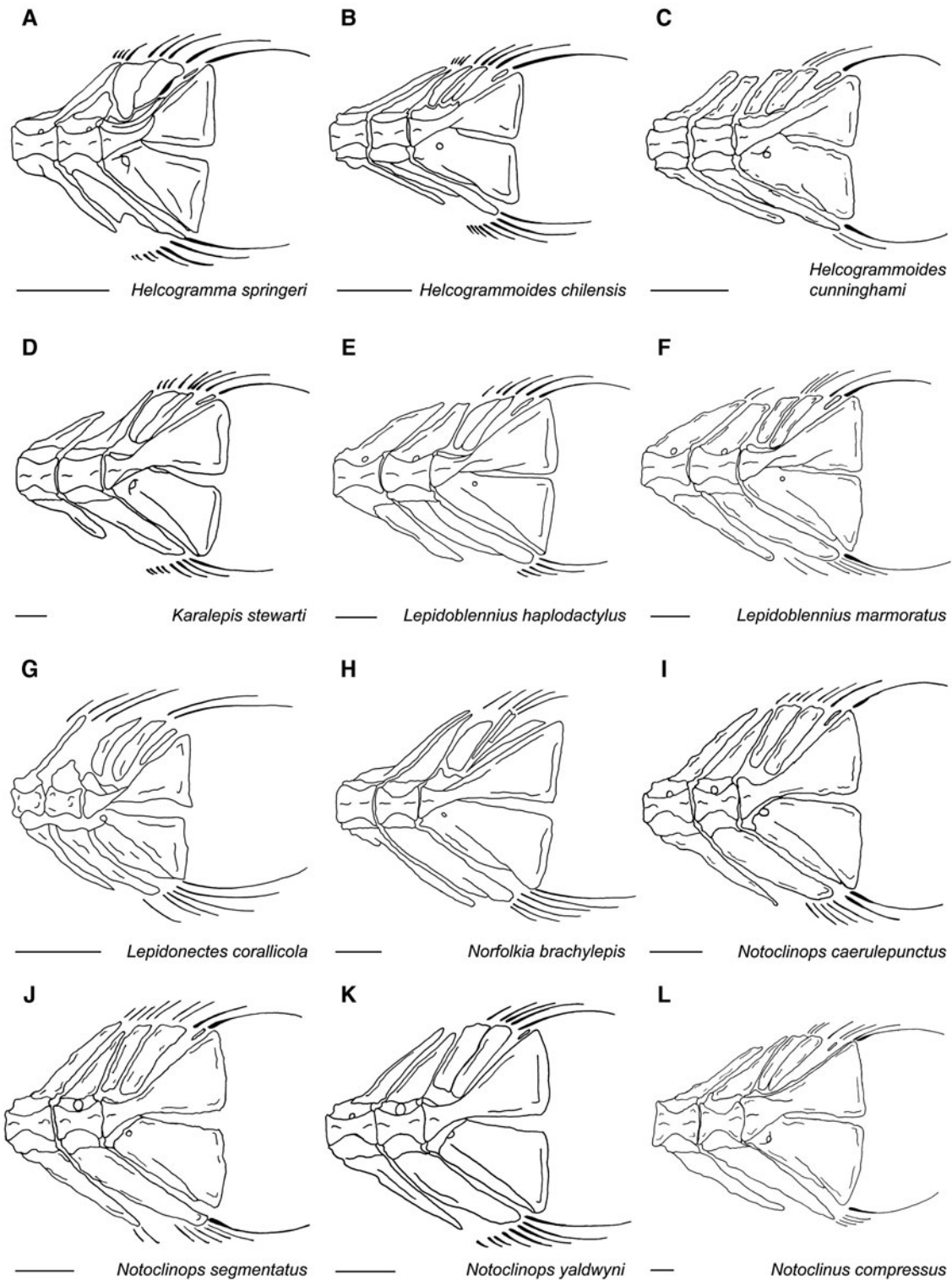


Fig. 11. Caudal skeleton of: A, *Helcogramma springeri*; B, *Helcogrammoides chilensis*; C, *Helcogrammoides cunninghami*; D, *Karalepis stewarti*; E, *Lepidoblennius haplodactylus*; F, *Lepidoblennius marmoratus*; G, *Lepidonectes corallicola*; H, *Norfolkia brachylepis*; I, *Notoclinops caerulepunctus*; J, *Notoclinops segmentatus*; K, *Notoclinops yaldwyni*; L, *Notoclinus compressus*. Scale bar = 1 mm.

three species with 4 and two species with 5 rays in this position.

There are 12 species with 3 ventral procurrent rays opposite HPU2. The remaining 26 species that were shown to have rays in this position had 1 ray (two species), 2 rays (nine species), 4 rays (two species), 5 rays (eight species) and 6 rays (five species).

Most of the triplefin species studied were found to have no ventral procurrent rays in the position between HPU2 and PH. There are 16 species with 1 ray and only *Notoclinus compressus* is characterized in having 3 rays in this position. This character can separate this species from the other species of the genus *Notoclinus*.

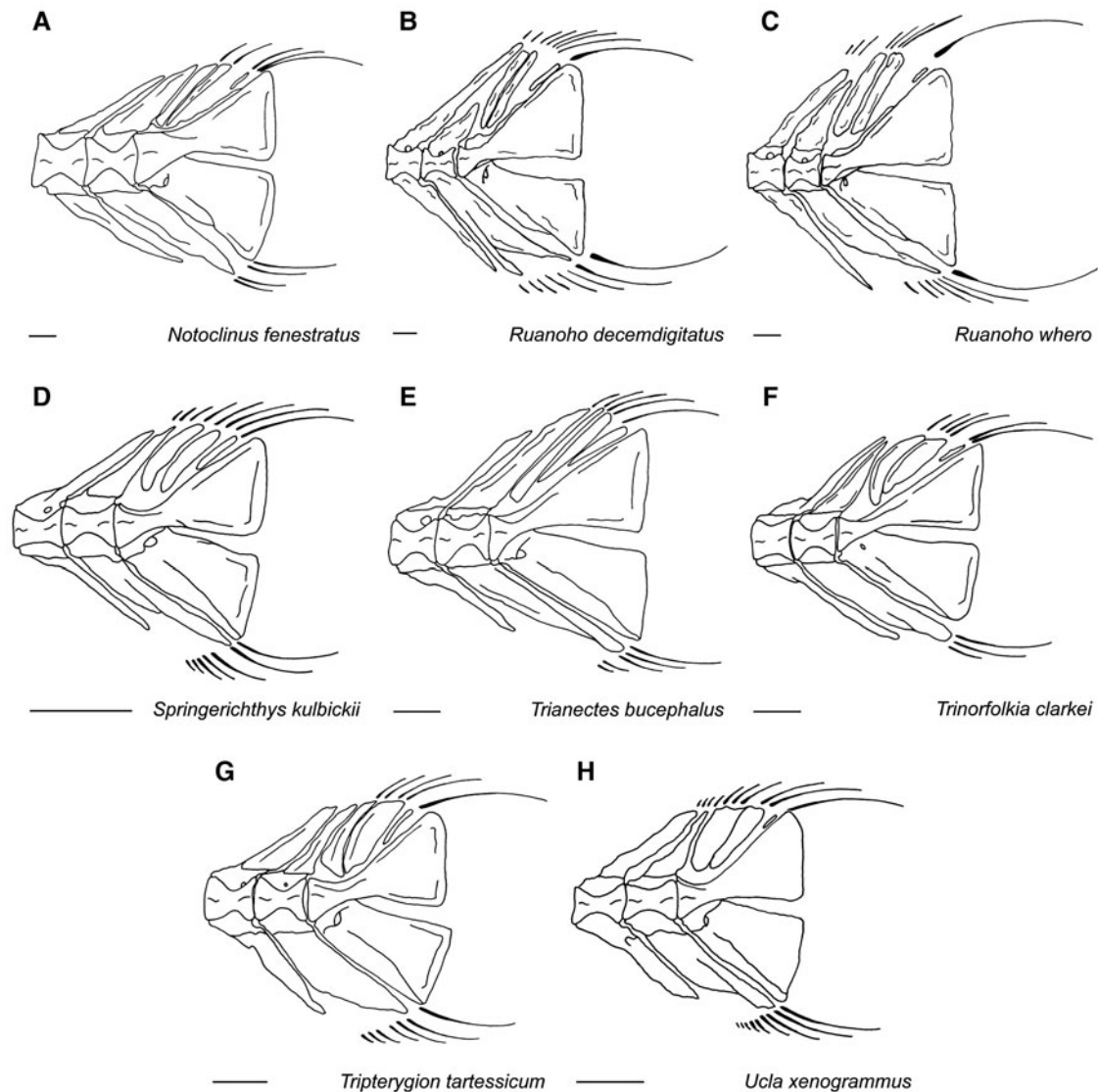


Fig. 12. Caudal skeleton of: A, *Notoclinus fenestratus*; B, *Ruanoho decemdigitatus*; C, *Ruanoho whero*; D, *Springerichthys kulbickii*; E, *Trianectes bucephalus*; F, *Trinorfolkia clarkei*; G, *Tripterygion tartessicum*; H, *Ucla xenogrammus*. Scale bar = 1 mm.

In general, there are no ventral procurrent rays opposite parhypural bone, but in the case of *Axoclinus lucillae* and *Blennodon dorsalis* there is 1 ray and in the case of *Notoclinops caerulepunctus* and *Enneanectes carminalis* there are 2 rays. This character is taxonomically useful to separate these species.

The only triplefin species was found to have ventral procurrent rays between parhypural bone and the lower lobe of the caudal fin skeleton are *Enneanectes carminalis*, *Norfolkia brachylepis* and *Notoclinus fenestratus* with 1 ray and *Enneanectes reticulatus* with 2 rays.

Ruanoho decemdigitatus can be separated from the rest of the triplefin species studied in having 1 ventral procurrent ray opposite the lower lobe of the caudal fin skeleton.

Tripterygiids have a blennioid-type caudal fin skeleton. The skeleton includes five hypurals with an autogenous ventral hypural plate that in some genera comprises the parhypural and fused first and second hypurals; a dorsal hypural plate that comprises fused third and fourth hypurals, which in turn is fused to the urostyle complex; the fifth hypural; two epurals; 13–14 segmented caudal fin rays of

which fewer than 10 are unbranched. Within this general structure of the caudal fin skeleton, the variations in the shape of the upper and lower hypurals showed some variation, making it impossible to use them as an aid to separate the species of the studied triplefins.

Gosline (1968) considered the condition of a well-developed fifth hypural bone as a primitive character in blennioid fishes. The comparative study presented in this work has shown that there are intermediate states between a complete absence and the presence of a fully formed bone. All studied triplefins have this bone. Clark (1980) did not show the fifth hypural in her drawings of the caudal fin skeleton of either *Helcogramma obtusirostris* or *H. springeri*. Hansen (1986) notes 'hypural 5 reduced to cartilage' and refers to it as a 'minimal hypural'; she does not make any mention 'that all twelve species of the genus *Helcogramma* have a variable size of this bone ...'. Both the authors' drawings show very small hypurals, which are assumed to be ossified. Holleman (1993) also argued for the presence of a very small fifth hypural bone in the caudal fin skeleton of *Ucla xenogrammus*. The results presented in this work support Holleman's (1993) finding.

The shape and size of the parhypural bone and whether or not it reaches the posterior end of the lower hypural plate are characters that show wide variation in the studied triplefins. A long and broad parhypural are the two characters that failed to separate triplefin species within certain genera. On the other hand, a short and narrow parhypural was a useful diagnostic character for certain species within some genera (*Notoclinops yaldwyni*). This is also true for the extent of the parhypural relative to the posterior end of the lower hypural plate.

Epural bones are paired bones (sometimes fused) within the caudal fin skeleton of the triplefins. Their shape, size and position in relation to the general fish body provide a set of characters that in several cases prove to be good diagnostic characters for certain species within some genera. Epurals not reaching the dorsal edge of the fish body is observed in only *Ceratobregma acanthops*, *Cryptichthys jojettae* and *E. carminalis*; and epurals not equal in length are seen in only six species. Cases of fusion or non-fusion of the two epurals are nearly equally present in the studied triplefins. The case of fused

epurals observed in this study (e.g. *Acanthanectes rufus*, *Enneanectes carminalis*, *Apopterygion oculus*) is in agreement with the results of Ruck (1976) for *Notoclinus compressus*.

The neural spine of the 2nd preural vertebra is considered a primitive condition by Rosen & Patterson (1969), but was later considered derived in some acanthopterygians by Rosen (1973). In the studied triplefins in this work, there are species with either a short or long neural spine of the second preural vertebra. This character cannot be taken as a means for separating those species, except in the case of *Ruanoho decemdigitatus* and *Trianectes bucephalus* where their neural spines are longer than the epural bones. Other characters of the neural spine of the second preural vertebra may be used as a taxonomic aid to separate triplefins. *Helcogramma rharhabe* and *Lepidoblennius marmoratus* are the only species that have a blunt tip of the neural spine of this vertebra. Characters obtained from the morphology of the haemal spine of the second preural vertebra are not useful characters to recognize the studied triplefins.

Table 6. Characterization of the family Tripterygiidae given by Springer (1993) and relative comments obtained from the present study.

Characters given by Springer (1993)	Comments from the present study
No dorsal-fin spine articulating with pterygiophore serially associated with first segmented ray 'posteriormost'	Confirmed
Dorsal fin divided (membranes deeply or completely incised) into two spinous and one segmented-ray portions (membrane between spinous dorsal fins usually deeply or completely incised)	Confirmed
Dorsal-fin spines more numerous than segmented rays	Confirmed
Segmented dorsal-fin rays branched or simple	Segmented dorsal-fin rays unbranched except for some species
Posteriormost dorsal-fin pterygiophore supporting 1 or 2 'last ray divided to base' fin-ray elements	Confirmed
Autogenous bony stay present or absent following posteriormost dorsal-fin pterygiophore	Absent
Anal-fin spines 0, 1, or 2	Confirmed
Anal-fin spines of mature males without fleshy bulbous distal swellings	Not examined
Posteriormost anal-fin pterygiophore supporting 1 or 2 fin ray elements	Confirmed
Autogenous bony stay present or absent following posteriormost anal-fin pterygiophore	Absent
Branched pectoral-fin rays present or absent	Not examined
Dorsal most pectoral-fin ray articulating entirely, or in part, with scapula	Not examined
Coracoid autogenous	Not examined
Some caudal-fin rays branched	Confirmed
Ventral hypural plate autogenous	Confirmed
Hypural 5 present (most genera) or absent	Confirmed
Scales present, some or most ctenoid, bearing only one row of cteni (except scales all cycloid in the two species of <i>Notoclinus</i>), with radii only in anterior field	Partially confirmed, one or two rows of scales are present
Lateral line contained on scales with free posterior margins (scales not embedded)	Partially confirmed
Lateral line extending half or more length of body (except restricted anteriorly in one undescribed Indo-Pacific genus)	Confirmed
Rostral cartilage absent	Not examined
Septal bone present or absent	Present
Ecto- and mesopterygoids autogenous	Not examined
Posterior end of interopercle extending posteriorly past posterior end of epihyal	Not examined
Premaxillae protractile	Not examined
No noticeably enlarged canine teeth posteriorly in jaws	Not examined
Free margins of lips entire (as opposed to fimbriate, crenulate or with lappets)	Not examined
No cordlike ligament extending from dorsoposterior portion of each ceratohyal to anteromedial end of its respective dentary	Not examined
Urohyal lacking vertical pair of processes on each side	Confirmed
Gill membranes broadly attached across isthmus	Not examined
Free bony margins of opercular bones not fimbriate	Not examined
Infraorbital bones 4 or 5	Confirmed
Palatine teeth present or absent	Not examined
Nape cirri absent	Not examined
Anterior ends of pelvises not extending anteriorly past their juncture with the cleithra	Not examined

There are usually 13 principal caudal-fin rays (7 in the upper lobe and 6 in the lower lobe). Fourteen caudal fin rays are found in only four species: *Crocodilichthys gracilis*, *Notoclinops yaldwyni* and *N. caerulepunctus*. In rare cases the number drops to 12 in *Brachynectes fasciatus* and *Helcogrammoides chilensis*. In *Notoclinus compressus* and *N. fenestratus*, the number of caudal-fin rays decreases to 9 and 10 respectively. The upper lobe usually has 5 unbranched rays, in a few cases it drops down to 4 (e.g. *Notoclinus compressus* and *N. fenestratus* or rises to 6 (e.g. *Gilloblenius tripenis*, *Notoclinops caerulepunctus*, *Ruanoho whero*, *Springerichthys kulbicki* and *Trianectes bucephalus*). The lower lobe usually has 4 or 5 branched rays, and a few species have 3 (three, i.e. *Enneapterygius abeli*, *Notoclinus compressus* and *Notoclinus fenestratus*), with 2 or 3 unbranched rays, except in *Gilloblenius tripenis*, *Notoclinus compressus*, *Ruanoho whero*, *Springerichthys kulbickii* and *Trianectes bucephalus*, which have only 1.

The caudal fin formula shows variations among the studied species of triplefins (Table 5). The caudal fin structure of teleost fish was described by Kner (1861). The caudal fin rays usually show low interspecific variation, as shown by Ginsburg's (1945) study on gobiid fish caudal fins. Fricke (1983b) supported this finding in his work on the callionymids. The development of a caudal fin formula will facilitate the comparison of fin counts for classification. This formula can replace the existing, complex terminology used for recording caudal fin ray counts. For example, in triplefins the median caudal fin rays are usually dichotomously branched. This fin is normally asymmetrical consisting of 2 unbranched dorsal, 5 branched median, and 2 unbranched ventral segmented rays, or 4 branched median rays.

The formula ii,5,4,ii is common among triplefins. In the modified caudal fin formula, the rays of the upper lobe are always on the left side of the formula while those of the lower lobe are on its right separated by a dashed line. However, unique and uncommon formulae were also obtained in this study, for example i,6,5,ii for *Acanthanectes rufus*; ii,5,4,iii for *Notoclinops yaldwyni*; and i,4,3,i for *Notoclinus compressus*.

Caudal-fin rays are usually branched only once, except in certain species where multiple branching was occasionally observed (e.g. *Bellapiscis medius*, one specimen; *Cremonochorites capensis*, one specimen; *Ruanoho decemdigitatus*, two specimens).

Regarding the branched and unbranched rays in the caudal fin, in the upper lobe the usual total number of fin rays (branched and unbranched) is 4, 5, 6 or 7. In the lower lobe, there are usually 6 branched and unbranched rays. Multiple branching of the caudal fin rays is an uncommon condition among triplefins; it is observed only in a few specimens of *Bellapiscis medius*, *Cremonochorites capensis* and *Ruanoho decemdigitatus*. It might be considered as an abnormality caused by environmental or genetic factors and needs further investigation.

Springer listed 34 features of the Tripterygiidae. Out of these, there are 16 characters that not confirmed with Springer's (1993) suggestions, 12 fully confirmed, one partially confirmed and the remaining five characters have the following designations. Segmented dorsal-fin rays unbranched except for some species; absence of bony autogenous stay following posteriormost dorsal-fin pterygiophore; absence of bony autogenous stay following posteriormost anal-fin pterygiophore; in most triplefin species, scales are not embedded, but they are so in members of the genus *Matanui* (Jawad &

Clements, 2004); and septal bone present. A full list of these characters is given in Table 6.

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APPENDIX 1

LIST OF THE MATERIAL EXAMINED FOR THE PRESENT STUDY

All localities are in New Zealand, except for those where the country is given. Specimens without a catalogue number belong to the University of Auckland, New Zealand. (AMS = Australian Museum, Sydney; UF = Florida Museum of Natural History; NMNZ = National Museum of New Zealand, Te Papa Tongarewa, Wellington; SIO = Scripps Institution of Oceanography; SL = standard length).

Acanthanectes rufus Holleman & Buxton, 1993 (N = 3). 27–28 mm SL, South Africa, 1997.

Apoptyrygion oculus Fricke & Roberts in Fricke, 1994 (N = 3). 48 mm SL, Mernoo Bank, Chatham Rise, Tangaroa, 12 Jan 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, Jun 1974, NMNZ P. 17205.

Axoclinus lucillae Fowler 1944 (N = 2). 21–23 mm SL, Pearl Islands: Isla San Jose, West of Punta Cruz, 29 Mar 1967, SIO 67–39.

Bellapiscis lesleyae Hardy, 1987 (N = 6). 2, 40–49 mm SL, Mathesons Bay, Hauraki Gulf, 27 Jan 1997; 2, 38–45 mm SL, Cape Rodney, Hauraki Gulf, 20 Nov 1997; 2, 44–47 mm SL, Stirling Point, 26 Jan 1998.

Bellapiscis medius (Günther, 1861) (N = 16). 6, 28–58 mm SL, Horseshoe Bay, Stewart Island, 3 Jan 1998; 10, 41–66 mm SL, Huia, Manukau Harbour, Auckland, 21 June 1998.

Blennodon dorsalis (Clarke, 1879) (N = 7). 2, 25–30 mm SL, Muriwai, 9 Oct 1999; 76 mm SL, Whatipu, Manukau Entrance, 8 Apr 2001; 4, 112–135 mm SL, First Point, Makara Beach, Wellington, 15 Apr 2001.

Brachynectes fasciatus Scott, 1957 (N = 32). 2, 25–32 mm SL, Rock Pier, Port Arthur, Tasmania, Australia, 2 Dec 1972, I.17551-001 (AMS); 21, 29–40 mm SL, Kingscote, Kangaroo Island, Australia, 13 Mar 1978, I.20189-032 (AMS); 9, 20–24 mm SL, off Cape Le Grande, Rob Island, Western Australia, 20 Mar 1978, I.20216-011 (AMS).

Ceratobregma acanthops (Whitley, 1964) (N = 6). 6, 23–36 mm SL, Lizard Island, South Australia, 24 Dec 1997.

Cremonochorites capensis (Gilchrist & Thompson, 1908) (N = 4). 4, 54–74 mm SL, False Bay, South Africa, Jan 1997.

Crocodylichthys gracilis Allen & Robertson, 1991 (N = 20). 20, 31–47 mm SL, Baja California, Mexico, 1997; 2, 20–22 mm SL, Bahia de Los Angeles, Isla Flecha, 17 Aug 1969, SIO 69–360.

Cryptichthys jojettae Hardy 1987 (N = 23). 6, 26–39 mm SL, Breaker Bay, Wellington, 9 Feb 1998; 6, 30–41 mm SL, Mokohinau Islands, 16 Apr 1998; 11, 22–28 mm SL, Three Kings Islands, 2 Mar 1999.

Enneanectes altivelis Rosenblatt, 1960 (N = 3). 3, 23–25 mm SL, off northeast shore of Buck Island Reef National Monument, Virgin Islands, USA, 6 August 2001, UF 149064.

Enneanectes carminalis (Jordan & Gilbert 1882) (N = 1). 1, 25–27 mm SL, NW end of Isla San Marcos, near offshore rocks, 2 Jul 1976, SIO 62-56.

Enneanectes reticulatus Allen & Robertson 1991 (N = 1). 1, 43 mm SL, rocky point at South end of Bahia Pulmo, 14 May 1976, SIO 76-284.

Enneapterygius abeli (Klausewitz, 1960) (N = 6). 6, 18–23 mm SL, Sodwana Bay, South Africa, 29 May 2001.

Enneapterygius ventermaculus Holleman, 1982 (N = 7). 7, 12–14 mm SL, Sodwana Bay, South Africa, 28 May 2001.

Forsterygion capito (Jenyns, 1841) (N = 44): 4, 79.1–82.3 mm SL, Enderby Island, Auckland Islands, 17 Mar 1954, NMNZ P. 1489; 24, 34.8–56.5 mm SL, Portobello, Otago Harbor, 13 Aug 1962, NMNZ P. 13491; 1, 72.4 mm SL, Oamaru, 1963, NMNZ P. 10663; 5, 34–82 mm SL, Elizabeth Island, Fiordland, 28 Feb 1985, NMNZ P. 16952; 5, 36–64 mm SL, Elizabeth Island, Fiordland, 9 Mar 1985, NMNZ P. 16955; 5, 72.7–82.4 mm SL, Antipodes Islands, 8 Mar 1985, NMNZ P. 17083.

Forsterygion flavonigrum Fricke and Roberts, 1994 (N = 50): 5, 42–46 mm SL, Paradise Beach, Port Pegasus, Stewart Island, 6 Feb 1989, NMNZ P. 24029; 18, 38–49 mm SL, North Cape, 28 Feb 1999; 5, 36–42 mm SL, Ti Point, 14 May 1998; 5, 33–40 mm SL, Great Barrier Island, 5 Sept 1997; 1, 38 mm SL, Nelson Island, Great Barrier Island, 5 Sep 1998; 2, 32–38 mm SL, Hen and Chickens Islands, 6 Feb 1997; 13, 32–42 mm SL, Mokohinau Islands, 9 Dec 1997; 1, 47 mm SL, Breaker Bay,

Wellington, 9 Feb 1998; 26–28 mm SL, RV 'Munida', Otago, 2 May 1998; 5, 45–50 mm SL, Ulva Island.

Forsterygion gymnota (Scott, 1977) (N = 34): 4, 36–58 mm SL, Muriwai Beach, Auckland, intertidal pools, 17 Jan 1962, NMNZ P. 13557; 3, 43–68 mm SL, Castle Rock, Seal Rocks, Sugar Loaf Islands, New Plymouth, 25 Mar 1985, NMNZ P. 17082; 10, 36–66 mm SL, Higgins Wharf, Napier Harbor, 22 Mar 1988, NMNZ P. 24347; 1, 47 mm south-eastern Tasmania, Aug 1976, NMNZ P. 25282; 2, cleared and stained, Kettering Jetty, S. Bell, 11 Jan 1966, NMNZ P. 25422; 3, 80–93 mm SL, Wrest Point, Hobart, Derwent River Estuary, 1982, NMNZ P. 30579; 2, 47–82 mm SL, Wrest Point, Hobart, Derwent River estuary, 1982, NMNZ P. 30580; 2, cleared and stained, Kettering Jetty, S. Bell, 11 Jan 1966, NMNZ P. 25422; 3, 80–93 mm SL, West Point, Hobart, Derwent River Estuary, 1982, NMNZ P. 30579; 2, 47–82 mm SL, Wrest Point, Hobart, Derwent River estuary, 1982, NMNZ P. 30580; 2, 45–71 mm SL, Musick Point, 31 Mar 1998.

Forsterygion lapillum Hardy, 1989 (N = 73): 60, 24–56 mm SL, Islet Cove, Stewart Island, 29 Jan 1989, NMNZ P. 24086; 5,

- 46–58 mm SL, Bowen Channel, Dusky Sound, Fiordland, 22 Mar 1993, NMNZ P. 30488; 18, 29–47 mm SL, North Cape, *Forsterygion malcolmi* Hardy, 1987 (N = 44): 5, 74–86 mm SL, Foul Point, Abel Tasman Park, Golden Bay, 3 Dec 1993, NMNZ P. 33542; 4, 38.8–45.2 mm SL, Ulva Island, Stewart Island, 30 Jan 1998; 9, 42–96 mm SL, Mokohinau Islands, 18 Feb 1998; 10, 52–71 mm SL, Great Barrier Island, 15 Oct 1997; 2, 72–74 mm SL, Nelson Island, Great Barrier Island, 12 Sep 1998; 9, 71–82 mm SL, Ti Point, 21 Oct 1997; 6, 48–116 mm SL, Breaker Bay, Wellington, 9 Feb 1998.
- Forsterygion maryannae* (Hardy, 1987) (N = 44): 5, 38–41 mm SL, North Cape, 28 Feb 1999; 18, 27–47 mm SL, Three Kings Islands, 1 Mar 1999; 21, 28–54 mm SL, Mokohinau Islands, 9 Dec 1997.
- Forsterygion nigripenne* (Valenciennes in Cuvier & Valenciennes 1836) (N = 29): 5, 55–84 mm SL, Wanganui River Estuary, Apr 1950, NMNZ P. 1327; 10, 40–69 mm SL, Mill Creek, Half moon Bay, Stewart Island, 3 Mar 1992, NMNZ P. 27830; 2, both 55 mm SL, Pataua Estuary, Ngunguru Bay, 3 Aug 1999; 12, 33–86 mm SL, Whangateau Wharf, Whangateau Estuary, 13 Dec 1999.
- Forsterygion varium* (Schneider in Bloch & Schneider 1801) (N = 44): 4, 79.1–82.3 mm SL, Enderby Island, Auckland Islands, 17 Mar 1954, NMNZ P. 1489; 24, 34.8–56.5 mm SL, Portobello, Otago Harbor, 13 Aug 1962, NMNZ P. 13491; 1, 72.4 mm SL, Oamaru, 1963, NMNZ P. 10663; 5, 34–82 mm SL, Elizabeth Island, Fiordland, 28 Feb 1985, NMNZ P. 16952; 5, 36–64 mm SL, Elizabeth Island, Fiordland, 9 Mar 1985, NMNZ P. 16955; 5, 72.7–82.4 mm SL, Antipodes Islands, 8 Mar 1985, NMNZ P. 17083.
- Gilloblennius tripennis* (Forster in Bloch & Schneider, 1801) (N = 3). 2, 93–113 mm SL, north end of Ringaringa Bay, Oban, Stewart Island, 7 Mar 1992, NMNZ P. 27627; 67 mm SL, Horoera Point, 23 Jan 1993, NMNZ P. 29990.
- Helcogramma rharhabe* Holleman, 2007 (N = 10). 10, 21–38 mm SL, Sodwana Bay, South Africa, 27 May 2001.
- Helcogramma springeri* Hansen, 1986 (N = 20). 18, 24–32 mm SL, Lizard Island, Queensland, Australia, 24 Dec 1997.
- Helcogrammoides cunninghami* (Smitt, 1898) (N = 3). 24–25 mm SL, Playa El Durazno, Quintero, Chile, 28 Nov 1999.
- Helcogrammoides chilensis* (Cancino in de Buen, 1960) (N = 3). 23–24 mm SL, Playa El Durazno, Quintero, Chile, 28 Nov 1999.
- Karalepis stewarti* Hardy, 1984 (N = 37). 19, 36–117 mm SL, Three Kings Islands, 1 Mar 1999; 18, 41–102 mm SL, Mokohinau Islands, 21 Jan 1998.
- Lepidoblennius haplodactylus* Steindachner, 1867 (N = 30). 30, 36–76 mm SL, Avalon, Sydney, Australia, 23 Apr 1997.
- Lepidoblennius marmoratus* (Macleay, 1878) (N = 5). 5, 30–95 mm SL, Israelite Bay, Western Australia, 3 Mar 1984, NMNZ P. 17273.
- Lepidonectes corallicola* (Kendall & Radcliffe 1912) (N = 1). 1, 54 mm SL, Isla Marchena (Bindloe Island): North shore, 1 mi West of Punta Montalau, 22 Sep 1966, SIO 97-170.
- Matanui bathytaton* (Hardy, 1989) (N = 31): 5, 80 mm SL, Pukaki Rise, Campbell Plateau, 22 Nov 1965, NMNZ P. 5046; 3, 58–69 mm SL, off SE corner of South Island, 3 Sep 1970, NMNZ P. 7097; 5, 42–80 mm SL, Oamaru, 1962, NMNZ P. 10705; 2, 35–36 mm SL, SE of Pitt Island, Chatham Islands, 3 Feb 1954, NMNZ P. 25495; 5, 35–60 mm SL, Mernoo Bank, 12 Jan 1979, NMNZ P. 25308; 4, 48–52 mm SL, 'Canyon C' off Otago Peninsula, 16 Aug 1955, NMNZ P. 25330; 2, 74–76 mm SL, Urry Bank, Oct 1979, NMNZ P. 35284; 7, 52–89 mm SL, RV 'Munida', Otago, May 1998.
- Matanui profundum* (Fricke and Roberts, 1994) (n = 22): 1, 87.8 mm SL, off Otago Peninsula, 10 May 1990, NMNZ P. 25094; 1, 87.8 mm SL, off Otago Peninsula, 10 May 1990, NMNZ P. 25094; 3, 68–72 mm SL, off Palmerston, 13 Dec 1971, NMNZ P. 7096; 1, 78 mm SL, Oamaru, Aug 1963, NMNZ P. 10642; 3, 68–76 mm SL, off the Boat Group, Stewart Island, 18 Feb 1972, NMNZ P. 25323; 3, 53–58 mm SL, Palliser Bay, 6 Feb 1955, NMNZ P. 25436; 3, 47–52 mm SL, Omaha Bay, Hauraki Gulf, 15 Jul 1976, NMNZ P. 28515; 1, 36 mm SL, Waitiu Bay, Marlborough Sounds, 5 Mar 1976, NMNZ P. 28819; 6, 46–55 mm SL, D'Urville Island, between Nile Head & Greville Harbour, 5 Mar 1976, NMNZ P. 30196.
- Norfolkia brachylepis* (Schultz 1960) (N = 2). 1, 28 mm SL, Vanuatu, Epi Island, N of Namuka Island, 16 Jun 1996, AMSA 37339-029; 1, 36 mm SL, Australia, Queensland, Raine Island, west end, 13 February 1979, AMSA 20757.
- Notoclinops caerulepunctus* Hardy, 1989 (N = 17). 5, 25–30 mm SL, Cathedral Rock, 20 Jan 1998; 12, 28–38 mm SL, Fanal Island, Hauraki Gulf, 20 Jan 1998.
- Notoclinops segmentaus* (McCulloch & Phillipps, 1923) (N = 11). 3, 15–26 mm SL, Hen and Chicken Islands, Hauraki Gulf, 6 Feb 1997; 8, 34–47 mm SL, Horseshoe Bay, Pukoro Bay, Stewart Island, 28 Jan 1998.
- Notoclinops yaldwyni* Hardy, 1987 (N = 13). 4, 20–47 mm SL, Mokohinau Islands, 20 Jan 1998; 9, 40–51 mm SL, Breaker Bay, Wellington, 9 Feb 1998.
- Notoclinus compressus* (Hutton, 1872) (N = 8). 5, 64–72 mm SL, Manukau Bay, Owenga, Chatham Island, 4 Feb 1991; 3, 54–58 mm SL, Rurina Island, off Whale Island, eastern Bay of Plenty, 7–10 m, 2 Jun 1998.
- Notoclinus fenestratus* (Bloch & Schneider [ex Forster] 1801) (N = 10). 116 mm SL, Oamaru Harbour, Jun 1965, NMNZ P. 10574; 6, 44–132 mm SL, south of Slipper Island, 5 Dec 1986, NMNZ P. 21628; 3, 55–85 mm SL, Wharekura Point, 30 Apr 1992, NMNZ P. 28263.
- Ruanoho decemdigitatus* (Clarke, 1879) (N = 11). 38 mm SL, Island Bay, 7 Feb 1998; 10, 62–102 mm SL, Breaker Bay, 9 Feb 1998.
- Ruanoho whero* Hardy, 1986 (N = 21). 9, 57–77 mm SL, Ulva Islands, Stewart Island, 30 Jan 1998; 12, 30–56 mm SL, Mokohinau Islands, 19 Jan 1998.
- Springerichthys kulbickii* (Fricke & Randall in Fricke, 1994) (N = 14). 3, 23–25 mm SL, Leeward side of reef, Banks Group, Rowa Island, Vanuatu, 20 May 1997, I.37928-060 (AMSA); 4, 21–24 mm SL, Reef Island, Santa Cruz Islands, Solomon Islands, 19 Sept 1998, I.39013-055 (AMS); 7, 20–24 mm SL, Nialo Point-east side of Forrest Passage, Reef and Lomlom Islands, Santa Cruz Islands, Solomon Islands, 18 Sept 1998, I.39010-094 (AMS).
- Trianectes bucephalus* McCulloch & Waite, 1918 (N = 4). 4, 65–67 mm SL, Portsea Pier, Port Phillip Bay, Victoria, Australia, 12 Apr 1977, I.19777-003 (AMS).
- Trinorfolkia clarkei* (Morton, 1888) (N = 24). 6, 35–57 mm SL, Port Phillip Bay, Victoria, Australia, 9 Apr 1997; 18, 42–50 mm SL, Port Phillip Bay, Victoria, Australia, 12 Feb. 2000.
- Tripterygion tartessicum* Carreras-Carbonell, Pascual & Macpherson, 2007 (N = 7). 7, 38–48 mm SL, Portinatx (Ibiza), Spain, July 2001.
- Ucla xenogrammus* Holleman, 1993 (N = 25). 25, 23–44 mm SL, Lizard Island, Queensland, Australia, 14 Dec 1997.