Ann. Mus. civ. St. nat. Ferrara	Vol. 9/10	2006/07	pp. 89-97	ISSN 1127-4476

Malformation of the lateral line and ambicolouration in the triplefin *Grahamina capito* (Jenyns, 1842) (Pisces: Tripterygiidae) from New Zealand

Laith A. Jawad*, Shane T. Ahyong & Andrew Hosie

Marine Biodiversity and Biosecurity, National Institute of Water and Atmospheric Research, Private Bag 14901, Wellington, New Zealand

* Corresponding author, e-mail: l.jawad@niwa.co.nz

Abstract

JAWAD L.A., AHYONG S.T. & HOSIE A., 2008 – Malformation of the triplefin *Grahamina capito* (Jenyns, 1842) (Pisces: Tripterygiidae) from New Zaland. *Ann. Mus. civ. St. nat. Ferrara*, 9/10 (2006/07): 89-97.
Malformation in the lateral line scales and ambicolouration are reported in the tripterygiid fish *Grahamina capito* collected from Bluff and Stewart Island, New Zealand. Severe damage to lateral line scales no. 9, 10 and 11 were observed and described. The Siamese scale condition was observed in scale no. 10. Different degrees of ambicolouration were observed in several *G. capito* specimens. White patches were present on both sides of the body. Genetic and epigenetic causes may be implicated in these anomalies.

Key words: Abnormality, lateral line, scales, ambicolouration, *Grahamina capito*, New Zealand.

Introduction

Morphological deformities in fish have been widely described and reviewed (JAWAD & HOSIE, 2007, JAWAD & ÖKTONER, 2007). Abnormalites in the lateral line of fish, however, have received little scientific attention (DAWSON, 1964, 1966, 1971; DAWSON & HEAL, 1971).

Incidence of malformation of the lateral line is relatively common in captive bred fish (CARRILLO et al., 2001), but rare in the wild (DIVANACH et al., 1996).

In fish, the mechanoreceptor neuromast cells, the major receptors for external vibrational and gravitational stimuli are associated with the lateral line system (BLECKMANN, 1986). Thus, malformations of the lateral line will be expected to directly affect sense reception, which may disrupt schooling behaviour, predator avoidance, feeding, social communication (PARTRIDGE & PITCHER, 1980; BLECKMANN, 1986) and possibly survivorship.

Colour abnormalities in fishes are of three types: ambicolouration, albinism, and xanthochroism. Albinism is a complete lack of pigmentation. Xanthochroism is a rare condition in which the melanophores are missing, though other pigment is present, typically producing a golden-orange colour (COLMAN, 1972). Ambicolouration is partial pigmentation on certain areas of the body. Most reports of these colour abnormalities have been for various flatfish species (e.g., DAWSON, 1962, WHITE & HOSS, 1964, TAYLOR et al., 1973, GARTNER, 1986, DIAZ DE ASTARloa, 1995, Venizelos & Benetti, 1999, Bolker & Hill, 2000, Chaves et al., 2002, Purchase et al., 2002, Macieira et al., 2006).

Reports of ambicolouration in fishes are few (Dawson, 1962, Moe, 1963, Hernandez & Sinovcic, 1987), being rare for wild populations of teleosts (Archey, 1924, Norman, 1934, Colman, 1972). There are no reports of lateral line deformities in New Zealand fish. Thus, the present report is the first for the region and an additional record of incidence in wild-caught adult triplefins (*Grahamnia capito* (Jenyns, 1842)) showing lateral line deformity and partial absence of pigmentation.

Species of *Grahamina* inhabit sheltered rocky pools with weed or shell bottom. In New Zealand, *G. capito* ranges from Cape Reigna to the Snares Islands (Francis, 1996). It has a specific colouration pattern that differs from the other *Grahamina* species. Mottled dark green colour covering the head and body with a series of light markings along the back; the dorsal fins and tail have several oblique rows of brown or black dots; the anal fin is pink or orange with white margins (Francis, 1960). *Grahamina capito* can also be separated from the remaining congeners by the following combination of morphological characters: snout profile sloping, concave or (rarely) steep; the relative positions of the premaxilla and orbit such that a line drawn through tip of premaxilla across ventral margin of orbit crosses the preoperculum or touches its dorsal extremity; nape naked or with superficial or embedded cycloid scales; no groove in front of first dorsal fin, although medial sensory pore may sit at base of depression (Clements et al., 2000). *Grahamina capito* has a long spawning period (4 months) peaking in August (Ayling & Cox, 1987) during which the male defends the nest. Nesting males can reach 120 mm (Hickford & Schiel, 2003, Wellenreuther & Clements, 2007). Larvae are usually found from early spring until late summer, with increased abundance in mid-spring and mid-summer. They are less abundant close to shore, but they are abundant in localities parallel to the shore (Hickford & Schiel, 2003).

Materials and Methods

One female *G. capito* (age 2^+) with lateral line malformation was collected on 16 February 2006 near Bluff, New Zealand (station 2BLU 151) (Fig. 1) by NIWA (National Institute of Water and Atmospheric Research, New Zealand) as part of a biosecurity survey of Bluff Harbour and surrounds. It was collected by small traps and is preserved in the NIWA biosecurity collection (MITS 4098). The specimen measures 64 mm in total length and 52 mm in standard length. Age was determined from scales viewed under light microscope. Body lateral line

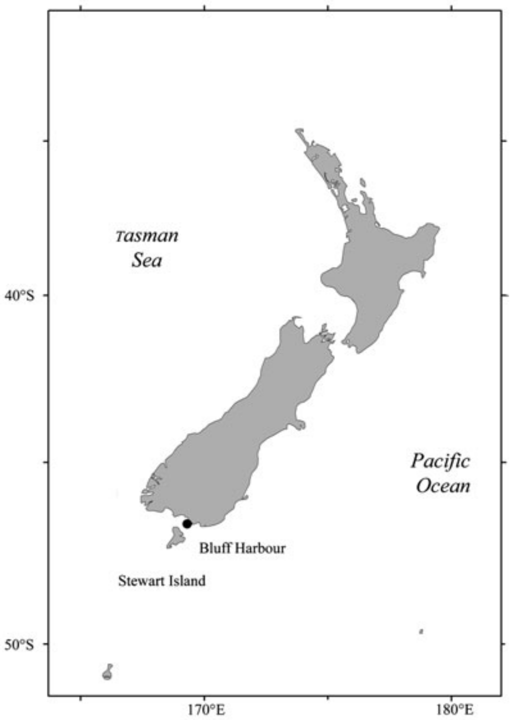

Figure 1. Map of New Zealand showing the sampling areas.

abnormality was assessed by determining the total number and distribution of scales on both sides of the fish. The body lateral line was divided into three sectors spanning 5–8 scales. The length of each sector (S_i) is measured to the nearest 1 mm. The scale density (D_i) for any given sector, i, along the body lateral line was quantified by the following equation:

$$D_i = n/R\,S_i$$

Where n represents the number of scales in sector I and RS_i the relative length of sector I expressed as a percentage of the total lateral line length, according to the following equation:

$$R\,S_i = (S_i /\text{™}\, S_i) \text{ x } 100$$

Where S_i is the length of sector I (mm) and ($\text{™}\, S_i$) represents the sum of all sectors in the lateral line (mm). The specimen was radiographed with soft X-rays to verify any potential correlation between body lateral line abnormality and osteological malformations. Sector I, snout to the anterior end of the 2nd dorsal fin; sector II, anterior end of 2nd dorsal fin to the mid-point of 2nd dorsal fin; and sector III, mid-point of 2nd dorsal fin to the posterior end of 2nd dorsal fin.

Six male *G. capito* (age 2^+, TL 72–94 mm, SL 60–82 mm) showing ambicolouration were collected on 16 November 2006 near Stewart Island, New Zealand (stations STW216, STW217). The specimens were collected by NIWA as part of a baseline survey of Stewart Island waters. Specimens with breeding and non-breeding colouration (TL 59–93mm) were obtained from stations GIS004, STW037 for comparison. Male *G. capito* usually exhibit dark colouration during the breeding season, which is entirely different from the non-breeding colouration (WELLENREUTHER & CLEMENTS, 2007).

Results

The lateral line of normal *G. capito* is continuous and relatively straight, with no dorsoventral curvature (JAWAD, 2005a). It is distinguishable as a line with tubes starting behind the operculum and running an average of 51.9% SL, along the middle of the flank, and ending at the posterior end of the second dorsal fin. On the abnormal side, the lateral line extends over 39.42% of the SL (Figure 2a). On this side, the lateral line loses continuity between scale 10 and 11 with a small intervening gap indicating missing scales at sector II. The distribution of scales by sector and total number in the lateral line system were different when on either side of the specimen (Table 1). The abnormal side had a lower scale

	Abnormal side	Normal side
Mean body lateral line scales number	5.33	6.33
Scale number range	5-6	5-8
Density		
Sector I	0.29	0.39
Sector II	0.12	0.17
Sector III	0.15	0.15
Abnormal scales	P	NP
Lateral line scales missing	3	0

Table 1. Main lateral line features of triplefin, *Grahamina capito* considering on abnormal and normal sides. P=present, NP= not present.

density than the normal side 0.15–0.29 versus 0.15–0.39 (Table I). The longest sector observed was sector II where both abnormal and normal sides had the highest number of scales. The density in sector III was the same on both sides (Table 1). X-ray examination revealed no osteological malformations of the spinal column in the region of the lateral line abnormalities (irregular trajectory, missing portion). The scales around the affected area of the lateral line, however, exhibit various abnormalities, as do the scales adjoining the lateral line (Figure 2b).

Scales number 9, 10, and 11 showed severe abnormalities (Figure 3a-i). Scale number 9 (Figure 3d) has an irregular shape with a deformed rostral and caudal end, and ventrally directed lateral line canal. Both number and position of ctenii in this scale were abnormal. The ctenii in the lateral line scales of this species usually fall into one group, forming a straight line (JAWAD, 2005a). Only few ctenii are present on scale 9 and they were widely separated. The rostral end of this scale was an incomplete oval in outline with clear damage to its dorsal side. Scale number 10 (Figure 3e) was directed ventrally instead of posteriorly as the case in normal lateral line scales. The deformity in this scale is interesting as the scale exhibits the "Siamese scales" condition (JAWAD, 2007), in which two scales are fused at their rostral ends. Though the dorsal side is normal, the ventral side of the rostral end of this scale is bipartite as if two scales were joined together. Both rostral and caudal ends were severely deformed in scale number 11 (Figure 3f). The lateral line canal was completely deformed, all ctenii on the caudal end were absent, and only half of the rostral end was present. The scale immediately dorsal to scale 11 (Figure 3g) had both rostral and caudal ends deformed, the caudal end being rounded instead of straight. In addition, the ctenii of the caudal end are rotated dorsally 90° so that its ctenii are directed dorsally. The scales beyond scale number 11 appeared normal (Figure 3h,i).

The six specimens with ambicolouration differ in the distribution of the areas devoid of pigmentation (Figures 4 and 5). They are compared with the normal breeding and non-breeding coloured specimens (Figure 2a, b). The head, the side of the body, and the abdomen were the areas with no pigmentation. All specimens show an affected lateral side (left or right), while only three have an affected head area (Figure 4c, d; Figure 5c), and two have an affected abdomen (Figure 4c, d). In the head region, the ventral side and the operculum lack pigmentation. Another specimen (Figure 4c) shows a broad white band extending dorsoventrally between the posterior edge of the eye and the anterior edge of operculum. Ambicoloured areas are present on both left and right sides of the body. On the left side, one specimen is completely white except for large spot of melanin at the centre and on the nape (Figure 4c). This specimen is unusual in that it illustrates a discontinuity between two distinct areas of anomalous pigmentation. The remaining specimens show variation in the position of the unpigmented areas (Figure 5). They range from the area under the pectoral fin to the middle-base of the 2nd dorsal fin, to the beginning of the base of the 3rd dorsal fin, to the base of the caudal fin, in the area between the anterior end of the 2nd dorsal fin to the middle base of 3rd dorsal fin, and at the posterior part of the 2nd dorsal fin. Three specimens have no pigmented areas on their right lateral side, one of which has a completely white side except for a dark patch present at the posterior end of the 2nd dorsal fin base, at the base of the 3rd dorsal fin, and dorsal side of caudal peduncle. On the remaining two specimens, unpigmented areas are present at the base of pectoral fin, posterior end of the 2nd dorsal fin, and the base of caudal fin.

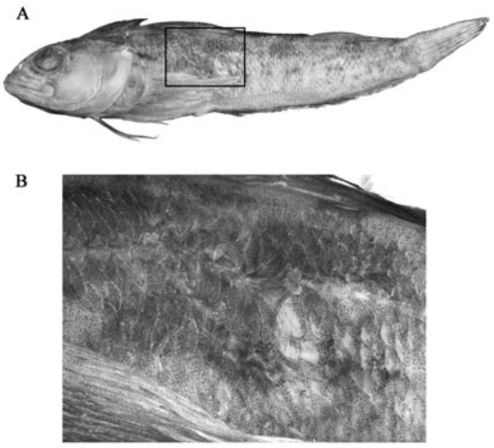

Figure 2. A. *Grahamina capito* (64 mm TL)(MITS# 4098) with a deformed lateral line; B. Close up deformed lateral line area.

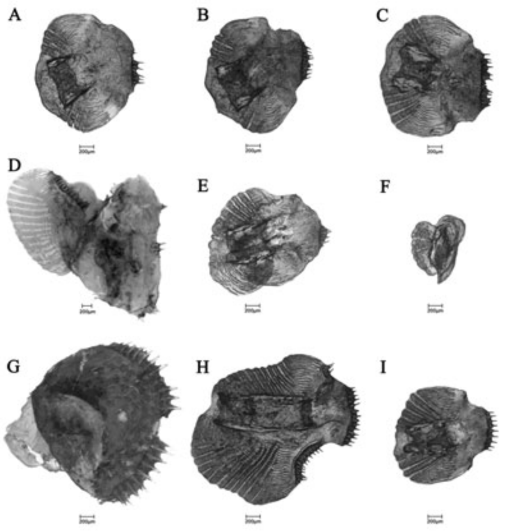

Figure 3. Lateral line scales of *Grahamina capito*. A. Scale no.2 (normal); B. Scale no.3 (normal); Scale no.7 (normal; D. Scale no.9 (abnormal); E. Scale no.10 (abnormal); F. Scale no. 11 (abnormal); G. Scale above scale no.11 (abnormal); H. scale no.12 (normal); I. Scale no. 14 (normal).

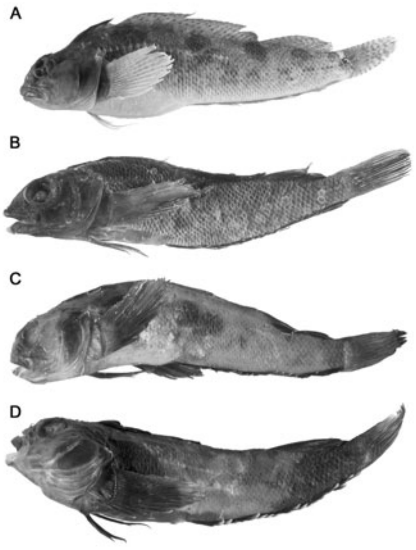

Figure 4. *Grahamina capito*, A. Non-breeding colouration (93 mm TL) (MITS # 389); B. Breeding colouration (63 mm TL) (MITS # 19566); C. Ambicolouration (72 mm TL) (MITS #17650); D. Ambicolouration (76 mm TL) (MITS # 17650).

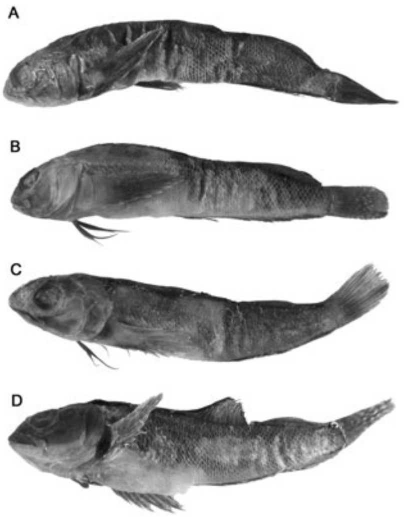

Figure 5. *Grahamina capito* showing ambicolouration. A. 82 mm TL, MITS # 17650; B. 94 mm TL, MITS # 17650; C. 74 mm TL, MITS # 17642; D. 85 mm TL, MITS # 17642.

Discussion

The density of the scales in any sector will be directly affected by any changes in the length of the lateral line. To date, there are no similar studies of other tripterygiid or related families. Thus, the present result is the first for Tripterygiidae and further studies are required for comparison with other teleosts. In the gillhead bream, *Sparus aurata* Linnaeus, 1758 (Sparidae), the highest density of the scales is near the caudal region (CARRILLO et al., 2001). The results of the present work showed a reverse distribution of the scale density for the normal side where the highest density is present close to the head. This scale distribution was not present on the left side owing to the malformation of the lateral line and associated scales. Centres of high scale density, however, might be phylogenetically correlated, accounting for the differences between the present results and those of CARRILLO et al. (2001).

Lateral line malformation and scale deformity has been attributed to several factors. The classical works of POPVICI (1930), POPOV (1931), and GEYER (1940) suggested that such anomalies are the result of irregular scalation, mechanical dysfunction in ontogeny, nervous system dysfunction, and environmental factors. KOZIKOWSKA (1960) and WHITFIELD et al. (1996) suggested that genetic mutations that affect the development of the lateral line produce such anomalies. Two genetic mutations were found to be responsible lateral line defects in zebrafish, *Danio rerio* (see WHITFIELD et al., 1996).

Of the several cases of scale deformity observed in the present study, the most interesting case is the Siamese scale deformity of scale number 10. Similar cases have been reported for other teleosts (JAWAD, 2005b, 2007). With respect to the Siamese scales described in the present work, it is plausible that the two scales were fused to form a common layer late in development owing to some development irregularity, probably caused by arrested growth initiated by several environmental or genetic factors. Despite the fusion, development of the ornamentation of the two scales has proceeded in a normal way. Four primary agents are considered responsible for scale abnormality: genetic disorder, disease, physical and chemical environmental variables (CORRALES et al., 2000). At present, too few data are available to speculate on the likely causes of the present cases of scale abnormality.

Ambicolouration in fishes is the result of several factors. MOE (1963) and COLMAN (1972) suggest that pigment difference is associated with wounds or bites received from other fish. HERNANDEZ & SINOVCIC (1987) related ambicolouration to genetic factors such as mutation. SEIKAI (1992) and SEIKAI & MATSUMOTO (1994) ascribe the case of ambicolouration to the local tissue environment. KANAZAWA (1993) proposed that deficiencies in diet may lead indirectly to melanophore differentiation. ARITAKI & SEIKAI (2004) suggested that increasing water temperature during the larval development has a direct affect on the development of skin pigmentation and on the scale asymmetry. OKADA (2005) concluded that thyroid hormone might cause ambicolouration in fish. Finally, BEN SOUISSI et al. (2007) suspected pollution, mainly heavy metals, as a factor behind partial loss of pigmentation in fish.

Wounds and bites as an agent for ambicolouration in *Grahamina capito* are unlikely as the specimens show no such injuries. Variations in water temperature were recorded in waters around Stewart Island. The mean variation of 0.8–2.2 °C was recorded between 1996 and 2003. In 2004, where the ambicolourated fishes in question were collected, mean variation in water temperature was 5.2 °C (Chris Jenkins, Environment Southland, personal communication). Such a large variation might be implicated on the development and distribution of pigment in fish skin (ARITAKI & SEIKAI, 2004). As for heavy metals, a record of high levels of these metals in both sediment (NIELSON & NATHAN, 1975) and marine organisms (FREW et al., 1997) present in the vicinity of Stewart Island. More recently, MORRISEY et al. (2000) reported elevated levels of heavy metals in the sediments at different sites around Stewart Island and LOVE et al., (2003) reported elevated levels of heavy metals in several commercial fish species obtained from waters around New Zealand. Nothing is known about the concentrations of heavy metals in the diet of *G. capito*, and should be investigated as a possible cause for ambicolouration. On the other hand, the effect of elevated surface water temperature on development is another aspect, in addition to possible heavy metal effects, that should be considered in investigating the causes of ambicolouration in fishes. Nothing is known of the specific diet or environmental stressors affecting the sampled population of *G. capito*. Clearly, more detailed investigation is required to determine the cause of ambicolouration observed here, but the present records are nevertheless significant owing to the rarity of the phenomenon in wild populations.

Acknowledgements

We wish to thank the NIWA port survey field teams for collecting the specimens, Raymond Coory and Andrew Stewart (both National Museum of New Zealand, Te Papa Tongarewa, Wellington, New Zealand) for technical help in preparing the figures and for confirming the species identification. Biosecurity New Zealand is gratefully acknowledged for financial support (contracts ZBS200518, ZBS200524).

Bibliography

ARCHEY, G., 1924 - An abnormality coloured specimen of the yellow belly (*Rhombosolea millari* Waite). *New Zealand Journal of Science and Technology*, 6: 342.

ARITAKI, M & SEIKAI, T., 2004 - Temperature effects on early development and occurrence of metamorphosis-related morphological abnormalities in hatchery-reared brown sole *Pseudopleuronectes herzensteini*. *Aquaculture*, 240: 517-530.

AYLING, T. & COX, G.T., 1987 - Collins guide to the sea fishes of New Zealand. *William Collins Publishers*, Auckland.

BEN SOUISSI, J., GOLANI, D., MEJRI, H., BEN SALEM, M.& CAPAPE, C., 2007 - First confirmed record of the halave's guitarfish, *Rhinobatos halavi* (forsskal, 1775) (Chondrichthyes: Rhinobatidae) in the Mediterranean Sea with a description of a case of albinism in elasmobranchs. *Le Cahiers de Biologie Marine*, 48: 67-75.

BLECKMANN, H., 1986 - Role of the lateral line in fish survival. *Journal of Fish Biology*, 21: 239-249.

BOLKER, J.A. & HILL, C.R - 2000. Pigmentation development in hatchery-reared flatfishes. *Journal of Fish Biology*, 56: 1029-1052.

CARRILLO, J., KOUMOUNDOUROS, G., DIVANACH, P. & MARTINEZ, J., 2001 - Morphological malformations of the lateral line in reared gilthead sea bream (*Sparus aurata* L.1758). *Aquaculture*, 192: 281-290.

CHAVES, P.T., GOMES, I.D., FERREIRA, E.A., AGUIAR, K.D. & SIRIGATE, P., 2002- Ambicolouration in the flatfish *Symphurus tessellates* (Cynoglossidae)from southern Brazil. *Acta biologica Paranaense,* Curitiba, 31: 59-63.

CLEMENTS, K.D., JAWAD. L.A. & STEWART, A.L., 2000- the New Zealand triplefin *Grahamina signata* (Teleostei; Tripterygiidae): a junior synonym of *G. gymnota* from Tasmania. *Journal of the Royal Society of New Zealand,* 30: 373-384.

COLMAN, J.A., 1972 - Abnormal pigmentation in the sand flounder. *New Zealand Journal of Marine and freshwater Research*, 6: 208-213.

CORALLES, J., BARIBEAU, N.L.B., GASSMAN, N.J. & SCHMALE, M.C., 2000 - Characterization of scale abnormalities in pinfish, *Lagodon rhomboids* from Biscayne Bay, Florida. *Environmental Biology of Fishes*, 57; 205-220.

DAWSON, C.E., 1962 - Partial albinism in the fish *Astroscopus y-graecum*. *Copia*, 4: 837-838.

DAWSON, C., 1964 - A bibliography of anomalies of fishes. *Gulf Research Report*, 1: 308-399.

Dawson, C., 1966 - A bibliography of anomalies of fishes. Supplement 1. *Gulf Research Report*, 2: 169-176.

Dawson, C., 1971 - A bibliography of anomalies of fishes. *Gulf Research Report*, 3: 215-239.

Dawson, C. & Heal, E., 1971 - A bibliography of anomalies of fishes. Supplement 3. *Gulf Research Report*, 5: 35-41.

Diaz, de Astarloa, J.M., 1995 - Ambicolouration in two flounders, *Paralichthys patagonicus* and *Xystreuris rasile*. *Journal of Fish Biology*, 47: 168-170.

Divanach, P., Boglione, C., Menu, B., Koumoudouros, G., Kentouri, M. & Cataudella, S., 1996 - Abnormalities in finfish mariculture: an overview of the problem, causes and solutions. In: Chantain, B., Saroglia, M., Sweetman, J., Lavens, P. (Eds.). Seabass and seabream culture: Problem and prospects. International Workshop. Verona, Italy. October 16-18, 1996. *European Aquacultural Society*, Oostende, Belgium, 21 pp.

Francis, M., 1996 - Coastal fishes of New Zealand. An identification guide. *Reed Publishing Ltd.*, New Zealand, 72 pp.

Frew, R.D., Hunter, K.A. & Beyer, R. 1997 - Cadmium in oysters and sediments from Foveaux Strait, New Zealand. *Proceedings of the Trace element Group of New Zealand*, Waikato University, New Zealand.

Gartner, A., 1986 - Observations on anomalous conditions in some flatfishes (Pisces: Pleuronectiformes), with a new record of partial albinism. *Environmental Biology of Fishes*, 17: 141-152.

Hernandez, V.A. & Sinovcic, G., 1987 - A note on a partial albino specimen of the species *Liza* (*Liza*) *ramada* (Risso, 1826) caught from the middle Adriatic. *Institut Za Oceanografiji I Ribarstvo,* Split, 68: 1-4.

Jawad, L.A., 2005a - Comparative scale morphology and squamation patterns in triplefins (Pisces: Teleostei: Perciformies: Tripterygiidae).*Tuhinga*, 16: 137-167.

Jawad, L.A., 2005b - Scale deformities in Nile tilapia, *Oreochromis niloticus* (Actinopterygii: Cichlidae) from Sudan. *Acta Ichthyologica et Piscatoria*, 35: 61-63.

Jawad, L.A., 2007 - Scale morphology of greater lizardfish, *Saurida tumbi* (Bloch, 1795) (Pisces: Synodontidae). *Journal Fish Biology*, 70: 1185-1212.

Jawad, L.A. & Hosie, A., 2007 - on the record of pug-headedness in snapper, *Pagrus auratus* (Forster, 1801)(Perciformes, Sparidae) from New Zealand. *Acta Adriatica*, 48: 205-210.

Jawad, L.A. & Öktoner, A., 2007 - Incidence of lordosis in the freshwater mullet *Liza abu* (Heckel, 1843)collected from Ataturk Dam Lake, turkey. *Anales de Biologia* 29: 105-113.

Kanazawa, A., 1993 - Nutritional mechanisms involved in the occurrence of abnormal pigmentation in hatchery-reared flatfish. *Journal of the World Aquaculture Society*, 24: 162-166.

Kozikowska, Z., 1960 - Interesting deviations from usual form in the lateral line of the carp, *Cyprinus carpio L.* from the breeding ponds near Radziadz in Silesia. *Zoologica Polonica*, 10: 333-336.

Love, J.l., Rush, G.M. & McGrath, H., 2003 - total mercury and methylmercury levels in some New Zealand commercial marine species. *Food Aditives and Contamination*, 20: 37-43.

Maciera, R.M., Joyeux, J.-C. & Chages, L.P., 2006 - Ambicolouration and morphological aberration in the sole *Achirus declivis* (Pleuronectiformes: Achiridae) and two other cases of colour abnormalities in achrid soles from southeastern Brazil. *Neotropical Ichthyology*, 4: 287-290.

Moe, M., 1963 - Partial albinism in a xanthic specimen of *Epinephelus morio* (Valenciennes) from the Gulf of Mexico. *Copeia*, 4: 703.

Moore, C.J. & Posey, C.R., 1974 - Pigmentation and morphological abnormalities in the hogehoker, *Trinectes maculates* (Piseces, Soleidae). *Copeia*, 3: 660-670.

Morrisey, D.J., Gibbs, m.M., pickmere, S.E. 7 Cole, R.G., 2000 - Predicting impacts and recovery of marine-farm sites in Stewart Island, New Zealand, from the Findlay-Watling model. *Aquaculture*, 185: 257-271.

Nielsen, S.A. & Nathan, A., 1975 - Heavy metal levels in New Zealand mollusks. *New Zealand Journal of Marine and Freshwater Research*, 9: 467-481.

Norman, J.R., 1934 - A systematic monograph of the flatfishes (Heterosomata), Vol. 1. Psettodidae, Bothidae, Pleuronectidae. *British Museum*, London, 459 pp.

Okada, N., 2005 - Development of tissues involved in eye migration and role of thyroid hormone in metamorphosing Japanese flounder (*Paralichthys olivaceus*). *Scientific Reports of Hokkaido Fisheries Experimental Station*, 68: 1-43.

Partridge, B.L. & Pitcher, T.J., 1980 - The sensory basis of schools: relative roles of lateral line and vision. *Journal of Comparative Physiolo-*

gy, 135: 315-325.

POPOV, A.M., 1931 - Einige bemerkugen über die variationen der seitenlinien bei *Hexagrammus stelleri* Til. (Pisces: Hexagrammidae). *Zoologischer Anzeiger*, 95: 51-55.

POPOVICI, Z., 1930 - Missbildungen der Seitenlinie bei einigen teleodeern. *Zoologischer Anzeiger*, 91: 125-138.

PURCHASE, C.F., BOYCE, D.L. & BROWN, J.A. 2002 - Occurrence of hypomelanization in cultured yellowtail flounder *Limanda ferruginea*. *Aquaculture Research*, 33: 1191-1193.

SEIKAI, T., 1992 - Process of pigment cell differentiation in skin on the left and right sides of the Japanese flounder, *Paralichthys olivaceus*, during metamorphosis. *Japanese Journal of Ichthyology*, 39: 85-92.

SEIKAI, T. & MATSUMOTO, J., 1994 - Mechanism of pseudoalbinism in flatfish: an association between pigment cell and skin differentiation. *Journal of the World Aquaculture Society*, 25: 78-85.

TAYLOR, G., STICKNEY, R.R. & HEARD III, R., 1973- Two anomalous flounders (Bothidae, *Etropus crossotus),* from Georgia estuarine waters. *Chesapeake Science*, 14: 147.

VENIZELOS, A. & BENETTI, D.D., 1999 - pigment abnormalities in flatfish. *Aquaculture*, 176: 181-188.

WELLENREUTHER, M. & CLEMENTS, K.D., 2007 - Reproductive isolation in temperate reef fishes. *Marine Biology*, 152: 619-639.

WHITE, J.C. & HOSS, D.E., 1964 - Another record of incomplete ambicolouration in the summer flounder, *Paralichthys dentatus*. *Chesapeake Science*, 5: 151-152.

WHITFIELD, T.T., GRANATO, M., VAN EDEN, F.J.M., SCHCH, U., BRAND, M., SEIKI, F., HAFFTER, P., HAMMERSCHMIDT, M., HEISENBERG, C-P., JIANG, Y-J., KANE, D.K., KELSH, R.N., MULLINS, M.C., ODENTHAL, J. & VOLHARD, C.N., 1996 - Mutations affecting development of the zebrafish inner ear and lateral line. *Development*, 123: 241-254.