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Causation of Saddleback Deformities in The Yellowfin Bream *Acanthopagrus australis* Fishery: Evidence of Physical Injury

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The yellowfin bream *A. australis* supports an important commercial net and angling fishery on the east coast of Australia. Saddleback, a deformity of the dorsal fin and profile, occurs in this species, with the occurrence of fish with saddleback being as high as 10% in some areas. The present study provides new information and analysis of causation of the saddleback deformity in the yellowfin bream fishery. Lateral line scale regeneration due to injury, and soft tissue abnormalities indicative of deep wounding are present in yellowfin bream with saddleback. X-ray images of the entire skeleton of specimens with saddleback were also examined. An unpublished government report on chemical residues in saddleback and normal yellowfin bream is appended and discussed. The absence of both chemical residues, and lack of other skeletal deformities in yellowfin bream with saddleback provide indirect evidence of physical injury as the cause of saddleback in this case. The role of discarding of meshed yellowfin bream, which are smaller than the legal minimum size, as causation of the saddleback deformity is evaluated.

Keywords: Saddleback deformity; injuries; developmental defects; fractured lateral line; deep wounding.

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1. INTRODUCTION

Saddleback in fish is an abnormality of the dorsal fin and profile, lacking one to all of the dorsal spines, accompanied by shape, number and position abnormalities of associated pterygiophores [1]. Saddleback deformities have been reported in several species of marine wild fish from locations throughout the world. Most of these reports are based on a single specimen or small numbers of a species, giving descriptions of the deformity and commenting on causation in some cases [2-7]. Saddleback in wild populations of fish has been attributed to several causes including physical injuries [2,6,8]. Other studies have identified developmental defects associated with unsuitable water conditions, including chemical contamination [4,9-11]. There are also studies showing that the saddleback deformity can be an inherited characteristic [12]. Initial reports of saddleback in wild populations of yellowfin bream proposed that the deformity was a developmental defect beginning at an early life stage [13,14]. Pollock [15] examined the incidence of saddleback deformities and other abnormalities in wild yellowfin bream. That study found scale loss, scale pattern misalignment and lateral line fracture are closely associated with the saddleback deformity. It also found that the saddleback deformity was significantly less common in small juveniles compared with the larger juveniles. Those results, together with the findings that scale loss associated with the saddleback deformity occurred at the mid-size juvenile stage indicated that the saddleback deformity and associated abnormalities in yellowfin bream result from physical injuries. The present study complements and extends the previous study by Pollock [15]. It provides new information on the saddleback deformity in wild yellowfin bream, including a description of lateral line scale loss and a histological examination of soft tissues (dermis, connective tissue and muscle) at the saddleback deformity site. The present study also provides information on the lack of chemical residues in tissues of deformed and normal yellowfin bream, an assessment of x-ray images of saddleback fish for other skeletal abnormalities, and a description of the commercial net fishery with an assessment of its role in saddleback causation.

The yellowfin bream is extensively fished by recreational anglers and commercial net fishers throughout its range on the Australian east coast [16,17]. Numerous studies of the population biology of wild yellowfin bream have been carried out due to its fisheries importance [17,18]. The yellowfin bream (F. Sparidae) is endemic to the Australian east coast. The species inhabits estuaries and coastal waters. It forms spawning aggregations in winter at the ocean/estuary interface. It is a highly fecund broadcast spawner with planktonic eggs and larvae inhabiting oceanic waters for several weeks before migration and settlement in estuaries as juveniles. Yellowfin bream is a protandrous hermaphrodite with males maturing at age 2 to 3 years. Sex inversion to females happens in subsequent age classes. The fisheries for yellowfin bream are based on fish in the range 4 to 8 years of age. Juvenile and adult yellowfin bream are demersal scavengers using a wide range of foods and habitats in coastal areas.

Moreton Bay, the present study area, is approximately 125 km long north to south and 35 km at its widest (Fig. 1). Four sand barrier islands protect the bay from the Pacific Ocean. Several rivers and creeks enter Moreton Bay. The current human population of the Moreton Bay catchment area is approximately 3.5 million, with the city of Brisbane being the largest population centre in the catchment. A major port exists at the mouth of the Brisbane River, and several marinas are present for small vessels.

2. MATERIALS AND METHODS

2.1 Yellowfin Bream Samples

A sample of yellowfin bream (n = 161, including 17 with saddleback), were collected by volunteer anglers in Moreton Bay (Fig. 1) during June and July 2020. All fish sampled exceeded the legal minimum size of 25 cm Total Length.

Nets were not used as these could damage the fish. At capture each yellowfin bream was killed humanely by the participating angler in accordance with the Australian national recreational fishing code of practice [19]. Each fish was immediately supplied to the author for recording of total length to the nearest cm and presence or absence of the saddleback deformity. Photographs (Canon IXUS digital camera) were taken of all fish with saddleback deformities and a subsample (n = 22) of normal fish. X-ray images of the skeleton of a subsample of two yellowfin bream with saddleback and one normal fish were taken (Shimadzu – Mobile Art Evolution MX7).

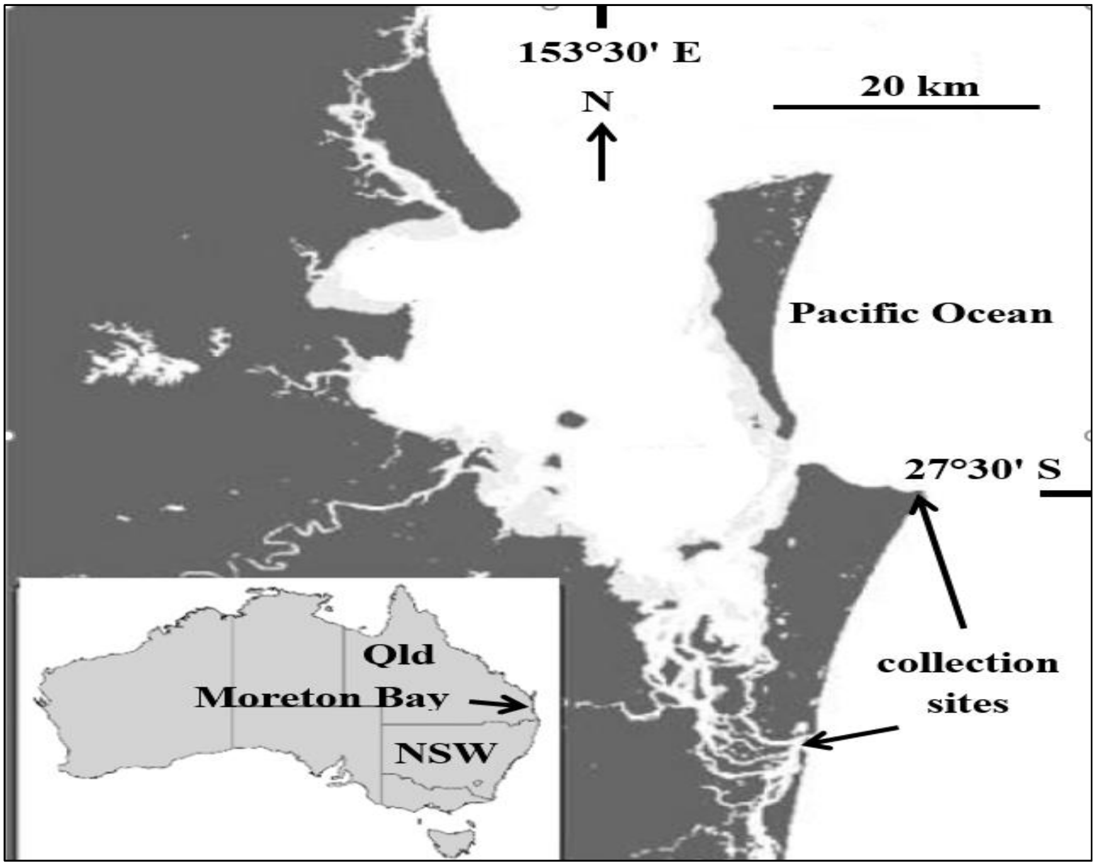

Fig. 1. Map of Moreton Bay, Queensland the present study area, and the neighbouring state of New South Wales. The collection sites for yellowfin bream *A. australis* are indicated.

2.2 Yellowfin Bream Lateral Line Scales

Lateral line scales were taken from all yellowfin bream with saddleback deformities (n = 17), and from a subsample of normal fish (n = 34) during June and July 2020. Eight lateral line scales in sequential order were carefully extracted from scale pockets on one side of each fish. Each scale sample was cleaned in water and compressed between two microscope slides. When dry, scales were examined under magnification and images taken (Leica M60 microscope, Leica IC90E digital camera or Canon IXUS digital camera).

2.3 Yellowfin Bream Tissue Samples

Soft tissue samples for histological examination were obtained within one hour of capture from a subsample of saddleback (n = 7) and normal (n = 5) yellowfin bream in June and July 2020. Following careful scale removal so as not to damage the underlying soft tissue, tissue samples were dissected at the site of the deformity in saddleback fish or from an equivalent area in normal fish. The tissue samples, approximately 6 mm × 6 mm and 4 mm deep, were taken using scalpels to penetrate the dermis, connective tissue and muscle [20]. Tissue samples were fixed in 10% neutral buffered formalin. Microscope slides of the tissues were prepared by wax embedding, microtome sectioning at 8 μm, and haematoxylin and eosin staining. The tissues were examined under magnification. Images of tissues were taken using a microscope (Nikon Eclipse 50i) with attached digital camera (Nikon DS Fi1).

2.4 Residues in Saddleback and Normal Yellowfin Bream

The author and commercial fishers provided samples of saddleback (n = 2) and normal yellowfin bream (n = 1) from Moreton Bay for the Queensland Department of Health to undertake testing for residues (PCBs, pesticides and heavy metals) (Appendix 1). These tests were carried out in 2009 on yellowfin bream greater than 23 cm Total Length, the legal minimum size for the species at that time.

3. RESULTS

3.1 Yellowfin Bream X-Ray Images

X-ray images of yellowfin bream in the present study (Fig. 2) confirmed the presence of the typical saddleback deformity. This is an abnormality of the dorsal fin and profile, lacking one to all of the dorsal spines, accompanied by shape, number and position abnormalities of associated pterygiophores. The x-ray images also show abnormalities in the position of the neural spines (Fig. 2). Examination of x-ray images found that no other skeletal abnormalities are present in yellowfin bream with saddleback.

3.2 Lateral Line Abnormalities and Scale Regeneration

Of the 17 yellowfin bream with saddleback deformities in the present study, two fish had fractures to one of the lateral lines (Fig. 3).

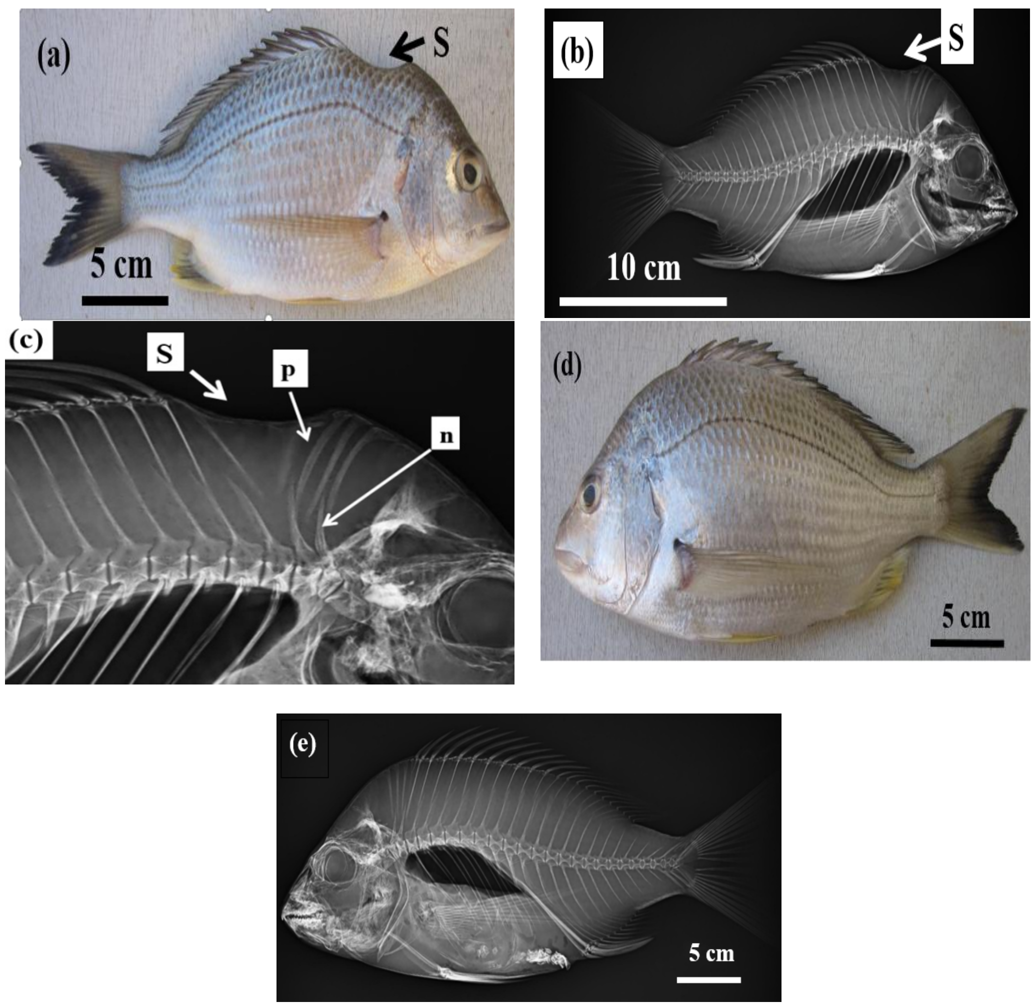

Fig. 2. Images of yellowfin bream *A. australis*. (a) Image of whole fish with saddleback deformity, lacking four dorsal spines. (b) X-ray image of whole fish with saddleback deformity, showing skeletal damage at the site of the deformity and no evidence of other skeletal anomalies. (c) X-ray image of the saddleback skeletal deformity. (d) Image of normal yellowfin bream. (e) X-ray image of normal yellowfin bream. S – saddleback deformity, n – neural spine with shape and position abnormality, p - pterygiophore with shape and position abnormality.

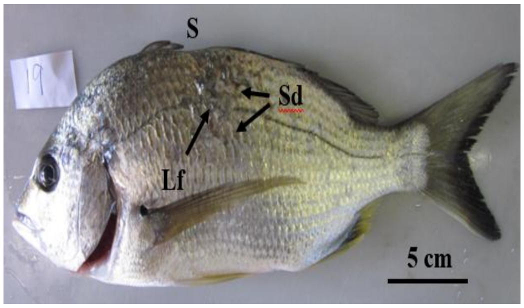

Fig. 3. Saddleback yellowfin bream *A. australis* with lateral line fracture (Lf) and scale pattern disruption (Sd). S – saddleback deformity.

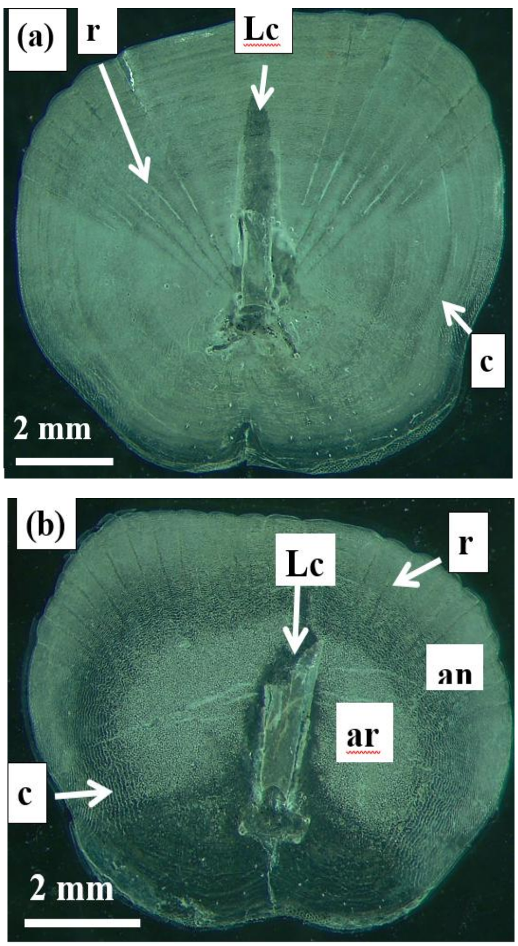

Fig. 4. Lateral line scales from yellowfin bream *A. australis*. (a) Normal lateral line scale. (b) Regenerated lateral line scale from a fish with the saddleback deformity. an - area of normal growth, ar - area of rapid regeneration, c - scale circuli, Lc - lateral line canal, r - scale radii.

Both normal and regenerated lateral line scales (Fig. 4) are present in the yellowfin bream with saddleback deformities.

The number of regenerated scales in the lateral line scale sequence varied from 1 to 3 (Fig. 5). In the case of those with fractured lateral lines (n = 2), regenerated lateral line scales were present in both specimens. In saddleback yellowfin bream with intact lateral lines, lateral line regenerated scales were present in 6 of the 15 fish examined. Examination of lateral line scales from a subsample of yellowfin bream lacking the saddleback deformity (n = 34) found no regenerated lateral line scales. None of these normal fish had fractured lateral lines.

3.3 Tissue Samples from the Saddleback Deformity Site

The microscope slides of soft tissues from yellowfin bream at the site of the saddleback deformity or an equivalent site in normal fish (dermis, connective tissue with adipose cells and muscle) were examined up to ×200 magnification. The dermis was similar in size and form in yellowfin bream with saddleback deformities compared with those without the deformity (n = 5 normal fish and 7 saddleback fish, Fig. 6). The connective tissue between the dermis and muscle was poorly developed in all yellowfin bream with saddleback deformities (n = 7), but well developed and large in all normal fish (n = 5) (Fig. 6). The connective tissue layer has 0 to 4 adipose cells in fish with saddleback deformities, and a larger layer of 5 to 8 adipose cells in normal fish (Fig. 6). The muscle layer at the site of the saddleback deformity in all normal fish (n = 5) had typical striated skeletal muscle cells which were not present in any of the saddleback fish (n = 7) at the site of the saddleback deformity. The muscle tissue in all fish with saddleback deformities had extensive granulation (Fig. 6), indicative of deep wounding [20].

3.4 Chemical Residues in Saddleback and Normal Yellowfin Bream

Chemical residues (PCBs and a wide range of pesticides) were not detected in the tissues of yellowfin bream with saddleback deformities or in normal yellowfin bream taken in Moreton Bay (Appendix 1). Heavy metal residues of mercury and arsenic were present in both saddleback and normal fish, but the concentrations were not unusually high.

4. DISCUSSION

4.1 The Present and Previous Studies of Yellowfin Bream

The initial studies of the saddleback deformity in wild yellowfin bream in Queensland reported incidences in catches of legal size fish (> 25 cm Total Length) as high as 5 – 10% [13,14]. In the present study the incidence is approximately 10% (17 from a sample of 161), indicating the persistence of this deformity. The present study examines x-ray images of saddleback yellowfin bream for other skeletal defects, lateral line abnormality and lateral line scale regeneration, and abnormalities of the soft tissues at the site of the saddleback deformity. The previous study by Pollock [15] obtained information on the timing of somatic scale loss and regeneration at the site of the saddleback deformity in wild yellowfin bream. In addition a large sample of yellowfin bream (n = 404) in the size-range 30 mm – 215 mm Total Length was examined for the presence of the saddleback deformity. That study found that the saddleback deformity occurs when yellowfin bream are 80 mm – 215 mm Total Length. In the yellowfin bream fishery, fish less than the legal minimum length must be released alive. The conclusion of the Pollock [15] study is that the saddleback deformity in wild yellowfin bream is caused by physical injury, most likely associated with discarding meshed fish from nets.

4.2 X-Ray Analysis for Skeletal Abnormalities

Examination of x-ray images of saddleback and normal yellowfin bream in the present study confirmed the typical saddleback deformity in yellowfin bream as defined Koumoundouros et al. [1]. Other skeletal abnormalities described by Boglione et al. [21] such as lordosis (an abnormal ventral curvature of the vertebral column), abnormal calcification of vertebrae, caudal kyphosis, or pelvic fin and opercular anomalies are not present in saddleback yellowfin bream examined using x-ray images.

4.3 Lateral Line Abnormalities and Scale Regeneration in Yellowfin Bream

The lateral line is an important sensory organ in fish [22]. The lateral line system is involved in behaviours such as detection of predators and prey, obstacle avoidance, and schooling. Regeneration of the lateral line has been shown to occur in some species following physical damage [22,23]. Lateral line fracture in yellowfin bream in the present study (Fig. 3) and the previous study [15] occurred in approximately 12% of fish with saddleback deformities. Regenerated scales of the lateral line are present at the site of the lateral line fracture, but also in approximately half of saddleback yellowfin bream where the lateral line is intact. The regeneration of lost scales in teleosts involves rapid scale regrowth to cover the exposed area [24]. The resulting regenerated scales lack circuli and radii in the scale mid-region which are present in normal scales (Fig. 4), making the two scale-types readily distinguishable. Lateral line fracture and lateral line regenerated scales are not present in the yellowfin bream lacking the saddleback deformity. These findings indicate that lateral line fracture and lateral line scale regeneration are associated with the saddleback deformity in yellowfin bream. The area of rapid regeneration within the lateral line scales in the present study is large (Fig. 4b) indicating that scale loss occurred well into the life of individual yellowfin bream [25]. Sfakianakis et al. [23] also concluded that lateral line deformities in the wild sparid *Sparus aurata* in western Greece, similar to the lateral line deformity and scale regeneration observed in the present study, are the result of an accident during the life of the fish and not a deformity in development.

4.4 Tissue Abnormalities at the Saddleback Deformity Site

Three tissues-types at the site of the saddleback deformity in yellowfin bream were examined in deformed and normal fish in the present study. Injured tissue underlying the saddleback deformity in the adult fish examined was most likely caused after the fish had reached 80 mm Total Length. It is therefore expected that tissue regeneration has occurred over a period of 2 – 4 years, given the normal growth rates of yellowfin bream. Differences were observed at the site of the saddleback deformity in the connective tissue between the dermis and muscle layers, and in the skeletal muscle. In yellowfin bream with the saddleback deformity, the connective tissue between the dermis and muscle is poorly developed and fragile with a thin layer of adipose cells. In comparison the connective tissue at the same site in normal yellowfin bream is well developed and strong with a thick layer of adipose cells (Fig. 6). In the case of deep wounds, the muscle tissue does not fully recover [20], but forms granulation tissue. The muscle granulation in the present case is characterised by fibrotic scar tissue rich in collagen fibres [26]. Muscle granulation tissue is abundant at the saddleback deformity site in all fish examined (n = 7) but absent in yellowfin bream lacking the saddleback deformity (n = 5) (Fig. 6). In yellowfin bream without the saddleback deformity normal striated skeletal muscle was present in all fish. Muscle granulation tissue in place of normal skeletal striated muscle in yellowfin bream is indicative of deep wounding and subsequent wound repair [20]. These tissue abnormalities in yellowfin bream with the saddleback deformity are consistent with physical injuries at the site of the saddleback deformity. Several studies have found that the scales and associated dermis rapidly regenerate after injury, particularly in sparids [25,27,28]. The absence of scaring and the abundance of regenerated somatic scales at the site of the saddleback deformity in yellowfin bream [15] is consistent with remodelling of the skin following injury. Consequently, visual inspection of the saddleback deformity in yellowfin bream and some other species, particularly sparids, indicates the skin lacks scaring and scale pattern disruption (Fig.2a), but this section of the skin was injured prior to remodelling.

4.5 Chemical Residues in Yellowfin Bream

Chemical residues and heavy metal contamination occur in intertidal and subtidal sediments of Moreton Bay [29-31]. Concentrations of these pollutants within sediments are highest in the western mainland areas, becoming progressively lower in eastern Moreton Bay [32]. Yellowfin bream are highly fecund broadcast spawners [18]. The adult fish spawn in or close to oceanic waters, with planktonic eggs and larval stages having an obligatory oceanic phase for several weeks prior to migration and settlement of the planktonic post larvae in sheltered areas of Moreton Bay. Juvenile stages inhabit the turbid waters of western Moreton Bay where bioaccumulation of chemical residues and heavy metals in the tissues of these fish is possible [32]. However organic chemical residues and heavy metal contaminants are absent or at very low levels in yellowfin bream with saddleback deformities in Moreton Bay (Appendix 1). The absence of contaminants in the tissues of saddleback yellowfin bream in Moreton Bay is inconsistent with claims that the saddleback deformity is a developmental defect caused by chemical residues [14]. The results of screening for residues (Appendix 1) was done on a small sample of two saddleback and one normal adult yellowfin bream. There is an unlikely possibility that chemical residues acquired by early life stages or juveniles of saddleback yellowfin bream become undetectable in adult fish. Further screening for chemical residues involving larger samples and all size-classes of saddleback and normal yellowfin bream would be an important addition to the information currently available (Appendix 1).

4.6 The Inshore Net Fisheries of Queensland and New South Wales

Commercial net fishers commonly use monofilament or multifilament mesh nets and seines to catch yellowfin bream and other species in Queensland and New South Wales [17]. In Queensland these nets vary from 400 m to 800 m in length, with mesh sizes as low as 12 mm [33]. In Queensland commercial fishers may also use very small bait nets (a cast net with mesh no greater than 28 mm; a seine net 16 m in length with mesh less than 28 mm).

Fig. 5. A sequence of lateral line scales from a yellowfin bream *A. australis* with the saddleback deformity. The sequence starts and ends with normal lateral line scales. Three regenerated lateral line scales are present.

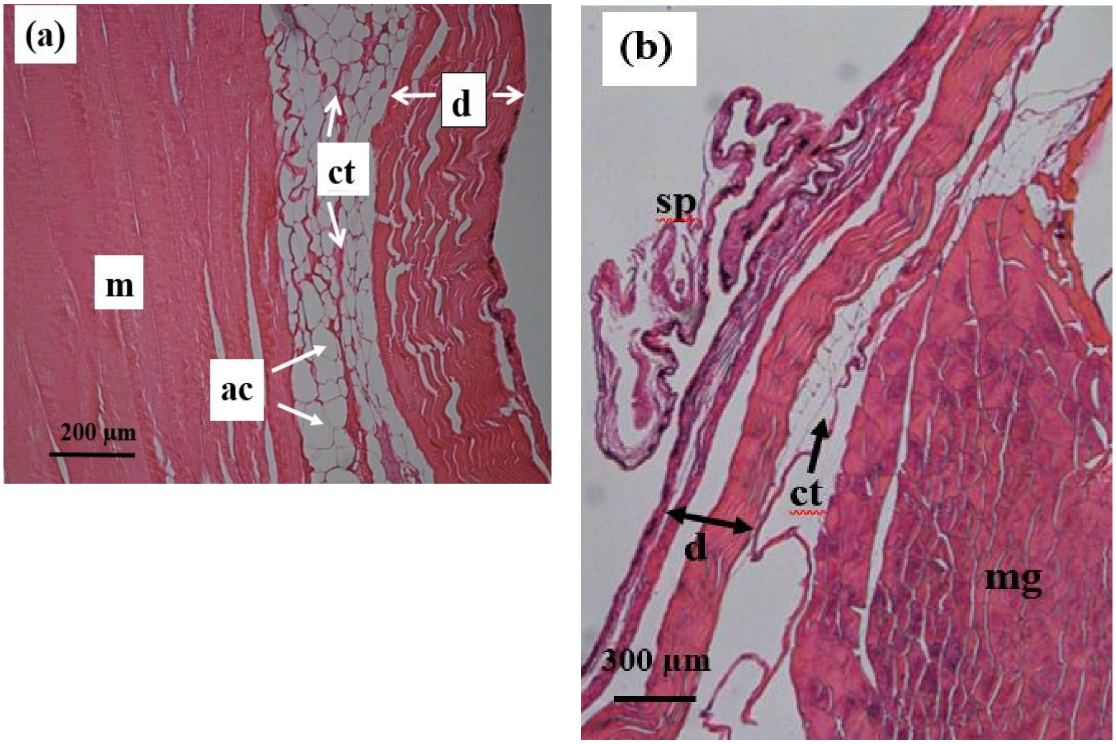

Fig. 6. Tissue structure associated with the saddleback deformity in yellowfin bream *A. australis.* Haematoxylin and eosin stained histological sections. (a) Tissue sample from a normal fish at the location where the saddleback deformity is usually present, showing a thick connective tissue layer with adipose cells and striated skeletal muscle. (b) Tissue sample from the saddleback site of a fish with saddleback deformity, showing a thin connective tissue layer with few adipose cells and muscle granulation tissue. ac – adipose cell, ct – connective tissue, d – dermis, m – skeletal muscle striated, mg – granulation muscle tissue, sp – scale pocket with scale removed.

Recreational fishers in Queensland may also use these small bait nets. Annual total catches of bream (mostly yellowfin bream *Acanthopagrus australis* with small amounts of tarwhine *Rhabdosargus sarba*) by commercial net fishers in the present study area (Moreton Bay) during to period 1990 to 2018 ranged from 48 tonnes to 195 tonnes [34]. The numbers of licenced net fishing operations taking bream in Moreton Bay ranged from 52 to 110 annually, with total annual fishing days ranging from 1089 to 2844 days [34]. No information is recorded on the use of bait nets by recreational fishers in Queensland, but the catch of yellowfin bream is expected to be very low. The legal minimum size for yellowfin bream in Queensland was 23 cm Total Length prior to 2009, but 25 cm Total Length since then. Yellowfin bream less than the legal minimum size must be release alive. Annual time-series data on discards in not recorded.

Halliday et al. [35] found that approximately half the yellowfin bream caught in commercial net fisheries in Queensland are discarded because they are under the legal minimum size. They also observed that the majority of yellowfin bream discards are removed from gill nets tail-first as their body morphology makes meshed fish easier to remove this way rather than forcing the whole fish forwards through the net. The resulting injuries to discarded yellowfin bream have not been examined. However injuries are expected due to this handling method.

Estuarine nets used by commercial fishers in the neighbouring state of New South Wales (Fig.1), have regulated minimum mesh sizes of 95 mm. In the New South Wales estuarine gill net fishery yellowfin bream was the third most important species when the minimum mesh size for estuarine mesh nets in New South Wales was 80 mm, accounting for 5% of the total catch by number [36]. A total of 36% of the yellowfin bream catch in New South Wales was discarded from the gill nets, being smaller than the legal minimum size of 25 cm Total Length. As a result of the study by Gray et al. [36] the mesh size for estuarine mesh nets in New South Wales was increased to 95 mm to reduce bycatch levels.

5. CONCLUSIONS

The present and previous studies [15] provide information on the total trauma of saddleback in wild yellowfin bream. In association with the saddleback deformity in this species are scale pattern disruption, scale loss and regeneration at the site of the saddleback deformity, lateral line fracture and lateral line scale regeneration, and disruption and subsequent regeneration of soft tissues at the saddleback site, including granular muscle formation indicative of deep wounding. Back-calculation from regenerated scales and significant differences in the incidence of saddleback in juveniles [15] indicate that the saddleback deformity first occurs in mid-size juveniles. In saddleback yellowfin bream skeletal deformities are only present at the saddleback site, and chemical residues in tissues are absent or present in very low concentrations. The obligatory planktonic early life stage of yellowfin bream occurring in oceanic waters for several weeks before migration of post larvae to estuaries ensures that these life stages are not in contact with chemical residues concentrations in upper estuaries.

The method of discarding undersize yellowfin bream from nets in the present study area is consistent with the total trauma associated with saddleback in yellowfin bream in the present study area. In net fisheries where large numbers of fish are meshed but discarded it is usual for injuries to be present in subsequent catches. The study of gill-netting in inshore waters in New Zealand by Hickford & Schiel [37] found that several fish species become entangled. The authors categorise the resulting injuries in order of severity: chafing or scale loss, minor lesions and fin damage, major lesions and flesh loss, and loss of skeletal material. All of these types of injuries are present in wild yellowfin bream with saddleback, further supporting net injuries being the cause of saddleback in yellowfin bream. In New South Wales the mesh sizes of estuarine nets were increased in 2005 to 95 mm to reduce bycatch, including bycatch of yellowfin bream. Mesh sizes of nets used to catch yellowfin bream in Queensland are much lower than those in New South Wales. This is most likely the reason that the saddleback deformity is more common in Queensland than in New South Wales.

The alternative hypothesis, that saddleback in wild yellowfin bream is a developmental defect [14], is not supported in the present case. Further research to examine the net fishery bycatch of yellowfin bream in Queensland, especially discard injuries and their level of occurrence across species, is important. The incidence of saddleback in yellowfin bream in Queensland could be reduced by increasing the mesh sizes of nets used in the commercial net fishery, similar to what has already been done in New South Wales [36].

The yellowfin bream is an iconic species. It is highly prized by many recreational fishers, and has an ancient history associated with Australian aboriginal culture. It is also a valuable commodity for the commercial fishing sector, and is regarded as an excellent food species by the broader local community. The relevant fisheries management agencies have strict provisions to ensure the sustainable use of this species. Given the importance of yellowfin bream, there is a social responsibility to support research into saddleback causation aimed at reducing the incidence of this deformity.

DISCLAIMER

The scientific equipment used for this study is commonly used in this area of research. The research was not funded by any Government agency or suppliers of equipment or services.

ETHICAL APPROVAL

This study did not require official or institutional ethical approval. Fish were captured by anglers, treated and killed humanely by them in accordance with the Australian national recreational fishing code of practice [19].

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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Appendix 1. Report on chemical residues in tissues of yellowfin bream *Acanthopagrus australis* taken in Moreton Bay. Permission given by State of Queensland to reproduce in whole.

Forensic and Scientific Services
A Clinical and Statewide Service

Queensland Government
Queensland Health

30 September 2009

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Laboratory Reference: SSP0019142
09KE5849-5851

LABORATORY REPORT

Project Details:

Received 3 samples of fish from Ross Quinn of DEEDI for pesticides, PCB's and trace metals screening for possible causes of Saddle Back Syndrome. The samples were analysed for a range of pesticides and PCB's by GC/MS techniques and trace metals by ICP/MS .

Sample Details:

Laboratory Reference	Client Reference	Specimen type	Specimen detail	Collected Date	Received Date	Commenced Date
09KE5849	2718894 15322987	Bream	Commercial Saddle Back	4/08/2009	06/08/2009	07/08/2009
09KE5850	2744308 15324732	Bream	Recreational Saddle Back	26/07/2009	06/08/2009	07/08/2009
09KE5851	2718894 15322987	Bream	Commercial Normal	4/08/2009	06/08/2009	07/08/2009

Results on the attached page(s) have been approved and checked by the following Analyst:

S. Turner
Analyst

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Continued, 09KE5849-5851

RESULT OF ANALYSIS

QISS Reference / Client Reference / Sample Type	Units	09KE5849 / [illegible] / Bream	09KE5850 / [illegible] / Bream	09KE5851 / [illegible] / Bream	ANZFA Food Standard	Reporting Limit
Organophosphorus Pesticides						
Diazinon	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Malathion	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Chlorpyrifos	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Profenofos	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Ethion	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Azinophos ethyl	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Organochlorine Pesticides						
HCB	mg/kg	< 0.01	< 0.01	< 0.01	0.1	0.01
Lindane	mg/kg	< 0.01	< 0.01	< 0.01	1.0	0.01
Heptachlor	mg/kg	< 0.01	< 0.01	< 0.01	0.05	0.01
Heptachlor Epoxide	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Aldrin	mg/kg	< 0.01	< 0.01	< 0.01	0.1	0.01
Dieldrin	mg/kg	< 0.01	< 0.01	< 0.01	0.1	0.01
DDD pp	mg/kg	< 0.01	< 0.01	< 0.01	1.0	0.01
DDE pp	mg/kg	< 0.01	< 0.01	< 0.01	(Total DDT)	0.01
DDT pp	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Endosulfan alpha	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Endosulfan beta	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Endosulfan Sulfate	mg/kg	< 0.01	< 0.01	< 0.01		0.01
Synthetic Pyrethroid Pesticides						
Transfluthrin	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Bifenthrin	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Phenothrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Tetramethrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Cyhalothrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Permethrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Cyfluthrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Cypermethrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Fenvalerate isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Fluvalinate isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Deltamethrin isomers	mg/kg	< 0.02	< 0.02	< 0.02		0.02
Total PCB's		<0.15	<0.15	<0.15	0.5	0.15
Lipid content of Flesh extracted	%	1.8	1.0	3.2		
Trace Metals						
Mercury	mg/kg	0.07	0.15	0.06	0.5	0.01
Arsenic (Total)[3]	mg/kg	3.4	3.0	1.2	2.0[3]	0.01
Lead	mg/kg	< 0.05	< 0.05	< 0.05	0.5	0.05
Cadmium	mg/kg	< 0.01	< 0.01	< 0.01		0.01

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Continued, 09KE5849-5851

Note 1: Results are reported on a whole weight basis.

Note 2: The ANZFA Food Standard Code contains a maximum level of contamination of Arsenic in Fish of 2 mg/kg. This is in the form of Inorganic Arsenic, the results reported above are for Total Arsenic. Inorganic Arsenic normally makes up approximately fifteen percent of Total Arsenic. The levels obtained for Total Arsenic in these samples are not considered to be unusually high for marine fish. Unfortunately at this time the laboratory is unable to distinguish between Total and Inorganic Asrenic.

Method of Analysis:

(1) Analysis of Seafood for Organophosphorus, Organochlorine and Synthetic Pyrethroid Pesticides 22276R2
Solvent extraction. Florisil Column cleanup. GCMS Analysis.

(2) Heavy metal determination in Foods, Method Reference QIS:12659
Microwave/ acid digestion of sample. ICP/MS analysis.

(3) Lipid content by gravimetric weight difference of solvent extract obtained from tissue.

Comments:

No pesticide or PCB residues were detected in the samples above the reporting limits stated above.

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