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Tactical Research Fund: incidence and possible causes of Saddleback Syndrome in the fish species of south east Queensland

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Matthew Campbell and Michelle Landers

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Tactical Research Fund: incidence and possible causes of Saddleback Syndrome in the fish species of south east Queensland

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i Glossary of Terms

Abiotic	Non-living factors that may affect an ecosystem.
Biotic	Applied to the living components of the biosphere or of an ecosystem.
Centra	Round centre of the vertebrae
Demersal	Living on or near the sea bed
Distal	Remote from the point of attachment.
Hypoplasia	Underdevelopment or incomplete development of a tissue or organ.
Kyphosis	Excessive outward curvature of the spine, causing hunching of the back.
Lepidotrichia	Of dermal origin, they form the soft rays of the fins.
Lordosis	Inward curvature of the spine.
Meristics	Method of differentiating fish species based on fin ray or scale counts.
Notochord	Longitudinal supporting axis of body which is eventually replaced as a support by the vertebral column in teleost fishes.
Ontogeny	The development of an individual organism.
Ossification	The process of bone formation.
Oocytes	A female gametocyte involved in reproduction.
Progeny	An immediate offspring
Protandrous	Male reproductive organs come to maturity before the female - opposite of protogynous.
Proximal	(Latin <i>proximus</i> ; nearest) describes that part of a fin ray, bone, etc closest to the point of attachment – opposite of distal.
Pterygiophore	Internal cartilage or bone that supports a median fin ray or spine.
Skeletogenesis	The process of skeleton formation.

2010/070 Tactical Research Fund: incidence and possible causes of Saddleback Syndrome in the fish species of south east Queensland

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OBJECTIVES:

1. Quantify the extent of Saddleback Syndrome in Queensland using existing databases.
2. Review national and international published and grey literature in order to document the occurrence of Saddleback Syndrome and its' causes.
3. Convene a workshop of stakeholders to present the results of the database searches and literature review.

1 Non-technical Summary**OUTCOMES ACHIEVED TO DATE**

This project was a coordinated approach to evaluate Saddleback Syndrome; its prevalence, occurrence worldwide and provide a forum to discuss the results of these reviews. The primary outcome of this project is that further research is required regarding Saddleback Syndrome in south east Queensland. The objectives of further research are as follows:

- 1) Sample recruitment areas to determine if SBS is more or less prevalent in juveniles;
- 2) Combine eggs and sperm *in situ* of bream with SBS and rear larvae at the Bribie Island Research Centre to determine if SBS is genetic; and
- 3) Monitor catches at areas known to have high incidences of SBS in order to supplement the monitoring undertaken by Assessment and Monitoring.

Yellowfin Bream, *Acanthopagrus australis*, is an important commercial and recreational fish species in Queensland, with a commercial harvest in 2009/10 of 165t and the recreational catch in the millions of individuals per year. *A. australis* is endemic to coastal and estuarine waters between Townsville and Victoria on the east coast of Australia, inhabiting shallow seagrass and mangrove areas in turbid estuaries within

Moreton Bay. *A. australis* are demersal, feeding on benthic plants and animals such as sea grass, molluscs, crustaceans, worms, fish and ascidians. The spawning season occurs at lower water temperatures in the winter near surf bars during which females produce a large number of eggs.

A skeletal deformity, characterised by a crescent-shaped indentation of the dorsal surface, has occurred in natural populations of *A. australis* for decades, with recreational anglers in south east Queensland claiming that the deformity was a result of either commercial fishers carelessly removing undersize fish from gill nets or attacks by predators such as birds and sharks. This deformity has been identified (Diggles, in press) as Saddleback Syndrome (SBS) which, for the purposes of this study, is defined as:

An abnormality of the dorsal fin and profile, lacking one to all of the hard spines and rays, accompanied by shape, number and position abnormalities of the associated pterygiophores.

Pterygiophores are internal cartilage or bone that support median fin rays or spines and are located between the vertebral spines and the spines and rays of the dorsal fin (see Figure 7.1, page 10).

Queensland's peak recreational fishing representative body, Sunfish Queensland, was concerned that the incidence of this deformity had increased in the years preceding 2009. This increasing incidence was corroborated by commercial tunnel net fishers from Moreton Bay. As such, in 2009, Fisheries Queensland was provided with three *A. australis* - two with the deformity and a control - for testing in order to determine the edibility of the deformed fish. Queensland Health reported that the levels of pesticides and heavy metals in the affected individuals were acceptable for human consumption. The samples provided to Queensland Health, mentioned by Pollock (2010), revealed that the SBS-affected individuals had 2.4 mg/kg and 3.0 mg/kg, respectively, of arsenic compared to 1.2 mg/kg for the control specimen. Mercury, lead and cadmium levels were similar for both affected and unaffected fish. Similarly, pesticide and PCB levels were identical for both affected and unaffected individuals.

An analysis of data collected by Fisheries Queensland's Assessment and Monitoring (A & M) Unit indicated that SBS occurs in approximately 3.3% of *A. australis* caught in south east Queensland. The data indicated that SBS was most prevalent on the Sunshine Coast, specifically the Maroochy, Mooloolah and Noosa Rivers, and the beaches adjacent to these estuaries. The incidence of SBS did not differ significantly between 2009 and 2010. This sampling was undertaken as part of A & M's routine sampling which focuses on gathering age and length data for stock assessments and, as

such, may not have been representative of catches where high incidence of SBS has been reported including the Gold Coast Broadwater and Jumpinpin.

A review of the international scientific literature revealed that SBS has been identified in several species, including some similar to *A. australis*. For the most part, SBS has occurred in cultured populations or populations that are relatively isolated. From these studies, a range of factors have been identified that *may* cause SBS, although the authors of these studies fail to identify a single factor or combination of factors that cause SBS.

In wild populations, one study suggested that heavy metal contamination may have been the cause of SBS in the green sunfish *Lepomis cyanellus* in a freshwater lake situated adjacent to a coal-fired power station. Another study failed to identify a single factor causing SBS in three sparids – sea bream *Archosargus rhomboidalis*, silver porgy *Diplodus argentus* and pinfish *Lagodon rhomboids* – from a semi-enclosed, sub-tropical estuary lagoon in Florida, USA. These authors suggested that the populations of these species had declined in this estuary to the extent that genetic variability had been substantially reduced.

Several authors have reported SBS in cultured populations of fish, however, few describe the causative factor, or combination of factors, responsible. During ontogeny (early larval stages), developmental deformities were linked with nutrition. Studies have found that SBS could be caused by feeding conditions, quantity and quality of larval food. One study noted a higher rate of deformity in cultured populations of ayu, *Plecoglossus altivelis*, compared to natural populations. This author suggests that the higher incidence in reared populations could be attributed to unfavourable environmental conditions, such as temperature and oxygen levels, during ontogeny and also rearing condition, but failed to identify a single cause of the deformity. Another study suggested that SBS in a cultured population of the blue tilapia *Sarotherodon aureus* may have been caused by gene mutation. A Greek study found that stocking density and nutrition in cultured populations may have caused SBS in the sparid *Dentex dentex*. The authors of this study stated that the larvae used in these experiments were produced by common parents, excluding any genetic basis for the deformity. A Turkish study published the first account of SBS occurring in gilthead sea bream, *Sparus aurata*, cultured in sea cages. These authors reported that nutritional phosphorus and micronutrients such as Vitamin A, C and D deficiencies are factors that can cause skeletal deformities and, as such, may be a causative factor in SBS.

The project workshop participants, consisting of relevant stakeholders, were presented with information from the literature review and the analysis of the A & M data. The

workshop participants concluded that further research was required regarding the causes of SBS in *A. australis* in south east Queensland. Specifically, the workshop participants formulated the following objectives for further research:

- 1) Sample recruitment areas to determine if SBS is more or less prevalent in juveniles;
- 2) Combine eggs and sperm *in situ* of bream with SBS and rear larvae at the Bribie Island Research Centre to determine if SBS is genetic; and
- 3) Monitor catches at areas known to have high incidences of SBS in order to supplement the monitoring undertaken by Assessment and Monitoring.

2 Acknowledgements

This project was funded by the Fisheries Research and Development Corporation (Project number 2010/070) and the Department of Agriculture, Fisheries and Forestry (formerly the Department of Employment, Economic Development and Innovation). We thank them for their support throughout this project.

We would like to thank Dr. Barry Pollock, John Crone, David Bateman, Marg Chittick, Judy Lynne, Luc Van Opdenbosch, Dave Thompson, Matt Barwick, Tony Ham, Dr. Jenny Ovenden, Natale Snape, Dr. Ben Diggles, Dr. Matt Landos and Dr. Peter Lee for generously giving their time for the project workshop. Also, we would like to acknowledge the advice given by Dr. Roger Chong during the development of the project proposal. Further, we thank Dr. Diggles for allowing us to use his x-rays in Figure 7.1.

We also thank members of the South Queensland Amateur Fishing Club's Association (SQAFCFA) for allowing us to observe competition weigh-ins. Their patience and help during the weigh-ins are gratefully acknowledged.

We are grateful for the assistance provided by the Research and Information Services team at the Primary Industries Building library. Specifically, we would like to acknowledge the patience and diligence of Zalee Crump, Pat Abbott, Mel Kippen, Paul Cottee and Diane Langford in providing prompt replies to the numerous requests for scientific papers throughout this project.

Further, we wish to thank Assessment & Monitoring staff for their invaluable assistance in providing information on the extent of SBS in south east Queensland, particularly the technical staff that collected and processed samples and Jason McGilvray for maintaining the collated data.

3 Background

Yellowfin Bream, *Acanthopagrus australis*, is an important commercial and recreational fish species in Queensland, with a commercial harvest in 2009/10 of 165t and the recreational catch in the millions of individuals per year. In recent years, *A. australis* has become the basis of a growing sportfishery, with professional competitions targeting *A. australis* specifically for catch-and-release tournaments along the eastern seaboard, including the Gold Coast Broadwater and Moreton Bay.

A. australis is endemic to coastal and estuarine waters between Townsville and Victoria on the east coast of Australia, inhabiting shallow seagrass and mangrove areas in turbid estuaries within Moreton Bay. *A. australis* are demersal, feeding on benthic plants and animals such as sea grass, molluscs, crustaceans, worms, fish and ascidians. The spawning season occurs during the lower water temperatures in the winter near surf bars during which females produce a large number of eggs.

A skeletal deformity, characterised by a crescent-shaped indentation of the dorsal surface, has occurred in natural populations of *A. australis* for decades (MC personal observation; Dave Thompson, commercial fisher, personal communication), with recreational anglers claiming the deformity was a result of either commercial fishers carelessly removing undersize fish from gill nets or attacks by predators such as birds and sharks.

In 2007, Sunfish Queensland, the peak recreational fishing representative body, was notified by delegates of the South Queensland Amateur Fishing Clubs Association (SQAFC) of a high incidence of deformed *A. australis* in catches from Moreton Bay. In August 2007, Sunfish contacted Fisheries Queensland, the management agency within the Department of Agriculture, Fisheries and Forestry (formerly the Department of Employment, Economic Development and Innovation) with photos of deformed fish, seeking advice as to what causes the deformity and whether the deformed fish were fit for human consumption. Sunfish categorised the deformed bream issue as their highest research priority in 2009 after they found that between five and ten percent of all bream weighed-in at a SQAFC competition were afflicted with the deformity.

In July 2009, Sunfish and commercial fishers provided Fisheries Queensland with three individual *A. australis* afflicted with the deformity. Queensland Health analysed the samples for heavy metals, pesticides and PCB's and found that the samples were safe for human consumption according to the then ANZFA Food Standard Code.

Sunfish then asked Dr. Daryl McPhee, a researcher from Bond University, to provide some information on the deformity, identified as Saddleback Syndrome (see Figure

3.1). Dr. McPhee found that there had been similar deformities in both natural and cultured populations of sparids in the Mediterranean Sea. For the purposes of the current study, SBS is defined as an “abnormality of the dorsal fin and profile, lacking one to all of the hard spines and rays, accompanied by shape, number and position abnormalities of associated pterygiophores” (Koumoundouros et al., 2001).



Figure 3.1: Saddleback Syndrome in *A. australis*. Note the anterior portion of the dorsal fin is absent (Image courtesy of Dr. Barry Pollock, Sunfish Queensland).

As such, Sunfish maintained their stance that research was required regarding the possible causes of SBS. Further, Ms. Linda Cupitt, Chief Executive Officer of the Moreton Bay Seafood Industry Association (MBSIA), and Mr. John Page, commercial tunnel net fisher, were consulted regarding the prevalence of SBS in fish caught in Moreton Bay. Mr. Page corroborated Sunfish’s opinion, inferring that the deformity had recently become more common in *A. australis* and is now occurring in luderick *Girella tricuspidata*.

A project proposal was submitted to the Queensland Fisheries Research Advisory Board (QFRAB) for assessment as part of the 2010 FRDC Expression of Interest call for funding proposals. However, the FRAB advised that a desktop study should be undertaken to determine potential causes of SBS in the international literature.

4 Need

Anecdotal evidence suggested that the incidence of Saddleback Syndrome (SBS), a skeletal deformity primarily affecting the development of the dorsal fin spines, is increasing. This increase in the prevalence of SBS may result in recreational fishers and the public losing confidence in catching and consuming fish afflicted with the syndrome. It is, therefore, important that objective information be available to address these concerns.

This project addressed one of the Queensland Fisheries Research Advisory Board's Research & Development priorities for 2010. Specifically, it addressed the "urgent need for research into the cause of a particular deformity of bream that is occurring in the important Moreton Bay fishery". QFRAB advised that a desktop study should be undertaken to determine potential causes of SBS in the international literature. Additionally, QFRAB advised that data from DEEDI's Long Term Monitoring Program should be analysed to determine the extent of SBS in Queensland.

Mr. Tony Ham, Fisheries Queensland Manager of Recreational Fisheries, advised during the formulation of the funding proposal for the current study that SBS was an important issue, requiring attention in order to determine the incidence and cause of the syndrome in key recreational fish species.

Further, the need to investigate the cause of SBS in *A. australis* in south east Queensland is of major importance and concern to the recreational fishing sector according to Sunfish Queensland, the recreational fishing representative group on the inshore finfish Scientific Advisory Group (SAG).

This project also addresses the concerns of commercial net fishers in Moreton Bay, specifically through the Moreton Bay Seafood Industry Association. These concerns relate to the potential difficulties in marketing bream and other species suffering from Saddleback Syndrome considering the perceived increase in the syndrome's prevalence in recent years.

5 Objectives

1. Quantify the extent of Saddleback Syndrome in Queensland using existing databases.
2. Review National and International published and grey literature in order to document the occurrence of Saddleback Syndrome and its causes.
3. Convene a workshop of stakeholders to present the results of the database searches and literature review

6 Methods

6.1. *Review of Saddleback Syndrome in the scientific literature: identification, cause and occurrence*

The literature review presents the current state of knowledge pertaining to Saddleback Syndrome (SBS), specifically investigating the factors contributing to its identification, occurrence and causes in Yellowfin Bream *Acanthopagrus australis*. The information sources used throughout this review have been derived from national and international publications, including the grey literature. In assessing the available literature, we

currently understand that SBS is possibly caused by a combination of factors including genetics, water quality, rearing conditions, injury and pollution, or a combination of some of these factors, all of which are known to give rise to deformities in individuals.

Further, information from media articles was also included in order to give the reader an idea of the extent of the issue in the mainstream media.

6.2. Saddleback Syndrome in Queensland

In order to determine the extent of SBS in south east Queensland, data from the Assessment and Monitoring (A & M) Unit of Fisheries Queensland (the management agency of the Department of Agriculture, Fisheries and Forestry – formerly the Department of Employment, Economic Development and Innovation) were analysed. A & M are responsible for the collection of fishery-dependent monitoring data from the commercial, charter and recreational sector. These data are collected via the representative sampling of biological material donated by fishers and processors in south east Queensland from Baffle Creek, just north of Bundaberg, to the New South Wales-Queensland border (Figure 6.1). Generally, data collected include age (via the examination of sagittal otoliths), sex and length from which stock assessment scientists are able to formulate Age-Length keys to determine total mortality. For some species samples, this information is then used in Stochastic Stock Reduction Analysis (SSRA) and/or Sex, Age and Length Stock Analysis (SALSA) modelling frameworks.

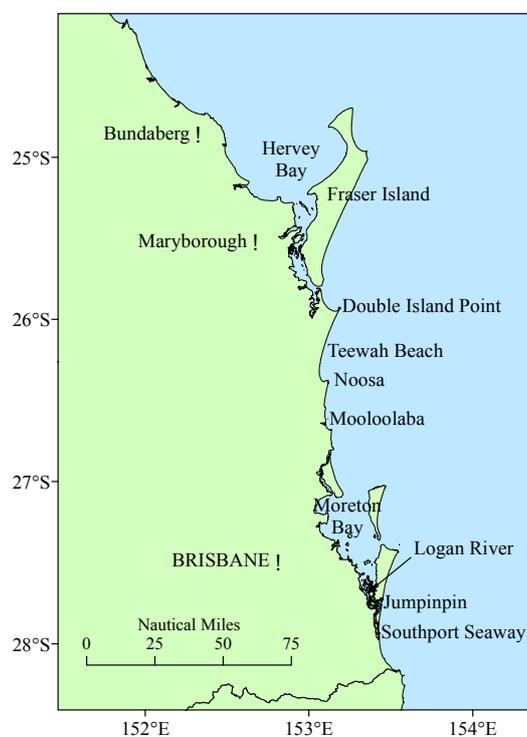


Figure 6.1: Locations of A & M sampling of *A. australis* June 2009 to June 2011, mentioned in the text.

As part of the routine sampling, A & M recorded the prevalence of SBS in *A. australis* samples between June 2009 and June 2011. A & M recorded the number of *A. australis* afflicted with SBS as a proportion of the total catch, together with the location of capture.

In order to quantify the spatial and temporal variation on the incidence of SBS in *A. australis* in these catches, the data were analysed via generalised linear modelling (GLM) using Genstat (2011). The data were modelled via a binomial distribution with a logit link function where the incidence of SBS as a proportion of total catch was the response variable. Year, month and location (Bundaberg, Fraser Inshore, Gold Coast, Great Sandy Strait, Hervey Bay, Jumpinpin, Logan River, Moreton Bay and Sunshine Coast) were added as factors, while habitat, a third categorical factor, was also added to quantify the variation attributable to the habitat in which the samples were caught, categorised as Bay, Beach, Estuary or Offshore.

6.3. *Saddleback Syndrome Workshop*

A stakeholder workshop was held in the Gillespie Room, Bribie Island Research Centre on 18 January 2012. The PowerPoint presentation from the workshop is included in Appendix 3, on page 42.

6.3.1. *Participants*

Dr. Barry Pollock (Sunfish Queensland)	Natale Snape (Biosecurity Queensland)
John Crone (Sunfish and QAFCA)	Dr. Ben Diggles (Independent Scientist)
David Bateman (Sunfish and SQAFCFA)	Dr. Matt Landos (Veterinarian)
Marg Chittick (Sunfish Queensland)	Dr. Peter Lee (Animal Science)
Judy Lynne (EO Sunfish Queensland)	Matthew Campbell (Animal Science)
Luc Van Opdenbosch (ANSA)	Michelle Landers (Animal Science)
Dave Thompson (Commercial fisher)	Jason McGilvray (A & M)
Matt Barwick (Recfish Research)	Tony Ham (Fisheries Queensland)
Dr. Jenny Ovenden (Animal Science)	
Apologies: Phil Kleise (ECOFishers Queensland)	

6.3.2. *Workshop objectives and background*

The literature review provided a knowledge base from which stakeholders were able to make an informed choice as to whether further research regarding SBS is required. The information gathered during the literature review was then presented at a dedicated workshop involving members from all stakeholder groups. The workshop was convened in order to give relevant stakeholders an opportunity to discuss issues relating to SBS and assess the benefits of further research, if any. As such, the primary planned objective of the workshop was to identify areas of further research relating to SBS.

The workshop was the culmination of several years of liaison between Sunfish Queensland, the peak recreational fishing representative body in Queensland, and the Fisheries Queensland. In August 2007, Sunfish reported a high incidence of *A. australis* landed with what is now known to be SBS. In July 2009, Sunfish advised Fisheries Queensland that SBS was nominated as a priority for research in Queensland.

Sunfish then provided several *A. australis* for analysis by Queensland Health, which found that low levels of contaminants were found in the samples of *A. australis* with SBS, but were within food safety guidelines. Sunfish continued to prioritise SBS as a topic for research until November 2010, when the current project was funded. The project workshop was seen as the best method to convey current knowledge on SBS and discuss any further action required.

7 Results and Discussion

7.1. Review of Saddleback Syndrome in the scientific literature: identification, cause and occurrence

From the literature review, Saddleback Syndrome (SBS) is defined as:

An abnormality of the dorsal fin and profile, lacking one to all of the hard spines and rays, accompanied by shape, number and position abnormalities of the associated pterygiophores.

This definition was first used by Koumoundouros (2001) and was confirmed, using radiographs, by Diggles (in press) as the cause of the deformities seen in Yellowfin Bream in south east Queensland. The radiographs in Figure 7.1b show the absence of the pterygiophores and dorsal fin spines characteristic of SBS, compared to an unaffected individual shown in Figure 7.1a.

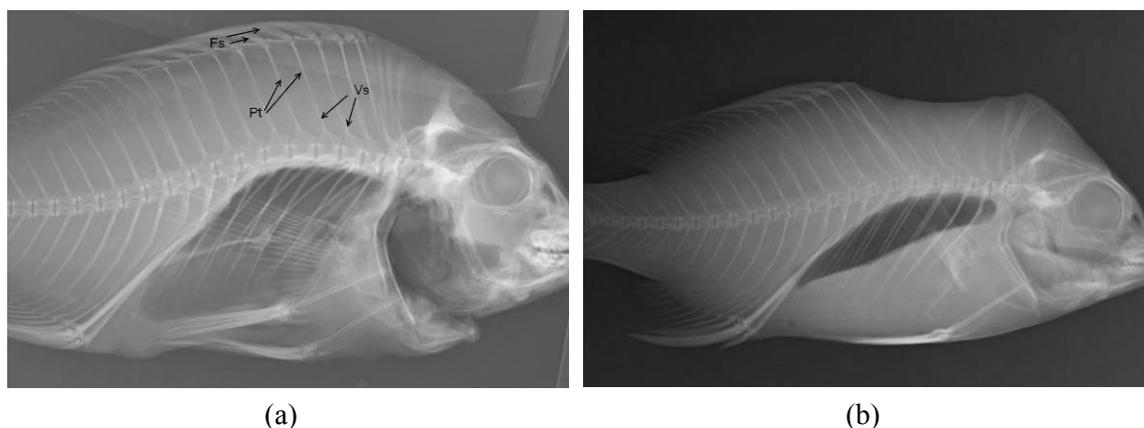


Figure 7.1: (a) X-ray of a normal *A. australis*. Pt – pterygiophores, Vs – vertebral spines, Fs – dorsal fin spines. (b) X-ray of an *A. australis* afflicted with SBS. Note the absence of pterygiophores and dorsal fin spines at the site of the deformity. Photos courtesy of Digsfish Services Pty Ltd.

Yellowfin Bream in Queensland

The Yellowfin Bream *Acanthopagrus australis* is an important commercial and recreational fish species in Queensland. *A. australis* is endemic to coastal and estuarine waters between Townsville and Victoria on the east coast of Australia (Kerby and Brown, 1994). *A. australis* inhabit shallow seagrass and mangrove areas in turbid estuaries within Moreton Bay (Kerby and Brown, 1994). The spawning season occurs during the lower water temperatures in the winter near surf bars during which females produce a large number of eggs. However, not all adults participate in the spawning each year; around half will stay at their feeding grounds (Kerby and Brown, 1994; Pollock, 1982a). The non-migratory fish will reabsorb the yolk-stage oocytes gaining the lipids and proteins as an energy source usually lost during spawning (Kerby and Brown, 1994; Pollock, 1984). *A. australis* are protandrous hermaphrodites; smaller fish usually have functional male gonads and larger fish often having functional female gonads (Hesp et al., 2004; Kerby and Brown, 1994; Pollock, 1982b). Juvenile *A. australis* only undertake small-scale movement of less than six kilometres whereas adult fish undertake larger scale migration (10 - 90km) to spawning areas where they stay before dispersing back throughout Moreton Bay at the end of spawning (Kerby and Brown, 1994; Pollock, 1982a).

Eggs are spawned at high tide at surf bars. The planktonic larvae are carried to the ocean and return to the estuary by lunar and tidal influence around September (Pollock, 1985; Pollock et al., 1983). In wild populations of *A. australis*, Kerby and Brown (1994) reported that water temperature may be an important environmental cue influencing seasonal reproductive development. Planktonic post-larvae use a diel-tide phase with movement and abundance reported to be affected by a full moon ebb tide (Pollock, 1985; Pollock et al., 1983; Trnski, 2001). Fry are not found in Moreton Bay after September (Pollock, 1982b) and, as such, are thought to grow to juvenile stage quickly. Gillanders and Kingsford (2003) reported that *A. australis* spend varying lengths of time in estuaries and, therefore, absorb differing concentrations of minerals.

Although SBS has been found in several species of Sparids, the manifestation of the syndrome differs significantly, even within species. Figure 7.2, Figure 7.4 and Figure 7.5 show SBS in *A. australis* caught by recreational anglers during a fishing competition in July 2011, in the area around South Stradbroke Island.

Saddleback Syndrome in Queensland – a review of media articles

Saddleback Syndrome has been identified in fish species with importance to recreational fishing in south east Queensland. Recreational fishers have, in recent years, insisted that SBS has become more prevalent and is now occurring in species other than *A. australis* such as tarwhine, *Rhabdosargus sarba*, and snapper, *Pagrus auratus*,

(Bateman, 2010a; Bateman, 2010b). Recreational fishers were convinced that the saddle-like deformity is an injury sustained during removal from commercial gill nets. This, combined with a perceived increase in prevalence of SBS, motivated the recreational fishing peak body, Sunfish Queensland Incorporated (hereafter referred to as Sunfish), to launch a monitoring program in 2009, whereby Sunfish members were encouraged to provide information regarding the location and date of any fish captured showing signs of SBS (Bateman, 2009). In the same article, Mr. Bateman states “First reports came from the Jumpin pin [sic] area but after some exposure to our members it appears that the problem is widespread & [sic] occurs in approx 5% of fish taken in some areas”.

On 30 September 2009, Queensland Health released a report detailing the analysis of three *A. australis*, two afflicted with SBS and one not afflicted, provided by Dr. Ross Quinn from Fisheries Queensland, on behalf of Sunfish Queensland Incorporated. These animals were analysed for a range of pesticides, PCBs and trace metals and were found to be safe for human consumption according to the Food Standards Australia New Zealand (FSANZ – formerly ANZFA) Food Standard Code. Although from a small sample, the observed lipid content was lower in SBS-afflicted fish compared to the control fish, while the levels of total arsenic were higher in the SBS-afflicted fish. The elevated arsenic levels were not considered unusually high for marine fish.

As part of his Chairman’s Column in the October 2009 edition of the Sunfish Magazine (Pollock, 2009), Dr. Barry Pollock conveyed that Sunfish had provided samples for analysis by Queensland Health but had yet to receive feedback regarding the results. The results (above) were reported in the January 2010 edition of the Sunfish Magazine (Pollock, 2010), with Dr. Pollock stating that the analyses revealed “... that there are nil or very low concentrations of contaminants in deformed bream and hence these fish appear OK [sic] to eat”.

On 10 May 2010, Mr. David Bateman from Sunfish, along with Jim Groves, the then Managing Director of Fisheries Queensland, and Matt Landos, an aquaculture veterinarian, were interviewed as part of the Morning program on the ABC (see Gaffney, 2010). During these interviews, Mr. Bateman stated that one in ten bream caught by Sunfish members exhibited signs of SBS, which he described as “an indentation on the top of the head that has well-and-truly healed-up”. Mr. Bateman went on to state that the Sunfish monitoring program mentioned earlier had shown that SBS was present in samples from “as far north as Mackay and also well into New South Wales, but mainly in Moreton Bay” and that “it looks like it’s now mutating into other species as well and increasing in numbers”. Mr Bateman gave a small snapper *P. auratus* as an example of how SBS had then ‘mutated’ into other species as well as

luderick, *G. tricuspidata*, and tarwhine, *Rhabdosargus sarba*. During the interview, Mr Bateman suggested that the SBS-related deformity "...could be started off by chemicals and then reproduced, genetically, through the reproduction system of the fish" and that "...it looks more like it's some sort of a genetic defect caused by a chemical of some sort".



Figure 7.2: SBS in Yellowfin Bream with both anterior and posterior dorsal spines absent. This individual was caught by a recreational fisher during a competition on 2 July 2011 in proximity to South Stradbroke Island.



Figure 7.3: Saddleback Syndrome in a Yellowfin Bream. Note the absence of the anterior dorsal spines and the saddle-shaped deformity characteristic of SBS in this species. This fish was caught by a recreational fisher on the Gold Coast during a fishing competition on 19 June 2011 (TL = 29cm).

In interview with Ms. Gaffney, Mr. Groves stated that the deformity is "...a naturally-occurring phenomenon in a number of species of fish world-wide. It's known as Saddleback Syndrome, it appears as a notch on the top of the spine..." and that "it does look like a healed wound". Mr. Groves then went on to state that "...it occurs or is generated in the pre-larval stage". Mr. Groves also pointed out "...that it's a naturally-occurring phenomenon that has no adverse consequences for either the fish or for people who catch the fish". Mr. Groves then conceded that scientists could not rule out "that there has been some kind of chemical interaction at the larval stage of the fish and it is being genetically reproduced", a question asked by Ms. Gaffney.

When interviewed, Mr Landos immediately stated that it was "extremely unlikely that this is any kind of genetic issue. We're talking about wild fish here, breeding, where there is no real chance of inbreeding to be taking place". Mr. Landos went on to state that "...industrial pollutants and pollutants that are coming via sewerage which have endocrine-disrupting effects and can alter the way in which embryos are developing and cause deformities".

Later that day, an article appeared on the ABC News website that summarised Mr. Bateman's interview (Anonymous, 2010a). The article highlighted Mr. Bateman's comparison of SBS with deformities observed at a fish hatchery on the Noosa River, the symptoms of which manifested as two-headed embryos.

Bateman (2010b) published an article in the June 2010 edition of Sunfish Magazine, reporting on the monitoring program Sunfish had established. The author stated "The most intensely monitored area has been the Jumpinpin area where the incidence is now reportedly 10% in some catches". Further, the author gives an account of an undersize snapper, *Pagrus auratus*, exhibiting signs of SBS with an accompanying photograph showing the individual with the deformity. In the same article, Mr. Bateman stated that "At the current rate of increase it is possible the [sic] 50% of the catch will be affected in 5 years time and it will be too late then to remedy the cause but more importantly to stop the spread to other species".

On 24 September 2010, Queensland Fisheries Director General Jim Groves was quoted by the Australian Times as describing SBS as "naturally occurring", that fish afflicted were "perfectly safe for human consumption" and that the affliction "...posed no adverse health risks". Mr. Groves was also quoted as saying that in regards to testing "Nothing was found that was a concern whatsoever" (Hill, 2010).

An article appeared on the website of the Brisbane-based Courier Mail (Williams, 2010) quoting the then Sunfish Chairperson, Dr. Barry Pollock as saying that

“...fishermen [sic] had been catching deformed bream for about 10 years but the problem had been getting worse over the past five years”. The article also listed causes of SBS “...including physical, genetic, environmental, nutritional and infectious, but interaction with fishing nets was ruled out”, although this was not attributed to a particular source article or quote.



Figure 7.4: SBS in Yellowfin Bream with anterior dorsal spines absent (fish caught by a recreational angler as part of a competition on 2 July 2011).

On 24 September 2010, an article appeared on the Tweed Daily News website (Anonymous, 2010b). This article quoted fishing guide, Mr. Brad Smith, as saying that he was “...getting at least one deformed bream for each charter on the Tweed River, but he has seen it for the last twenty years”. The article states that “Local ACORF representative Charlie Howe has been contacted by fisheries managers from Sydney asking what the situation was on the Tweed. Unfortunately it is not good”. The article goes on to say that “Charlie has personally caught two”. The article then states that “...polluted waterways is [sic] thought to be the primary cause”.

Also in September 2010, an article by Sunfish representative, David Bateman, appeared in the Sunfish Magazine (Bateman, 2010a), reporting on the capture of an SBS-afflicted tarwhine, *Rhabdosargus sarba*. An attached photo depicts a 10cm (TL) specimen with a spinal deformity. A close-up of the deformity shows that the fish was afflicted with what appears to be Saddleback-like Syndrome (see Appendix 4) as dorsal spines are present.

In the December 2010 edition of the Sunfish Magazine (Anonymous, 2010c), the author states “Attempts by Sunfish for scientists to do research to find the cause of deformities

in bream and other species (Snapper [sic] and Tarwhine[sic]) have been supported by the commercial fishing sector but OPPOSED [sic] by Fisheries Queensland”. The author states that “...the incidence of the deformed bream can be as high as 10% of the catch at some popular fishing locations”.

As a result of the increasing pressures from Sunfish and other sources, the Queensland Fisheries Research Advisory Board (QFRAB) announced, as one of their Research and Development priorities for 2010, that there was an “urgent need for research into the cause of a particular deformity of bream that is occurring in the important Moreton Bay fishery”. As such, a research project was proposed and submitted (15 September 2010) by the Principal Investigator of the current project seeking significant funds (\$245,000 from the Fisheries Research and Development Corporation) with aims of determining the cause of SBS using a range of techniques including otolith microchemistry and genetic methods. This proposal was unsuccessful, with QFRAB suggesting that the current work be undertaken.

7.1.1 *SBS in wild populations*

In the scientific literature, very few papers describe SBS in wild populations. Browder et al. (1993), cite several articles that report on “morphological abnormalities similar to saddleback” including Code (1950) and Lewis (1961) which may or may not have been SBS. Code (1950) reported the capture of cutthroat trout (*Oncorhynchus clarkia*, formerly *Salmo clarkii*) from the South fork of Sheep Creek in Utah, USA. Included in the article were photographs and X-rays depicting fish with symptoms similar to those observed in SBS-afflicted fish. Lewis (1961) reported on missing dorsal spines in a wild population of sockeye salmon (*Oncorhynchus nerka*). This article includes X-rays of a normal dorsal fin and an “abnormal” fin, with the author stating “A close inspection of the dorsal fin area revealed no scar, and the scale rows appeared to be normal. No dorsal fin rays and no distal radial or proximal radial bones were present”. The X-ray of the “abnormal” dorsal fin appears to conform to the definition of SBS, although the published X-ray is difficult to interpret with certainty. Both of these articles fail to call the observed abnormalities by name.

Möller and Anders (1986) discuss skeletal deformities and state that “In general, externally visible skeletal deformations occur in less than 1% of natural fish populations”. These authors give an example of the prevalence of visible skeletal deformities in cod from an estuary over a twelve month period, with the percentage of deformed fish less than 1.2% for most of the study period. However, during the summer months (June – August), the deformation rate increased to between 27.3% and 53.8% before decreasing again to 1.2% in September. Möller and Anders (1986) state that healthy fish had left the estuary, leaving only deformed fish. No mention of SBS is

made by these authors, nor do they discuss the skeletal anomalies observed in the cod studied. Skeletal anomalies in herring were also quantified, with deformation rates between 2.5% and 4.8% quoted across three spatial regions of the North Sea. Of the seven skeletal deformities discussed by Möller and Anders (1986), including lordosis and scoliosis, none are similar to SBS appearance. These authors mention parasites, fungi, toxicants and abiotic factors (impairing the calcium budget) as causative factors of skeletal deformities.

Lemly (1993) cited selenium contamination as the cause of deformities in ten species of fish located in a freshwater lake adjacent to a coal-fired power station. The author explained that water from the lake was used to cool power generating units and also to mix with bottom ash from coal burners. The bottom ash mixture was then pumped into settlement ponds adjacent to the lake before returning to the lake with high concentrations of selenium (150-200 $\mu\text{g/l}$). Lemly (1993) reported that the elevated levels of selenium led to 1) an accumulation of selenium in the gonads of reproducing fish, with a resultant “very high percentage of abnormal larvae” and 2) the selenium levels were lethal to adults, eliminating predation pressures on the deformed larvae. Both of these factors resulted in the high numbers of deformed fish observed. This author found a correlation between selenium concentration and the incidence of skeletal, eye, head and fin abnormalities. This report shows an X-ray of a green sunfish *Lepomis cyanellus* exhibiting symptoms of SBS, as defined by the case definition on page 10, notably the absence of “three hard dorsal spines and five supporting pterygiophores” from the posterior part of the first dorsal fin. It is difficult to determine if other species mentioned were afflicted with SBS as the author does not mention SBS by name and only refers to “fin abnormalities”. For example, another figure shows a mosquitofish *Gambusia affinis* with missing pelvic fins. Unfortunately, all fin abnormalities were grouped together and the incidence of SBS was not quantified. Lemly (1993) stated that “the most frequent types of abnormalities were lordosis, kyphosis and fin defects...” and “...fin and head defects were restricted to juvenile fish”.

Browder et al. (1993) described SBS in ten species of fish in a semi-enclosed, sub-tropical estuary lagoon in Florida, USA. These authors described SBS as an “incomplete dorsal fin with one or more missing or stunted dorsal spines, sometime accompanied by a depression in the upper body profile at the site where the spines are missing”. The deformity “...usually involved the anteriormost [sic] dorsal spines and individuals sometimes had other abnormalities”. Further, “...some of the specimens had posterior spines missing with the anterior-most dorsal spines intact”. These authors suspected that in the one location a range of deformities were caused by the same or a group of environmental contaminants common to all affected species.

Of the ten species affected, three – sea bream *Archosargus rhomboidalis* silver porgy *Diplodus argentus* and pinfish *Lagodon rhomboides* – were of the Family Sparidae. Other species affected were the snapper (Lutjanidae) *Lutjanus griseus*, the grunts (Pomadasyidae) *Haemulon parrai*, *Haemulon plumeri*, *Haemulon sciurus*, the Bermuda chub (Kyphosidae) *Kyphosus sectatrix*, the scrawled cowfish (Ostraciidae) *Lactophrys quadricornis* and the checkered puffer (Tetradontidae) *Spheroides testudineus*. Given that multiple species were observed with SBS, Browder et al. (1993) suggested that “...something in the environment common to all species may have caused the deformity” and that SBS “...may have arisen through the environmental induction of mutation at some labile genetic focus shared by all fish groups”. As such, these authors failed to identify a specific cause of the deformities stating “PCBs, other chlorinated hydrocarbons, and certain heavy metals found in Biscayne Bay have been associated with skeletal deformities”. However, these authors also state that “fish populations have declined to the extent that genetic variability has been substantially reduced”, adding “...this might be the mechanism by which saddleback is produced”.

Koumoundouros (2008) described SBS in a single parrotfish *Sparisoma cretense*, caught in the Aegean Sea off Greece, but failed to identify any potential causes of the deformity. It was found that in *S. cretense*, SBS manifested as a shorter profile of the dorsal fin with two missing dorsal spines. The associated pterygiophores were also absent. This author reported that SBS may not significantly affect fish survival; however, factors such as predator avoidance, prey capture and locomotion performance are affected by some skeletal deformities. Koumoundouros (2008) also reported that fish affected by SBS are more susceptible to stress and less hardy in changing environmental conditions. It was found that behavioural elements such as attracting a mate in wild parrot fish may be affected as dorsal fin displays are used to attract a mate.

The most recent study of SBS was conducted by Diggles (in press). In this study, the author collected three *A. australis* samples from Moreton Bay and had radiographs taken of each fish. The first fish was classified as normal, with the dorsal surface normal (Figure 7.1a). A second fish was classified as having a mild case of SBS, while a third was classified as having “severe” SBS (Figure 7.1b). The deformity in this individual was consistent with those reported by other authors (e.g. Koumoundouros et al., 2001) and lacked pterygiophores and dorsal spines. Diggles (in press) confirmed that the deformity in *A. australis* can be described as SBS and that the deformities were not due to injury. This author suggested that SBS may develop as a result of an “...environmental induction of genetic mutation at some labile gene focus...” as cited from Browder et al. (1993). This author also pointed out that anthropogenic pollution may be a cause of the deformity as a result of significant declines in water quality within Moreton Bay.

Many recent studies in the scientific literature attribute skeletal deformities in wild fish populations with pollution (e.g. Messaoudi et al., 2009; Sun et al., 2009). Messaoudi et al. (2009) stated that spinal deformities observed in their study were observed only in polluted waters. These authors studied the association of spinal deformities with heavy metal bioaccumulation and found that kyphosis, scoliosis and lordosis deformities occurred at 10.72 % and were higher in polluted waters, which contained higher levels of cadmium, copper and zinc, than in unpolluted waters.

Sun et al. (2009) collected tilapia seasonally from four contaminated rivers in south western Taiwan. The study looked at morphological deformities as biomarkers for pollution. A strong relationship was found between deformity and bad water quality including high ammonia, lead and zinc concentrations and low dissolved oxygen. The study concluded that morphological deformities were found to be significantly higher in fish collected in the rainy season possibly due to increase river flow stirring up organic material and heavy metals from the river bed. Sun et al. (2009) found that "...tilapia from these rivers that have different types and concentrations of pollutants such as heavy metals of [sic] mercury, zinc, lead, copper, chromium, serious organic pollution as evidenced by high ammonia levels, biological oxygen demand, coliform counts and low dissolved oxygen along with high suspended solids with high flowing speed during heavy rainfall, developed a suite of morphological deformities in response to those pollutants".

Gagnon and Rawson (2009) found that the incidence of spinal deformities in *P. auratus* increased with increasing concentrations of diuron, a herbicide used in anti-foulant paints applied to marine vessels. These authors report that this chemical was banned in the UK in 2002 after high concentrations were found to be present in European marinas and ports. Gagnon and Rawson (2009) performed experiments on larval *P. auratus* and found deformities in 20% of fish at 50µg/l. Given that *P. auratus* are located in diverse habitats including marinas, it is likely that some fish may be exposed to such chemicals.

7.1.2 SBS in cultured populations

Several authors have reported SBS in cultured populations of fish (Akashi and Abe, 2011; Komada, 1980; Korkut et al., 2009; Koumoundouros et al., 2001; Roo et al., 2010; Tave et al., 1983; Valente, 1988); however, few describe the causative factor, or combination of factors, responsible. During early larval stages, developmental deformities were linked with nutrition. Studies have found that SBS could be caused by feeding conditions, quantity and quality in larval food (Korkut et al., 2009; Koumoundouros, 2008).

Komada (1980) described deformities in natural and cultured populations of ayu, *Plecoglossus altivelis*, in the Hokkaido area of Japan. No mention is made of SBS by this author, however, Koumoundouros et al. (2001) classifies at least one of the deformities as SBS. Komada (1980) state that “the frequency of morphological deformities found in hatchery-reared ayu was about 100-500 times higher than in nature”. This author suggests that the higher incidence in reared populations could be attributed to unfavourable environmental conditions, such as unfavourable temperature and hypoxial conditions, during ontogeny and also rearing condition, but failed to identify a single cause of the deformity.

SBS was first identified and described by Tave et al. (1983) in reared tilapia *Sarotherodon aureus*. These authors stated that “Saddleback *S. aureus* are missing part or all of the dorsal fin” and that SBS was “...quite variable and exhibits a continuous distribution ranging from those that lack only the first spine to those that have no dorsal fin”. The appearance of SBS ranges from an absence of the anterior-most dorsal spines or sections of dorsal spines to completely lacking a dorsal fin (see Figure 7.3). The absence of dorsal spines coincides with an absence of pterygiophores, the internal bones that support the muscle and dorsal spines (Browder et al., 1993; Koumoundouros et al., 2001), resulting in a lack of structural support for the muscle, giving rise to the saddle-like deformity (Tave et al., 1983). In severe cases of SBS, other fin deformities may also be present affecting the pectoral, pelvic or anal fins (Tave et al., 1983).

Tave et al. (1983) give a genetic explanation for SBS, stating that it is a ‘dominant autosomal gene’ in the Auburn population of blue tilapia *Sarotherodon aureus*. The study experimented on phenotypic ratios and found that “...the S gene interferes with normal embryological development and ossification¹ of fin rays and associated skeletal structures”. Although the experimental population was highly inbred, this was found not to influence the saddleback phenotype. Genetically, the study found that a saddleback parent always produced saddleback progeny and that SBS had a heritable basis in reared *S. aureus*. The authors went on to state that “...all saddlebacks are heterozygotes (S+) and that all homozygous (SS) individuals are aborted”. Further, it was found that by culling all fish with SBS the dominant gene can be eliminated from any population in a single generation.

Tave et al. (1983) state that “qualitatively, saddlebacks seemed to be less hardy than normal fish” continuing to note that “saddlebacks seemed to be more sensitive to handling stress and appeared to die in disproportionate numbers when environmental conditions changed in the ponds”. This was quantified by exposing 953 fingerlings to a *Saprelegnia* infection resulting in a 33% mortality rate in deformed fish compared to

¹ Ossification refers to the formation of bony structures.

5% mortality in unaffected fish. Tave et al. (1983) reported individuals afflicted with SBS were found to have had difficulty maintaining upright equilibrium if they lacked most, or all, of the dorsal fin, however, the absence of the anterior half of the dorsal fin had no noticeable effect on swimming behaviour.

Tave et al. (1983) reported that "...in fish where ray loss is not consecutive, rays that remain are either vestigial or grossly deformed". Further, when the dorsal or anal fins were missing the associated pterygiophores were also absent. These authors also reported that in extreme cases of SBS, pectoral, pelvic and anal fin deformities can also occur.

Valente (1988) reported the presence of a fin abnormality in crucian carp (*Carassius carassius*) but did not refer to the abnormality as SBS. However, the typical saddle-like abnormality is obvious in both individuals from the photographs published in the article. The posterior end of the dorsal fin appears to be absent in one individual while the anterior portion of the dorsal fin is absent in the second individual. This author does not indicate likely causes of fin deformities in crucian carp apart from referring to Welch et al. (1963): "...such anomalies might originate through unfavourable environmental conditions during embryonic development". However, Valente (1988) stated that their "data do not provide evidence" that environmental conditions caused the deformities.

Koumoundouros et al. (2001) studied the development of SBS in *Dentex dentex* in extensive and semi-extensive rearing conditions. Koumoundouros et al. (2001) reported that 4.0-4.4% of cultured *Dentex dentex* larvae reared under semi-extensive conditions were afflicted with SBS during experiments, while those reared under extensive conditions, or wild-caught, exhibited no signs of the syndrome. This suggests that differences in rearing strategies, particularly those associated with stocking density and nutrition, may influence the occurrence of SBS in cultured populations of *D. dentex*. The semi-extensive system represented conditions that reared larvae would experience during culture, with higher densities of juveniles than those expected in a natural system. Using meristic characteristics and osteological appearance for comparison, semi-extensive individuals had the highest incidence of SBS, while juveniles caught in the wild exhibited no signs of the deformity. Genetic factors did not have a direct involvement in the development of SBS in *Dentex dentex* because all experimental fish were from the same broodstock.

Koumoundouros et al. (2001) found that, anatomically and ontogenetically, SBS and severe caudal fin deformities were found to be related in *Dentex dentex* and originated in the early developmental stage. Internal identification shows that SBS was first

identified in fish at the early larval stage (3.6 – 15.5mm Total Length, TL) and was evident from the seventh post-feeding day, with the size of individuals at 4.8 mm and 5.2mm TL. No morphological abnormalities were present during the autotrophic phase (egg incubation and yolk sac larval phase). The authors suggest that SBS can be identified after the development of dorsal spines.

Although the deformity reported by Setiadi et al. (2006) in cultured *Epinephelus akaara* appears to be Saddleback-like Syndrome, no indication was given as to likely causes of the deformity, simply stating that “the deformity reported in this study might possibly be caused by rearing conditions”. These authors studied geometric morphometrics to identify effects on body shape and size of red spotted grouper, *Epinephelus akaara*, by SBS and vertebral deformity. These authors reported that before the development of dorsal distal radials, spines and pterygiophores, SBS is found in *E. akaara* at the pre-flexion stage and was found to affect the first to fourth dorsal proximal radials and neural spines at the pre-flexion stage. Although Setiadi et al. (2006) refer to the deformity as SBS, photographic evidence suggests that the *E. akaara* studied were afflicted with Saddleback-like Syndrome (see Appendix 4, page 51), as dorsal spine counts are the same for fish with and without the deformity.

Korkut et al. (2009) published the first account of SBS occurring in gilthead sea bream, *Sparus aurata*, cultured in sea cages in Turkey. These authors observed individuals with all dorsal spines absent along with associated pterygiophores. They also reported that SBS-afflicted *S. aurata* had a 20% lower growth rate than normal. It is noted by the authors that the fin deformities might negatively affect survival, growth and weight development. These authors fail to identify causative factors, suggesting that further studies should be focused on identifying the causative factors, specifically nutrition, genetics and abiotic factors. Korkut et al. (2009) reported that nutritional phosphorus and micronutrients such as Vitamin A, C and D deficiencies are factors that can cause skeletal deformities and, as such, may be a causative factor in SBS.

Roo et al. (2010) analysed skeletal deformities in the red porgy *Pagrus pagrus* cultured using different rearing techniques. These authors examined a range of deformities such as lordosis, kyphosis and cranial deformities. SBS was included in this study but was reported in the “other deformity” category and as such, very little information regarding SBS is presented in this paper. Despite this limitation, Roo et al. (2010) state that “Reared fishes generally display a higher variability of meristic characters and higher numbers of deformities than natural populations”. These authors discussed the observation that deformity rates and stocking densities were correlated.

7.1.3 Summary

SBS has been shown to affect several species in both natural and cultured populations of fish. The scientific literature suggests that pollution and a lack of genetic diversity may be causative factors affecting the incidence of SBS in natural populations. Although a high concentration of selenium was cited as a probable causative factor of deformities observed in a freshwater lake by Lemly (1993), Browder et al. (1993) fail to identify a single pollutant or other causative factor that led to the deformities observed in a suite of species in a sub-tropical estuary in Florida.

Möller and Anders (1986) report that parasites, fungi, toxicants and abiotic factors (impairing the calcium budget) can cause skeletal deformities in wild populations. However, these authors do not describe SBS as skeletal deformities observed in Europe. Instead, these authors discuss bullheadedness, shortening of the spine, lordosis, scoliosis and deformations of the jaw and gill cover. Although such deformities do occur in Yellowfin Bream, SBS is by far the most common deformity observed in this species in south east Queensland. The incidence of SBS in Yellowfin Bream from the current study is similar to that reported by Möller and Anders (1986) for the aforementioned skeletal deformities.

Lemly (1993) described the effects of selenium pollution in an enclosed freshwater lake that had been polluted by waste-water from a coal-fired power station. It is difficult to draw comparison between the events described by this author and the incidence of SBS in *A. australis*, given that Belews Lake is a freshwater lake adjacent to a coal-fired power station and is landlocked.

The study by Browder et al. (1993) is a more appropriate comparison as Biscayne Bay is a saltwater bay adjacent to a large city (Miami, population 2.5 million) at approximately 26°N. These authors stated PCB's, other chlorinated hydrocarbons and certain heavy metals found in Biscayne Bay were associated with skeletal deformities in laboratory studies. However, these authors reported that species from different and diverse families were affected including Lutjanidae, Pomadasysidae (similar to grunter *Pomadasys* spp.), Kyphosidae (similar drummer, *Kyphosus* spp) and Ostraciidae (cowfish, *Lactoria* spp.), with the Lutjanids displaying the highest incidence of abnormalities. In contrast, the species affected in southern Queensland are mostly from the family Sparidae, including *A. australis* and snapper *Pagrus auratus*.

The samples provided to Queensland Health, mentioned by Pollock (2010), revealed that the SBS-affected individuals had 2.4 mg/kg and 3.0 mg/kg, respectively, of arsenic compared to 1.2 mg/kg for the control specimen. The Queensland Health report fails to mention selenium; however, mercury, lead and cadmium levels were similar for both

affected and unaffected fish. Similarly, pesticide and PCB levels were identical for both affected and unaffected individuals.

In cultured populations, rearing condition is the most common causative factor of SBS cited, although no author has identified a single factor or suite of factors responsible. Temperature, oxygen levels, nutrition and stocking density have been suggested by authors who observed SBS in cultured fish populations as possible causative factors of SBS.

The genetic transference of the *S* gene, as suggested by Tave et al. (1983), is a complicating factor. It is possible that the SBS observed in *A. australis* may be caused by pollution or an environmental factor as suggested by Diggles (in press), with affected individuals passing on the syndrome to their progeny. However, this is speculative and cannot be confirmed at this time.



Figure 7.5: SBS in Yellowfin Bream with posterior dorsal spines absent (fish caught by a recreational angler as part of a competition on 2 July 2011).

Although several causes have been suggested by authors of scientific journal articles, no one factor has been found to cause SBS. Given this result, it is difficult to ascertain definitively why SBS is more likely in *A. australis* than other species. As mentioned earlier, species affected in south east Queensland, including *A. australis*, snapper, *Pagrus auratus*, and luderick *Girella tricuspidata*, have an inshore component of their life-cycle, particularly during their larval phase.

The high density of larvae at the settlement stage may induce SBS through competition for food. Skeletal deformities have been attributed to nutritional deficiencies in cultured populations and may cause SBS in post-settlement *A. australis*. It is possible that *A. australis* settle in specific habitats such as seagrass beds, where competition for food may cause density-dependant developmental deformities like those observed in cultured populations, particularly in years of above-average recruitment

Some authors (e.g. Tave et al., 1983) suggest that SBS can cause swimming difficulties in some species, which may lead to higher levels of mortality. This is of particular relevance in *A. australis* populations, where predation of deformed individuals may result in significant increases in natural mortality. Diggles (in press) also made this observation stating that the number of adults afflicted with SBS may be the “tip of the iceberg”, with the deformity possibly causing significant reductions in survivorship of individuals afflicted with SBS in early life stages. Similarly, Möller and Anders (1986) report that deformities are a negative selection factor and, as such, the prevalence of deformed fish should decline with age. However, Tave et al. (1983) reported that the swimming ability of the tilapia they studied was hindered in fish only where the posterior margin of the dorsal fin was affected by SBS. In the majority of SBS-afflicted Yellowfin Bream, the anterior margin is affected, with very few animals presenting with symptoms like those in Figure 7.5.

Given the lack of evidence as to the causes of SBS, designing a sampling regime with the objectives of determining the causes of SBS in *A. australis* would be a difficult task. Diggles (in press) suggests an experiment crossing affected and unaffected individuals would determine if the deformity was heritable. This author suggests larval rearing trials in controlled experiments, in contaminated water from areas known to hold populations of *A. australis*. Other factors such as temperature, pH and dissolved oxygen could then be manipulated to determine if they have any effect on the incidence of SBS in the reared larvae.

7.2. Saddleback Syndrome in Queensland

As part of this sampling, A & M recorded information on 5,728 *A. australis*, from 629 individual catches from Bundaberg to the Gold Coast (Figure 6.1). Of these, 189 (3.3%) individuals were observed to have been afflicted with SBS. The GLM indicated that location, habitat and month significantly ($P < 0.001$) affected the incidence of SBS in *A. australis* catches collected by A & M (Table 1). The Sunshine Coast had the highest incidence of SBS, while the Logan River, Fraser Inshore and Bundaberg had no incidences of SBS (Figure 7.6).

Table 1: Accumulated analysis of deviance table from Genstat (2011). The incidence of SBS in *A. australis* as a proportion of total catch was the response variable.

Change	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Location	8	70.159	8.770	8.77	$P < 0.001$
Habitat	3	16.379	5.460	5.46	$P < 0.001$
Month	11	34.788	3.163	3.16	$P < 0.001$
Year	2	1.768	0.884	0.88	$P = 0.413$
Residual	603	293.423	0.487		
Total	627	416.517	0.663		

SBS was found to be confined to estuary, bay and near-shore habitats, with no *A. australis* caught offshore being afflicted with SBS (Figure 7.7), although sample size was low ($n = 19$). The incidence of SBS in the winter months, when catches are highest as a result of fishers targeting spawning fish, was approximately 3% (Figure 7.8), with 3.9% of *A. australis* caught in August exhibiting symptoms of SBS. The observed incidence of SBS from fish caught in November was 6.1%, however, the model adjusted this upwards as a result of the fact that the catches landed in November during the sampling were caught in bay habitats, where SBS is highest. The incidences of SBS in catches landed in the months March to September are likely to approximate the actual incidence of SBS in *A. australis* populations, given the large number of fish caught during these months and the resultant sample sizes during the routine monitoring program conducted by A & M. As such, the actual incidence of SBS in south east Queensland is likely to be approximately 3.3% - the observed mean incidence of SBS.

This result differs from anecdotal evidence supplied by recreational fishers in south east Queensland, where incidences of 5-10% have been reported. Project staff attending a SQAFA competition weigh-in held in the Gold Coast Broadwater noted an incidence of 5-10%, despite the low incidence (0.4%) observed in Gold Coast samples collected by A & M over the SBS sampling period from 258 *A. australis*.

Such results are likely given that the A & M sampling of *A. australis* is driven by management needs, specifically the collection of length and age data for stock status reporting, rather than being driven by a need to answer questions relating to the incidence of SBS. That is, low sample numbers in areas where the incidence of SBS is anecdotally high are a consequence of the lack of targeted sampling. Further research should, therefore, include a targeted sampling program that ensures adequate coverage of relevant areas such as Pumicestone Passage, Jumpinpin, the Gold Coast Broadwater and the estuaries of the Sunshine Coast. This sampling should involve a co-operative program between researchers and recreational fishers, particularly those involved in fishing competitions where the incidence of SBS is reportedly high. We also

recommend that A & M continue collecting information regarding the incidence of SBS in *A. australis* in south east Queensland.

SBS.

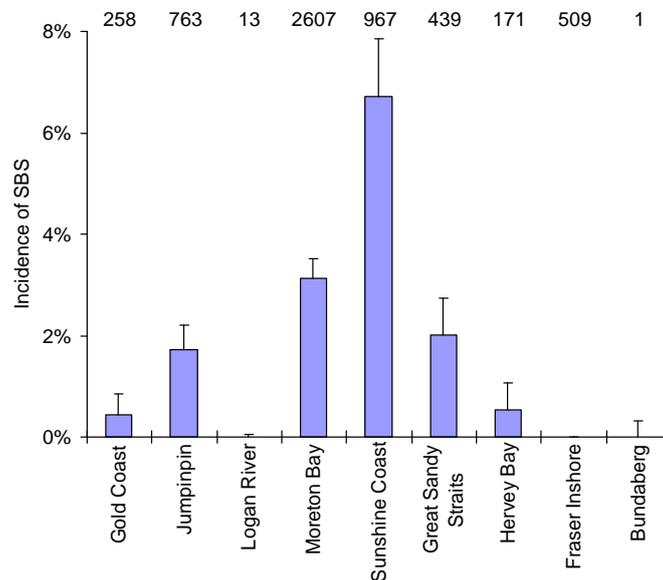


Figure 7.6: Incidence of SBS as a function of location. Sample sizes are shown at the top of the graph. Based on data collected by A & M between June 2009 and June 2011.

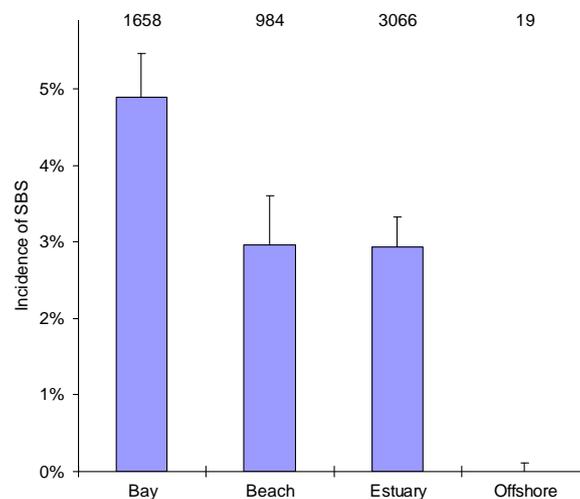


Figure 7.7: Incidence of SBS as a function of habitat type. Sample sizes are shown at the top of the graph. Based on data collected by A & M between June 2009 and June 2011.

7.3. Saddleback Syndrome Workshop

Below are the minutes from the stakeholder workshop convened on 18 January, 2012.

MC welcomed participants before handing over to BP, who gave an account of why the FRDC-funded project was initiated and supported by Sunfish Queensland. BP

presented some slides (Slides 3 – 23) outlining some previous research on Yellowfin Bream and highlighted the fact that the deformity was not mentioned by the authors of three separate studies (Munro, Dredge and Pollock). BP went on to provide details of the background of SBS in south east Queensland and the fact that SBS has been observed by members of fishing clubs at competition weigh-ins. Several slides were presented displaying SBS-afflicted Yellowfin Bream from recent SQAFCFA competition weigh-ins.

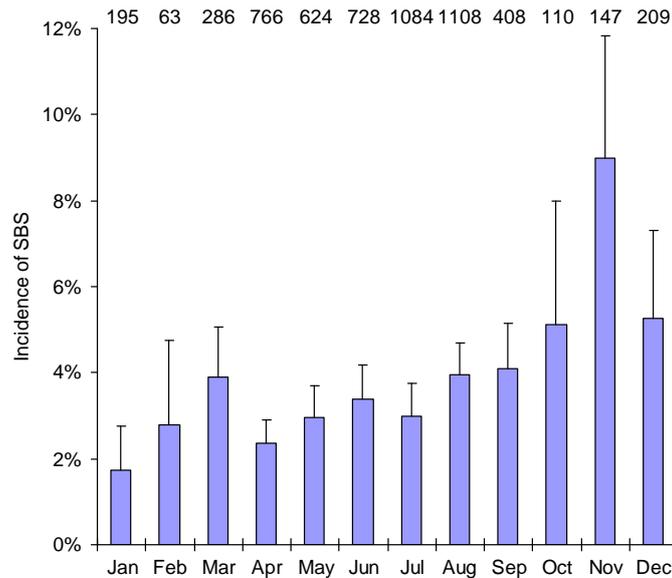


Figure 7.8: Incidence of SBS as a function of month. Sample sizes are shown at the top of the graph. Based on data collected by A & M between June 2009 and June 2011.

DT stated that he thought that the incidence of SBS was decreasing, despite the anecdotal evidence from recreational anglers. He stated that he had observed SBS in striped butter bream and small mulloway.

DB said that he had received reports of SBS occurring in snapper and tarwhine. DT also had seen SBS in snapper. DB went on to say that Sunfish had been hampered by the fact that they were unable to retain undersize specimens due to minimum legal size (MLS) restrictions. MC said that there is scope for up to six fishers to retain a small number of undersize animals under the provisions of a General Fisheries Permit. DB said that he had seen small bream afflicted by SBS in the Newport canal system but was unable to retain these due to the MLS. DB also said that the retention of smaller individuals may be beneficial in determining if the deformity occurs in the early life stages or later in life.

DT stated he would be happy to have observers on-board to collect samples. He said that Peel Island was a place where SBS was first noticed during the 60's and 70's.

MC then gave a definition of SBS for the purposes of the current project (Slide 25) – SBS is an abnormality of the dorsal fin where at least one spine and the associated pterygiophore(s) were absent. BP was unhappy with this definition, stating that he has seen many bream with only a very small indentation at the start of the dorsal fin and that only 50% have significant deformities.

MC gave some details about the current FRDC-funded project (Slide 26) and also some background information on Yellowfin Bream (Slide 27).

MC started a discussion regarding the samples sent to Queensland Health for analysis. Of interest was that lipid content of fish with and without SBS was different, with lower lipid content in SBS-afflicted bream. Also, arsenic levels were higher in SBS-afflicted bream, although these levels (2.4mg/kg and 3.0mg/kg) were not regarded as high for marine fish. Further, these levels were for total arsenic in the samples where inorganic arsenic is the trace metal of concern. Queensland Health stated that inorganic arsenic makes up approximately 15% of total arsenic and deemed the samples fit for human consumption on that basis.

DB made the point that the levels of arsenic may be safe for human consumption but there are no guidelines as to what concentrations of arsenic and other pollutants can affect the health of the fish. BD made the point that although pesticide and trace metal concentrations may be safe for human consumption, levels of 0.01 mg/kg of some elements can cause biological effects on fish.

MaL pointed out that the type of tissue tested for analysis has a bearing on the concentration of trace elements in the samples, with organs such as the gonads and liver and also fatty tissues, containing much higher levels than the flesh. This causes an underestimation of the concentrations of these elements in fish samples. This is particularly important as the gonads can have ten fold increases in the concentration of these elements, which may contribute to developmental problems in offspring. JL suggested that given the results, it would be advisable to determine where the arsenic (and other possible contaminants) is coming from and gave an example of the poultry farms adjacent to Pumicestone Passage as one source of arsenic. MaL said that it is a key part of the sampling template, should sampling take place in during further research, it is important to understand where fish are spawning. There may be a seasonal component to the deformity and some year classes may be more affected than others. BD added that there may be some associated epigenetic² effects (gene switching).

² Epigenetic effects are those where the environment influences the DNA of an organism during its life. Where these changes are in reproductive cells, these changes can be passed on to offspring.

MC started a discussion regarding the A & M Long Term Monitoring Program. JM said that he was made aware of Sunfish's interest in SBS when Ross Quinn was given samples by Sunfish in 2009. At that point, A & M began collecting information on SBS in Yellowfin Bream as part of their routine monitoring of commercial and recreational catches. Casual staff measure catches at boat ramps, recreational anglers donate samples as part of the Keen Anglers Program and catch information is recorded from commercial catches. Numbers of fish affected by SBS were recorded as was total catch to provide information as to the proportion of catches that were affected. This sampling was undertaken between June 2009 and August 2011. MC explained that the results from the A & M sampling revealed that approximately 3.3% of total catch exhibited signs of SBS. Location was a significant factor affecting the incidence of SBS with the Sunshine Coast and Moreton Bay having the highest incidence of SBS with 6.27% and 3.13%, respectively. There was no significant difference in the proportion of fish with SBS caught in 2009, 2010 and 2011, suggesting that the A & M sampling does not confirm the anecdotal evidence that SBS is increasing. However, given that sampling occurred over only two years, detecting significant changes are unlikely. JC suggested that the A & M data does not reflect what he is seeing at Jumpinpin and the Broadwater. BP stated that A & M sampling should continue if further research is funded. He said that he would like to see a 3-year research project funded by FRDC. JL said that it is important to keep sampling, especially with the water quality issues regarding the trace elements highlighted in the Queensland Health report. LVO suggested that any further research should target the effect of trace elements on the health of the fish and not the human consumption aspect. DB observed that all species affected by SBS have an inshore component in their life history. DB then said that if there is a cause of SBS, what do we do about it? TH then asked what can we do about it? Questions asked at higher levels will be "what if SBS is a genetic issue – what can be done? What if SBS results from a marginal decrease in water quality – what can be done?".

TH stated that as manager of recreational fisheries, those in higher levels of DEEDI will ask why are we doing research on SBS and what benefit is the research to recreational fishing in QLD? Unless there is some link to a decrease in stock size attributable to SBS or a genuine increase in the prevalence of SBS, it will be difficult to get support for further research. Anecdotal evidence is unacceptable as evidence and there needs to be some way of proving that SBS is detrimental to bream stocks in south east Queensland. MaL suggested that most inshore fisheries are in decline.

7.3.1. Literature review

JO talked about the Tave paper (Slide 39) saying that SBS is a dominant gene and that the fish that survived would be heterozygotes, having a normal gene and a recessive

saddleback gene. When mating, these fish would produce normal offspring, offspring affected by SBS and offspring that don't survive. This would reduce the number of fish in a population as a lot of fish would die. MaL suggested that the advancements in genetic methods since the Tave paper was published changes our understanding of heritability and epigenetics. BP stated that he thought genetic mutations are rare, yet SBS has been observed in several species. If it were genetic, why does it occur in several species that aren't related? BD suggested that an environmental trigger may alter the genetic make-up of a fish that can then pass on heritable traits to progeny (by epigenetic means).

MaL suggested that, in the Browder study (Slides 41 and 42), it is likely that the deformities mentioned were likely caused by an interaction of several chemicals. Mixture effects are becoming more well-known, specifically interactions of agri-chemicals, PCBs and heavy metals. This is of concern at the early developmental stages when cells divide and transform into various components of the body. Very small doses of chemicals between cells at parts per trillion inform each cell as to its function and pollutants affect this process. Embryological studies have high relevance when researching deformities as it is likely at this stage when the deformity is occurring.

PL described the Koumoundouros study (Slides 46 to 50). MaL stated that the aquaculture industry has spent a lot of money to minimise skeletal deformities as deformed fish generally grow slower and are not fit for sale. Skeletal deformities in Australian barramundi tend to occur between day 12 and day 25 (post hatch). This is at the time when the skeleton is being formed and any deformity acquired at this stage will remain with the individual until death. BP reported that Yellowfin Bream larvae enter estuaries in their millions after the June/July spawning period. He suggested that any individual that is deformed is likely to die as a result of predation or competition for food. DB suggested that 50% of all larvae entering an estuary could be afflicted with SBS, most of which die, leaving only a small proportion of the total population with SBS but a significant proportion may already have succumbed to the effects of SBS. This comment was agreed upon by the majority of participants.

7.3.2. Scale patterns on deformed bream

(BP, Slides 57 to 65)

BP stated there seems to be some correlation between SBS and scale pattern deformities. BP reported that 10% of the fish with SBS have scale pattern deformities. Further research is required to determine if this correlation is coincidental. PL reported that there were correlations between SBS and caudal fin deformities. PL suggested that the same processes causing SBS are impacting the formation of other parts of the skeleton.

7.3.3. *Group discussion and input from participants*

(Slides 66 to 69)

PL discussed the effect of nutrition as a possible cause of SBS. Not only is the nutrition of the larvae important, the nutrition of the adult can also impact on the development of progeny. Typical skeletal deformities are lordosis, scoliosis, operculum deformities and missing fin rays, all of which are typical for Vitamin C deficiencies, for example. BD suggested that the type and quantity of food available can influence larval development. PL added that the type and quantity of food available can vary spatially and temporally. BD stated that fish populations have adapted to specific set of environmental conditions, some of which have changed in the last 200 years.

BD discussed pollution as a cause of SBS. There isn't enough information as to potential pollutants that may cause SBS and other deformities. MaL discussed some recent research into pollution in 15 Victorian streams. This research found that there were 50 separate pesticides present, with one stream containing 16 pesticides. The concentrations of these pesticides were well below what is permissible by law. However, analysis of the benthic biota revealed that there was a profound change to the structure of benthic invertebrates which was not associated with anything other than the presence of pesticides. MaL suggested that these results were likely to be similar for streams around Brisbane and, for example, Murray cod are concentrating levels of mercury which should be the subject of an advisory to the public, particularly for pregnant women who should be limited to 150g of Murray cod per week. Other studies by researchers at James Cook University has shown a continuous contamination of streams by pesticides in those catchments where agriculture is present. The safe levels of these substances are continually being revised downward. MaL pointed out that the northern rivers of NSW are contaminated, yet harbour Yellowfin Bream that are likely to migrate to Queensland during their lives. Pesticide levels are, for the most part, increasing. Brominated flame retardants used on, for example, the dash board of cars are present in waterways and are known to be hormone disrupters and accumulate in the body. Dioxins, which have been the focus of international regulation due to their association with reproductive deformities, are still present in agri-chemicals. JCU researchers suggest that herbicides used on the land significantly affect adjacent seagrass areas. BP asked why, if chemical run-off is a cause, other fish with similar life histories don't have the same incidence of SBS. BD suggested that prey items may be different for each species which may affect the incidence in SBS in these species. BD also suggested that if pollution is a problem then it would be pertinent to continue monitoring the incidence of SBS, given the floods of 2011.

JO discussed genetic aspects of SBS. Some aspects of the influence of genetics can be tested at minimal cost. Mature saddlebacks can be bred in captivity to determine if it is heritable. BD suggested that both the gene and the correct environmental conditions are required. JO suggested that it would be easy to determine if SBS was inherited and this would be a good first step. Following on from this, it would be then a matter of trying to induce SBS by the manipulation of environmental conditions to determine if there was some epigenetic effect. Some unaffected bream could be maintained in captivity and exposed to pollutants or changes to environmental conditions likely to produce SBS in the progeny of the cultured fish. Inbreeding can also be easily excluded as a factor.

DB asked whether it would be feasible to test SBS-affected fish for pollutants. MaL stated that it is costly to test for a range of contaminants and that it is advisable to narrow the scale of potential projects so that a research proposal may be more attractive for funding bodies. JM stated that the Queensland Health report cost approx \$3000 for the testing of 3 fish. BD suggested that FRDC are not likely to fund a chemical-by-chemical analysis.

7.3.4. Further Research

BP suggested that we don't have any understanding of the incidence of SBS in newly-settled fish and that this may be a good starting point for further research. Bream are able to settle on a diverse range of benthic habitats but high concentrations were found just inside coastal bars. PL suggested that if the incidence of SBS was higher in smaller bream then it would be reasonable to assume that those animals with SBS do not survive as well as unaffected fish. BD has observed SBS in juvenile fish (25-40mm) caught in cast nets with fine mesh.

If funding were available for some genetic analysis, it would be feasible to collect roe and milt from spawning fish in winter and culture fertilised eggs at BIRC to determine if SBS was passed to progeny. Several combinations of fish with and without SBS could be bred. The group agreed that this would be a worthwhile adjunct to the recruitment issue mentioned above.

Also, any further research should include further monitoring of the incidence of SBS in bream and other species. This monitoring should be conducted concurrently with A & M monitoring. BD said that this was vital given the flood events of January, 2011.

MB suggested that it may be difficult to garner funds for further research. TH stated that fishery managers will support further research if there were some important issue that is affecting fish stocks. Although a deformity is occurring, is it really detrimental

to the fishery? If it isn't a critical issue, support for funding is unlikely. TH suggested that a TRF would be an appropriate next step. All participants were in agreement. There was some discussion that a TRF would focus on establishing whether impacts at early life stages was impacting on survival and MB advised that FRDC may be more likely to consider a TRF focussing on this aspect. JO also suggested that an ARC linkage grant may also be appropriate. MaL agreed and said that if FRDC contributed some leverage via a TRF, an ARC linkage may be a way to source funds.

7.3.5. Outcomes

General agreement among the group was reached regarding further research via a TRF with the objectives:

- 1) Sample recruitment areas to determine if SBS is more or less prevalent in juveniles;
- 2) Combine eggs and sperm in situ of bream with SBS and rear larvae at BIRC to determine if SBS is genetic; and
- 3) Monitor catches at areas known to have high incidences of SBS in order to supplement the monitoring undertaken by Assessment and Monitoring.

8 Benefits and Adoption

Recreational and commercial fishers will benefit from the knowledge that *A. australis* displaying symptoms of SBS are fit for human consumption. The literature review has shown that SBS has been found in other species and, despite the fact that no one factor has been identified as the likely cause of SBS, recreational fishers, commercial fishers and Fisheries Queensland are now aware of some of the factors that can cause the deformity.

These stakeholders are also now aware of the extent of SBS in *A. australis* in south east Queensland, with A & M data indicating that approximately 3.3% of individuals sampled between June 2009 and June 2011 showed signs of SBS. Further, these stakeholders are now aware that SBS can also be found in other species, such as whiting *Sillago* spp., mulloway *Argyrosomus japonicus*, snapper *Pagrus auratus*, luderick *Girella tricuspidata* and tarwhine *Rhabdosargus sarba*, although at significantly lower levels than those observed in *A. australis*. For the most part, the saddle-like indentation can now be attributed to SBS, rather than injuries from previous encounters with predators or fishing nets.

The project workshop was beneficial to the stakeholders that attended as it was an efficient method of discussing the issue in an informal way, allowing stakeholders to present opinions and ask questions. This was a simple and inexpensive method of

conveying information to stakeholders, who were able to have input into further research priorities regarding SBS, the primary planned outcome of the project.

9 Further Development

The project workshop held as part of this project, which included relevant stakeholders, reached the conclusion that a small-scale, inexpensive project should be initiated to answer some questions regarding the effect of SBS. The group decided a second project utilising the Tactical Research Fund should have the following objectives:

1) *Sample recruitment areas to determine the incidence of SBS in juveniles*

This would go some way to quantifying the effect of SBS on juvenile *A. australis*. Workshop participants decided that sampling at river mouths in September, when post-larval settlement occurs, would determine the incidence of SBS in the population of juveniles. It was thought that if the incidence of SBS was significantly greater in juveniles, the deformity may be causing high mortality in the younger age classes of *A. australis* (see Figure 9.1 and Figure 10.1).

Some preliminary sampling has revealed that the incidence of SBS in juvenile *A. australis* varies considerably. This, unfortunately, raises more questions than it answers. As *A. australis* at the legal size of 25cm TL have a median age of five years (Jason McGilvray, pers. comm.), could the differential rates of SBS be a function of age rather than size? If so, the ages of sub-legal SBS-afflicted fish would need to be determined via examination of otoliths. It would then be possible to follow cohorts through time to determine if some cohorts have a higher incidence of SBS or whether these cohorts have higher mortality rates as a result of SBS.

2) *Rear *A. australis* larvae at BIRC to determine if SBS is genetic.*

Given that the literature review revealed that SBS has been linked with a genetic mutation and that the affected gene can then be passed to progeny, workshop participants proposed that the eggs and sperm of spawning *A. australis* exhibiting symptoms of SBS should be combined *in situ*. Fertilised eggs could then be transferred to the Bribie Island Research Centre for rearing by experienced aquaculture technicians. By combining the eggs and sperm from a combination of adult *A. australis* with and without SBS, the likelihood of inheriting the deformity could be quantified.

These larval fish could also be used in experiments to determine if SBS-afflicted fish are more susceptible to predation than normal fish. This would also determine if Möller and Anders (1986) were correct in hypothesising that “the prevalences [sic] in malformed fish should decrease as the age group gets older”.



Figure 9.1: Juvenile *A. australis* caught by A & M field staff sampling in the Noosa River. Note the characteristic deformity of the dorsal fin in the top fish.

3) *Monitor catches at areas known to have high incidences of SBS*

Given that project staff reported that 5-10% of *A. australis* caught during a SQAFCO competition on the Gold Coast Broadwater had SBS, workshop participants agreed that sampling be undertaken in order to supplement the sampling undertaken by Assessment and Monitoring. Workshop participants agreed that areas where the incidence of SBS is relatively high, such as the Gold Coast Broadwater and Jumpinpin, should be the focus of targeted sampling in order to increase sample sizes in these areas.

10 Planned Outcomes

1) *Provide information regarding the incidence of SBS in Queensland, the species affected and the potential range of incidence*

Using data collected by the Assessment and Monitoring Unit of Fisheries Queensland, project staff were able to determine that approximately 3.3% of *A. australis* caught by recreational and commercial fishers exhibited symptoms of SBS. *A. australis* exhibiting symptoms of SBS were found mostly in the bays and estuaries of southern Queensland, with high incidences on the Sunshine Coast.

Anecdotal evidence from commercial and recreational fishers suggested that, along with *A. australis*, SBS can be found in other species, such as whiting *Sillago* spp., mulloway *Argyrosomus japonicus*, snapper *Pagrus auratus*, luderick *Girella tricuspidata* and tarwhine *Rhabdosargus sarba*, although at significantly lower rates of incidence. Anecdotal evidence from commercial fishers suggests that SBS in *A. australis* has increased in recent years, while, at the same time, recreational anglers targeting spawning aggregations on the Gold Coast and at Jumpinpin have noted higher incidences of the deformity. The analysis of the A & M data indicated that the incidence of SBS did not change significantly from 2009 to 2010.



Figure 10.1: SBS in juvenile *A. australis* caught in the Runaway Bay (Gold Coast) canal system in December, 2012. Note the size of these individuals. Both of these fish would have been spawned in the previous winter and are likely 3-4 months old. Photos courtesy of Dr. Barry Pollock, Sunfish Queensland.

2) *Provide a literature review detailing the status of Saddleback Syndrome research worldwide*

The literature review conducted by project staff revealed that SBS has been the subject of very few scientific journal and grey literature articles. The literature revealed that SBS has occurred in both natural and cultured populations of fish in Europe and in North America. For the most part, the authors of these studies failed to identify the specific cause of the deformity. In cultured populations, stocking density, genetics and feed have been nominated as probable causes of SBS.

Although pollution has been cited as a cause of SBS in wild populations studied overseas, a Queensland Health analysis of samples provided by recreational and commercial fishers revealed that *A. australis* exhibiting symptoms of SBS contain acceptable levels of chemicals such as Organophosphates and Organochlorines. Further, these samples were found to have had acceptable levels of heavy metals such as arsenic, with the report stating that the levels of total (inorganic and organic) arsenic in the flesh of *A. australis* exhibiting SBS symptoms not considered “unusually high for marine fish”.

The genetic transference of a mutated gene that causes SBS may account for the perceived increase in SBS observed in *A. australis*. The mutation of a gene causing SBS may occur, due to an unknown factor or combination of factors, which is then passed on to the progeny of affected spawners. The author excluded inbreeding as a factor causing SBS as the experimental fish used in experiments were spawned from the same fish. In contrast, another author stated that a lack of genetic diversity in a semi-enclosed estuary may have caused deformities.

Further, some authors suggest that SBS can cause swimming difficulties in some species, which may lead to higher levels of mortality. This is of particular relevance in wild populations, where predation of deformed individuals may result in significant increases in natural mortality.

3) *Provide a stakeholder workshop to determine further research priorities*

The stakeholder workshop was an efficient method of transferring knowledge of SBS to stakeholder representatives. The workshop was designed to formulate research priorities regarding SBS after the participants had been informed of likely causes of SBS, through the literature review, and of the extent of SBS in south east Queensland through the analysis of A & M data. Sunfish Queensland are adamant that a large-scale project be initiated to determine the exact causes of SBS. However, they are also aware of the low likelihood of such funding and have given their support for another small-scale project. The objectives of this funding are detailed in Chapter 9 on page 35.

11 Conclusions

This project has described the extent of SBS in Yellowfin Bream in south east Queensland. It has also reviewed the scientific literature in order to collate information relating to the incidence and possible causes of SBS. This information was then used at a workshop convened with the aims of assessing the need for further research into the causes of SBS in Yellowfin Bream.

The analysis of the data collected by Fisheries Queensland's Assessment and Monitoring Unit indicates that, on average, approximately 3.3% of Yellowfin Bream caught in south east Queensland exhibit symptoms of SBS. Some recreational fishing representatives attending the project workshop were doubtful of the results from the analysis of the A & M data, suggesting that the incidence of SBS in Yellowfin Bream caught from the Gold Coast Broadwater (0.2%) and Jumpinpin (1.84%) were underestimated in the current study. Project staff also confirmed this with 5-10% of Yellowfin Bream caught during a fishing competition exhibiting signs of SBS. Currently, A & M collect representative samples of south east Queensland commercial and recreational Yellowfin Bream catches in order to provide information for stock assessments. As such, to ensure representative sampling of SBS, it would be prudent to target sampling at areas like the Gold Coast Broadwater and Jumpinpin, where anecdotal evidence suggests the incidence of SBS is highest.

SBS has been shown to affect several species in both natural and cultured populations of fish. The scientific literature suggests that pollution and a lack of genetic diversity may be causative factors affecting the incidence of SBS in natural populations. Further, in cultured populations, rearing conditions are the most common cause of SBS cited,

although no author has identified a single factor or suite of factors responsible. Temperature, oxygen levels, nutrition and stocking density have been suggested by authors who observed SBS in cultured fish populations as possible causative factors of SBS.

The participants of a project workshop, comprising representatives of relevant stakeholders, agreed that a small-scale, inexpensive project be submitted for consideration through the Fisheries Research and Development Corporation's Tactical Research Fund (TRF). The objectives of this funding would be to determine if SBS in Yellowfin Bream is passed on to progeny, assess the incidence of SBS in juvenile Yellowfin Bream and to supplement sampling by Fisheries Queensland by targeting areas known to have a high incidence of SBS such as Jumpinpin.

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13 Appendix 1: Intellectual Property

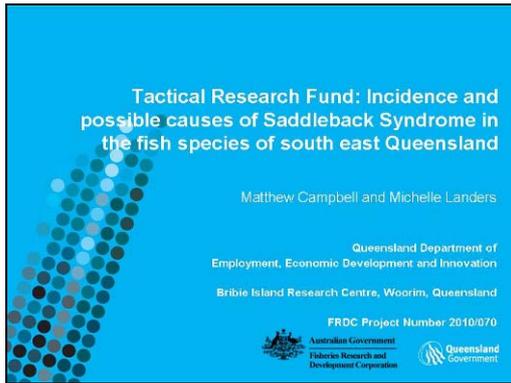
The information generated by this research is in the public domain and is, therefore, not subject to intellectual property considerations.

14 Appendix 2: Project staff

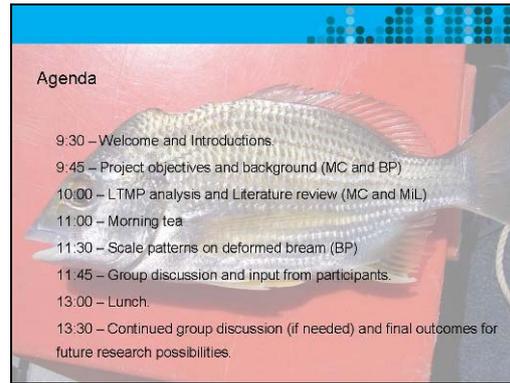
Matthew Campbell, Queensland Department of Agriculture, Fisheries and Forestry
Michelle Landers, Queensland Department of Agriculture, Fisheries and Forestry

15 Appendix 3: Workshop presentation

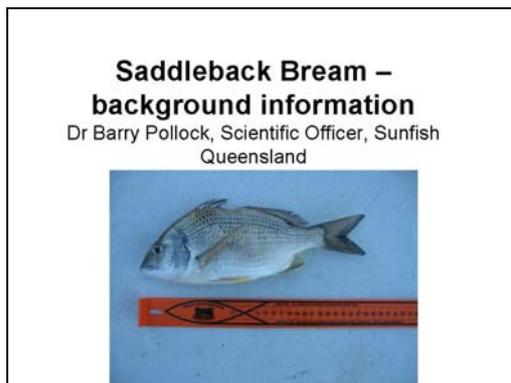
Below are the slides used during the project workshop conducted at the Bribie Island Research Centre on 18 January 2012.



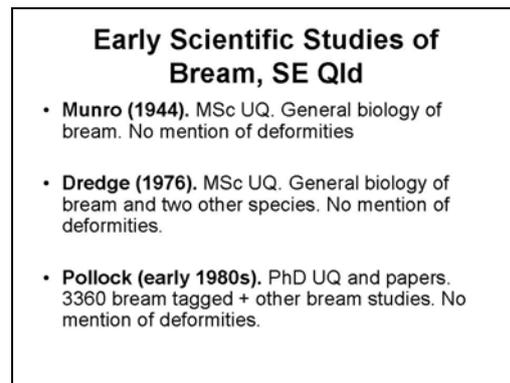
Slide 1



Slide 2



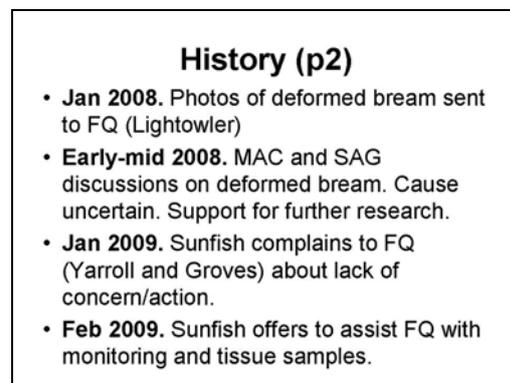
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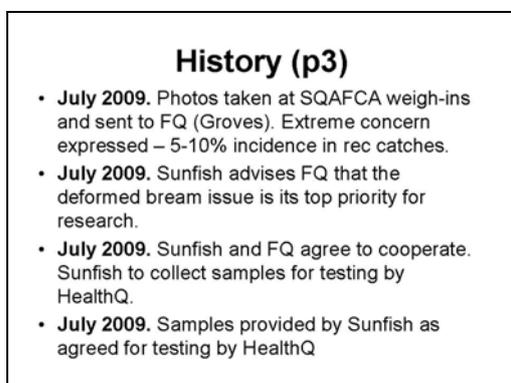
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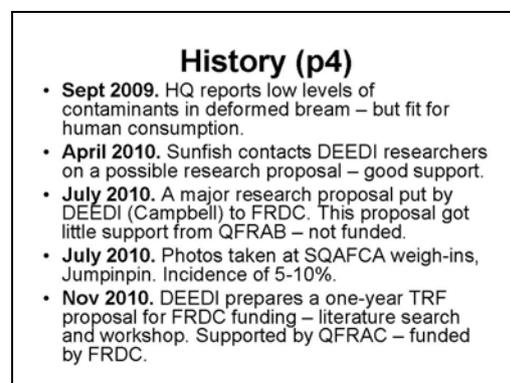
Slide 5



Slide 6



Slide 7



Slide 8

History (p5)

- **June-July 2011.** Photos taken at QAFCA and SQAFCA weigh-ins at Southport and Jumpinpin. Deformity incidence 5-10%.
- **Dec 2012.** Workshop on deformed bream.

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QAFCA club weigh-ins



Slide 10

Some points about weigh-ins

- **Accuracy and consistency of recording angler catches**
- **Bream targeted in June-July – at night**
- **Minimum size often set above legal size – penalties for non-compliance**
- **Few club anglers bag out on bream**
- **Saddleback not directly recorded**

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Slide 12



Slide 13



Slide 14

Severity of the saddleback deformity and location



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Slide 17



Slide 18



Slide 19



Slide 20

Importance of Bream for recreational fishing

- Bream is second only to Whiting in terms of the numbers of fish taken by recreational fishers in Qld.
- Bream comprises some 25% of the total recreational fishing catch by number in Qld.

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Media on Deformed Bream

- Courier Mail 18 Sept 2010 – detailed article by Brian Williams
- Photographs, articles and notes in Sunfish Magazines, 2008-2011.

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Deformed Bream

- What is the cause of the “saddleback” deformity?
- What is the overall impact on the bream population and fishery?
- Are deformed bream safe to eat?
- How can recreational fishers and their organisations cooperate with Government and other stakeholders?

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Overview - Definition

Saddleback Syndrome (SBS)

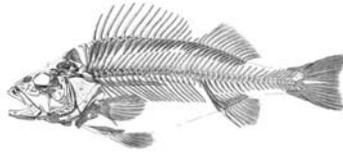
An abnormality of the dorsal fin and profile, lacking one to all of the hard spines, accompanied by shape, number and position abnormalities of associated pterygiophores - Koumoundouros et al. (2001).



Slide 24

Overview - Definition

An abnormality of the dorsal fin and profile, lacking one to all of the hard spines, accompanied by shape, number and position abnormalities of associated pterygiophores - Koumoundouros et al. (2001).



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Overview



- FRDC-funded Tactical Research Fund
 - Project aimed at addressing issues in the short term
- Co-funded by DEEDI
- Final report due 30 June 2012
 - Draft due at end of March
- Primarily concerned with yellowfin bream but aware other species are affected
 - Snapper, tarwhine and luderick

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Overview



- Yellowfin bream
 - Important fish species in Queensland
 - Commercial catch 165t in 2009/10
 - Rec catch in the millions of individuals per year
 - endemic to coastal and estuarine waters between Townsville and Victoria
 - spawning occurs in winter months
 - At river mouths, bar entrances
 - protandrous hermaphrodites
 - smaller fish usually have functional male gonads and larger fish often having functional female gonads

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Overview



[Queensland health report](#)

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Objectives



- Quantify the extent of Saddleback Syndrome (SBS) in Queensland using existing databases
- Review National and International published and grey literature in order to document the occurrence of Saddleback Syndrome and its causes
- Convene a workshop of stakeholders to present the results of the database searches and literature review

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Objective 1: LTMP database analysis



- Part of routine sampling of yellowfin bream since 2009
- Fishery-dependent
 - Commercial
 - Recreational
 - Charter
- SBS quantified as a proportion of total catch
- 629 individual catches, 5728 fish sampled
 - 189 (3.3%) exhibited signs of SBS

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Objective 1: LTMP database analysis



Accumulated analysis of deviance

Change	d.f.	deviance	Mean deviance	Deviance ratio	Chi sq prob
Location	8	92.9997	11.6250	11.62	<0.001
Habitat	3	21.0842	7.0281	7.03	<0.001
Year	2	0.2576	0.1288	0.13	0.879
Residual	613	304.1939	0.4946		
Total	628	418.5354	0.6665		

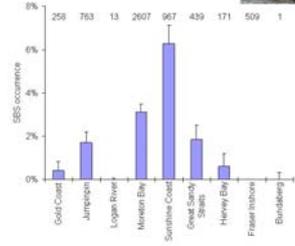
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Objective 1: LTMP database analysis



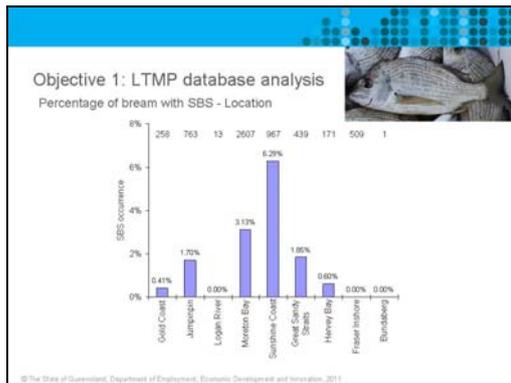
Percentage of bream with SBS - Location



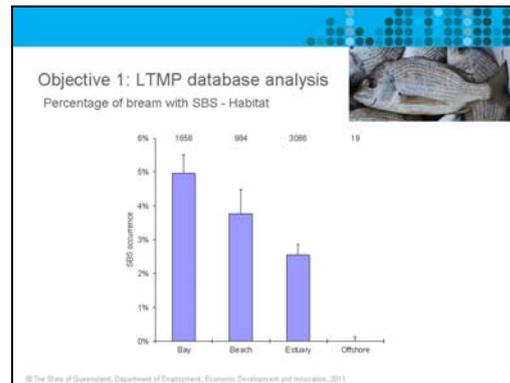
Location	Sample Size	SBS Occurrence (%)
Gold Coast	258	~0.5
Juncopion	753	~1.5
Logan River	13	~0.1
Moreton Bay	2607	~3.0
Sunshine Coast	957	~6.5
Great Sandb. Straits	439	~2.0
Hervey Bay	171	~1.0
Fraser Inshore	509	~0.2
Bundaberg	1	~0.0

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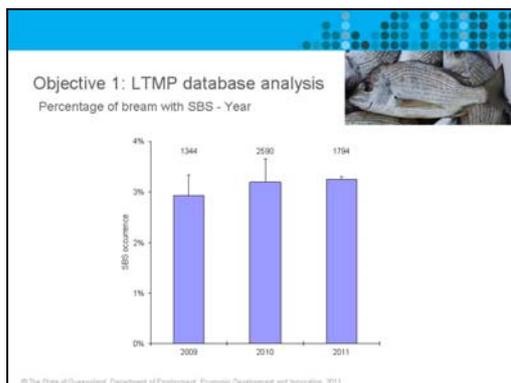
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- Objective 1: LTMP database analysis
- Highest incidence occurred at Teewah Beach
 - 30 out of 400 individuals
 - Sunshine Coast had highest incidence 6.2%
 - Noosa River/north shore
 - Mooloolah River
 - Maroochy River
 - Moreton Bay also high 3.13%
 - Includes Brisbane River and Pumicestone Passage

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- Objective 1: LTMP database analysis
- Do we need to continue measuring incidence of SBS?
 - Is targeting of specific areas necessary?
 - What is A&M's capacity to collect more information?

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- Objective 2: Literature review
- Very few papers on the subject in the scientific literature
 - Confusion between SBS and Saddleback-like Syndrome
 - Found to be present in both cultured and wild populations
 - Several causative factors possible
 - No one single factor responsible. Combination of two or more??
 - Pollution
 - Genetics
 - Environment

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Objective 2: Literature review

Tave et al. (1983)

- when the dorsal or anal fins were missing the associated pterygiophores were also absent
- Individuals lacking most or all of the dorsal fin had trouble maintaining upright equilibrium
- No noticeable effect on swimming behaviour of individuals lacking anterior half of the dorsal fin
- Culling all fish with SBS will result in elimination of the dominant gene in a single generation

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Objective 2: Literature review

Valente (1988)

- Incomplete dorsal fin formation in crucian carp *Carassius carassius*
- Anterior or posterior parts of the dorsal fin absent
- No factors identified as to cause
- Author suggests that their study did not provide evidence that such abnormalities originate through unfavourable environmental conditions during embryonic development

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Objective 2: Literature review

Browder et al. (1993)



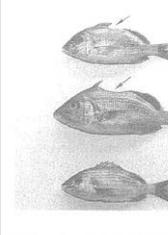
- 10 fish species studied including 3 Sparids
 - Pinfish, sea bream and porgy
- incomplete dorsal fin with one or more missing or stunted dorsal spines, sometime accompanied by a depression in the upper body profile at the site where the spines are missing
- may have arisen through the environmental induction of mutation at some labile genetic focus shared by all fish groups
- May have been PCB's or heavy metals

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Objective 2: Literature review

Browder et al. (1993)



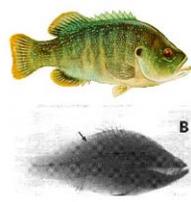
- populations have declined to the extent that genetic variability has been substantially reduced
- Semi-enclosed sub-tropical estuary
- authors suspected that in the one location a range of deformities were caused by the same or a group of environmental contaminants common to all affected species
- Failed to identify a single cause

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Objective 2: Literature review

Lemly (1993)



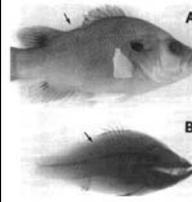
- Many species affected with skin, eye, jaw and fin abnormalities
- Green sunfish *Lepomis cyanellus* most likely affected by SBS
- three hard dorsal spines and five supporting pterygiophores absent
- Freshwater lake adjacent to coal-fired power station

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Objective 2: Literature review

Lemly (1993)



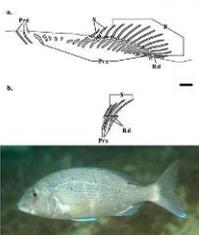
- Author suggests elevated levels of selenium from settlement ponds from power station
- Selenium accumulates in gonads resulting in a high percentage of abnormal larvae
- Selenium levels were lethal to adults, eliminating predation of abnormal fish
- What other contaminants present?

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Objective 2: Literature review

Koumoundouros et al. (2001)



- SBS and caudal fin deformities were related in cultured *Dentex dentex*
- SBS originated in early larval stage at the posterior tip of the notochord and the primordial marginal finfold
- Evident from the 7th post-feeding day
- SBS found to be caused by rearing, extensive vs. semi-extensive (PL)

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Saddleback and Sea Bream

Aquaculture

September 2011 (2011) 285-301
www.elsevier.com/locate/aqua-online

The effect of rearing conditions on development of saddleback syndrome and caudal fin deformities in *Dentex dentex* (L.)

G. Koumoundouros^{a,*}, P. Divanach^a, M. Kentouri^{a,b}

^a Institute of Marine Biology, of Crete, P.O. Box 7152, 71003 Iraklio, Crete, Greece
^b Biology Department, University of Crete, P.O. Box 2615, 26109 Rethym, Crete, Greece

Received 23 October 2010; received in revised form 28 January 2011; accepted 1 February 2011

ABSTRACT

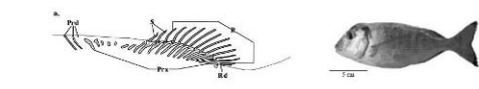
The development of saddleback syndrome and of caudal fin deformities in *Dentex dentex* (Linnæus, 1758) was compared under two rearing methods, extensive (E) and semi-extensive (S).

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Sea Bream - results

	Extensive	Semi-Intensive
• Saddleback		
Larval rearing (24 dph)	0%	4.0 - 4.2%
Weaning (51 dph)	0%	3.2 - 3.4%
• Survival	4.1% (1600)	5.2% (8300)



Figures reproduced from: Kottelat A (2006) Journal of Animal and Veterinary Advances 1(2):200-205; Koumoundouros et al (1998) Marine Biology 133:611-622

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Extensive vs Intensive

- Extremes of the spectrum of system operation
- Vary in "input" levels
- Extensive approximates "natural" conditions



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Sea Bream - methods

1. Egg incubation/yolk sac larvae (7 days) 
2. Larval rearing
 - a. Stocking
 - Extensive 0.5 larvae/L; Semi-intensive 2 larvae/L
 - b. 1st feeding (10 days)
 - Extensive – “natural” bloom from local seawater
 - Semi-intensive – phytoplankton & enriched rotifers
 - c. Feeding (7 days) – *Artemia* 
3. Weaning (27 days) 

Figures reproduced from: Bop 73, Jønting et al 1995 Fisheries Research 24:91-97, Kouskouzidou et al (1999) Marine Biology 135:963-977
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Sea Bream - implications

- What was different?
 - stocking density (S-I 4X higher)
 - 1st feeding
 - prey species, prey abundance, phytoplankton species
 - ? water chemistry
 - NH₃ (E<S-I); NO₂ (E>S-I)
 - ?? microbial fauna ?? minerals/micronutrients
- What about the timing?
 - Onset after hatch, prior to metamorphosis
 - ? Not arising during embryonic development

Figures reproduced from: Jønting et al 1995 Fisheries Research 24:91-97.
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Objective 2: Literature review

Neofytou (2006) 

- Cultured shi drum *Umbrina cirrosa* in semi-intensive system
- Similar to our mulletway
- Abstract from an aquaculture conference
- No information regarding possible causative factors
- Dorsal spines affected but pterygiophores present and deformed??

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Objective 2: Literature review

Koumoundouros et al. (2008) 

- (a)  – SBS found in a single sea cage cultured parrotfish *Sparisoma cretense*
- Aegean Sea off Greece
- (b)  – No causative factors identified
- Could be a problem for this species as dorsal fin displays are part of courtship

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Objective 2: Literature review

Korkut (2009) 

- SBS found in gilthead sea bream *Sparus aurata*
- Sea cages off Turkey
- No causative factors identified
- Could be factors such as nutrition, genetics, abiotic factors
- Nutritional phosphorus and micronutrients such as vitamins A, C and D can cause skeletal deformities

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Objective 2: Literature review

Sfakianakis et al. (2003) 

- Saddleback-like Syndrome found in white sea bream *Diplodus sargus*
- 22 cultured fish in Greece
- V-shaped dorsal profile
- Spines and pterygiophores present but deformed or dislocated
- Skeletal development takes place normally and causative factor acts later on

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Objective 2: Literature review

Setiadi et al. (2006) 

- (a)  – Saddleback-like Syndrome found in hatchery-reared red spotted grouper *Epinephelus akaara* in Japan
- (b)  – Deformities of the first to fourth dorsal proximal radials, neural spines and disposition of the dorsal spines which cause depression in the external dorsal body
- not associated with the lack of dorsal distal radials, spines, rays and pterygiophores

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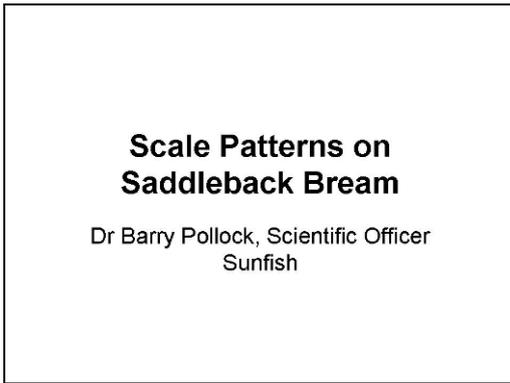
Objective 2: Literature review

Akashi and Abe (2011) 

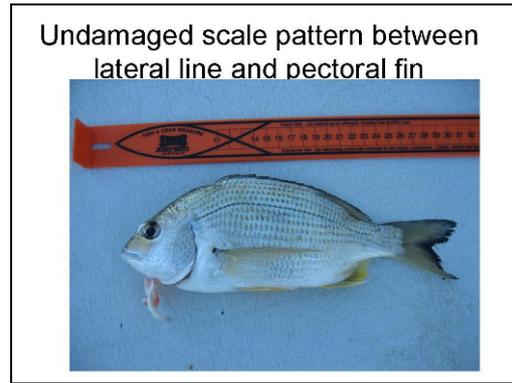
- Saddleback-like Syndrome found in hatchery-reared red spotted grouper *Epinephelus akaara* in Japan.
- Deformities of 1st through 5th pterygiophores
- Dorsal spines present but deformed

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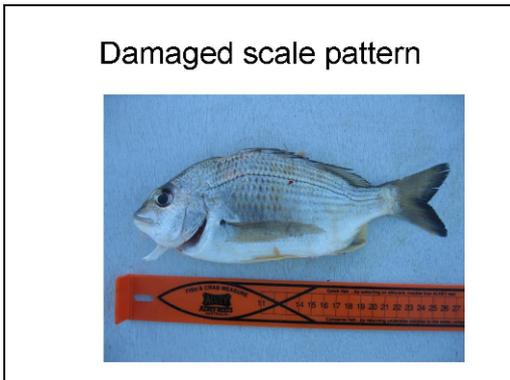
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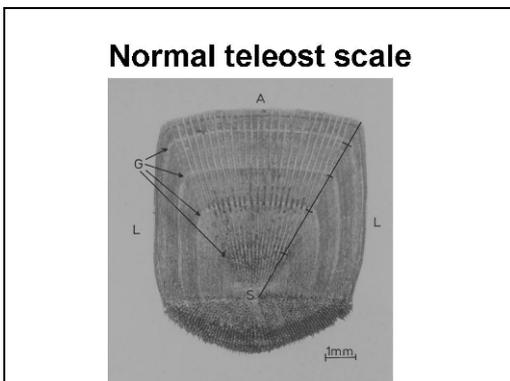
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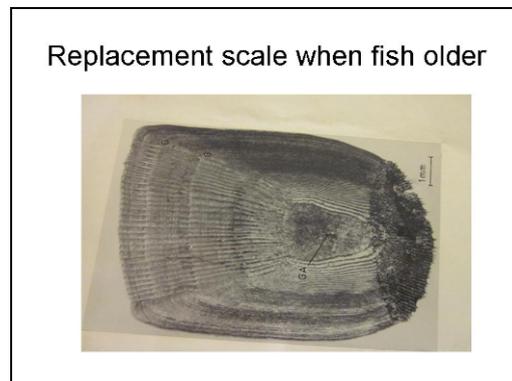
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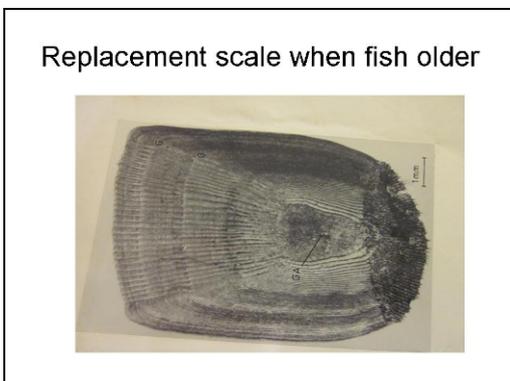
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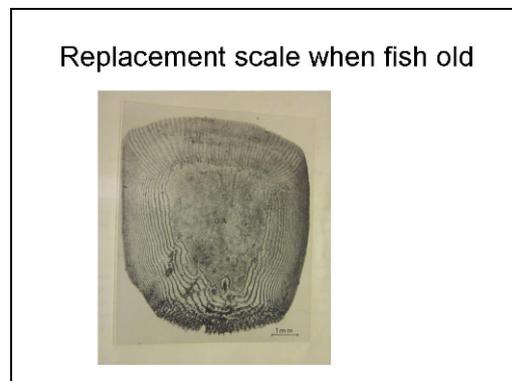
Slide 61



Slide 62



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Scale Pattern Issues

- **Why are scale patterns damaged on some, but not all, saddleback bream?**
- **Is scale damage directly associated with the saddleback deformity?**
- **At what age/size of the fish are the scales damaged?**
- **Further research needed on scale pattern damage in saddleback bream**

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Objective 2: Literature review

Conclusions

- No single causative factor
- Most likely a combination of several factors including (but not limited to):
 - Nutrition
 - Pollution
 - Likely pollutants in wild populations?
 - Genetics
 - Density of larvae (not restricted to aquaculture??)
 - Food?
 - Environment
 - Temperature, salinity, etc

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Objective 2: Literature review

Conclusions

- Is Saddleback-like Syndrome the manifestation of SBS in species other than Sparids?
- Why are Sparids affected most in Queensland?
 - *Acanthopagrus australis*, *Dentex dentex*, *Diplodus sargus*
 - Spawning areas
 - Pollution?
 - Density?

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Discussion

- Possible causes in yellowfin bream?
 - Genetics
 - Pollution
 - Environmental
 - Disease/parasites
- What other species show signs?
 - luderick
 - snapper
 - tarwhine?
 - whiting

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Discussion

- Is further research necessary?
 - Managers
 - Sunfish
 - Dr. Diggles, Dr. Landos
- What should be done regarding further research?
- What are the costs associated with more research?
 - [proposal](#)

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16 Appendix 4: Saddleback-like Syndrome

Saddleback-like Syndrome may have been identified as early as 1963 when Welch et al. (1963) described a rainbow trout (*Oncorhynchus mykiss*) that "...showed some unusual skeletal characteristics of the second dorsal fin. The pterygiophores of the second fin were bunched together and not aligned with the fin rays". The photograph published as part of the article is lacking in resolution and it is, therefore, difficult to determine if Saddleback-like Syndrome is present. The authors failed to identify the deformity by

name, although references were cited giving explanations for such deformities occurring due to radiation exposure or high temperatures.

Saddleback-like Syndrome was identified in *Diplodus sargus* and described as the appearance of a V-shaped dorsal profile externally, with a depression of the body line, fin spines and rays (Sfakianakis et al., 2003). Saddleback-like syndrome is identified by these authors as differing from SBS by "...being associated with (a) lack of dorsal fin elements, characterised by a concurrent deformation of both the dorsal fin and the ventral column, where each pterygiophore was fused with its underlying neural process". It was also noted that in Saddleback-like Syndrome of *D. sargus* there was no association between notochord and finfold abnormalities that are present in SBS as identified by Koumoundouros et al. (2001). Sfakianakis et al. (2003) found that pterygiophores were present, however they were deformed and dislocated in the affected area. This study also showed that in affected specimens, misalignment of the vertebral column caused by kyphosis and lordosis was evident as was fusing of each pterygiophore. It was assumed by the authors that the skeleton develops normally before the syndrome's causative factor acts.

Saddleback-like syndrome has been misidentified previously as SBS in papers by Korkut et al. (2009) and Setiadi et al. (2006). These authors erroneously refer to the deformity reported by Sfakianakis et al. (2003) as SBS, rather than Saddleback-like Syndrome. Although Korkut et al. (2009) cite Sfakianakis et al. (2003), the samples shown in photographs published as part of this article show SBS-afflicted *Sparus aurata*.



Figure 16.1: Saddleback-like syndrome in a juvenile tarwhine, *Rhabdosargus sarba*, as reported by Bateman (2010).

Setiadi et al. (2006) found that in hatchery-reared red spotted grouper, *Epinephelus akaara*, “SBS affects the deformities of the first to fourth dorsal proximal radials, neural spines and disposition of the dorsal spines which cause depression in the external dorsal body”. However, given that these authors found that SBS in *E. akaara* was “not associated with the lack of dorsal distal radials, spines, rays and pterygiophores”, it is difficult to determine whether the deformity reported was SBS. Another limitation with this study was that fish with multiple deformities were excluded despite Tave et al. (1983) stating that in extreme cases of SBS pectoral, pelvic and anal fin deformities can also occur. Setiadi et al. (2006) provide X-rays of *E. akaara* with Saddleback-like Syndrome showing pterygiophores present along with dorsal spines in the location of the deformity.

Similarly, Akashi and Abe (2011) reported on what the authors referred to as Saddleback Syndrome in hatchery-reared *E. akaara*. As with the study by Setiadi et al. (2006), Akashi and Abe (2011) published X-rays of individuals exhibiting a deformity similar to SBS; as reported by Setiadi et al. (2006), the pterygiophores and dorsal spines were present.

The articles by Akashi and Abe (2011) and Setiadi et al. (2006) both report on Saddleback Syndrome in *E. akaara*, yet by the definition used by Sfakianakis et al. (2003), these deformities appear to be Saddleback-like Syndrome. It is difficult to determine if the specimens in each of these studies were, indeed, afflicted with Saddleback-like Syndrome or whether the deformity associated with SBS manifests differently in species of the genus *Epinephelus*.

Bateman (2010b) published a photograph in the Sunfish magazine depicting a tarwhine, *Rhabdosargus sarba*, afflicted with Saddleback-like Syndrome. Figure 16.1 is reproduced from the magazine and clearly shows that the dorsal spines are present, excluding the deformity as SBS as defined in the current study.

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