Development of a Quality Index for Australian Seafoods

Principal Investigator and Editor: M. Boulter

Author's: A. Bremner, S. Poole, F. Kow, J. Weerasinghe, H. Williams.

Australian Government

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Curtin University of Technology

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OBJECTIVES:

1. To develop quality index (QI) schemes for the initial 6 nominated species – Snapper, Tiger Flathead, Black Tiger Prawns, Goldband Snapper, Atlantic Salmon and Sea Mullet
2. To validate the initial 6 QI schemes and investigate their application in appropriate commercial supply chains
3. QI Manual produced on 6 validated QI schemes
4. Develop QI schemes for 8 additional species - King Prawns, Scaly Mackerel, Silver Warehou, Pink Ling, Barramundi, Yellowtail Kingfish, Saddletail Snapper and Redthroat Emperor
5. Updated QI manual with 14 species produced

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

The main output from this project is the updated QI manual with QI schemes for 14 important commercial species of Australian seafoods. Thus the main outcome to date is that the industry can now be provided with, and trained in these QI schemes. Since these schemes cover a broad range of species types and characteristics, harvested by different methods from different areas and depths, it demonstrates that the approach is widely applicable and that it can be used by industry and scientists with confidence. It can also be used as a template for the development of QI schemes for other commercially important species.

The QI scheme provides a numerical index that, plotted on a straight line shows the rate of change with storage in ice at 0°C. Any batch of fish can be evaluated and the resulting score equated to equivalent days in ice. From this, any business can readily calculate the elapsed shelf-life and the remaining shelf-life, by appropriate criteria, under a range of storage temperatures. This allows for decision making about grading, setting product standards - such as only purchasing at a QI below 5 for premium products - for remote buying sight unseen and for separation into different product streams. It also has a role in trouble shooting along the distribution chain to ensure good temperature control, and in comparison of boats, skippers, suppliers, transporters and seasonal variations. Companies who adopt the practice can gain these and other benefits as it provides certainty and control.

The list of planned outcomes, described below, can now become reality as the advantages of the technique become progressively known and adopted.

- As a tool for setting clear guidelines, instructions and product specifications (if required) to buyers and suppliers;
- To open up greater potential for remote buying, electronic trading and auctioning;
- To improve buyer confidence in the product and improve marketing efficiencies in the supply chain; as a means of developing better price-quality information;
- For conflict resolution as it provides unbiased quality scores readily understood by all parties;
- As a way of providing a very good indication of remaining shelf-life;
- As a means of defining acceptable shelf-life for different contexts and uses;
- As a tool for evaluating performance of individual suppliers and catchers;
- As a check on transport conditions and procedures and in trouble-shooting;
- To reduce wastage of spoilt produce;
- As a tool for 'educating' retailers and supermarkets; and
- As a formal technique in training and educational courses and workshops at all levels.

As the QI manual has only recently been produced and has yet to be rolled out to industry uptake of the technique is currently low. However, Sydney Fish Market has used the technique to set freshness standards in product specifications for raw materials to be used in the range of Market Pride products. The outcome for the consumer is the benefit that it makes it possible to buy branded reliable product that is uniformly at the same standard.

The Coff's Harbour fishermen's cooperative, who have been given some training in freshness assessment and the Quality Index method through this project, have started branding fish with no QI demerits as 'Coff's Premium' to distinguish it from other product in the marketplace.

Estimating the quality characteristics of seafood has been very much a matter of debate, but now a systematic approach called the Quality Index (QI) has taken the mystery and controversy out of it. Supported by the Fisheries Research and Development Corporation (FRDC) and Sydney Fish Market (SFM) the QI project has now delivered a Quality Index Manual of standard schemes for 14 important Australian species of seafood. This is the main and continuing output of the project. Further schemes to bring the total up to 50 species are planned within the Australian Seafood Cooperative Research Centre (Seafood CRC).

Seafoods invariably deteriorate steadily and irreversibly after catch so that they gradually lose their desirable colour, aroma, flavour and textural properties. These changes seem to be barely detectable on a day-to-day basis but they add up to a poorer product.

The QI scheme has been designed to be the ideal for estimating these changes as it provides a numerical estimate in a linear response from point of catch, through the storage period to the end of commercial shelf-life.

In essence, the index is obtained by visual, sensory and tactile examination of the seafood and by giving demerit point scores to a range of characteristics such as the overall appearance, eye shape and colour, gill colour, slime, looseness of scales, appearance of belly and odour. These are commonly used characteristics in many schemes but in QI they are scored on restrictive scales from zero up to 3 so that no single characteristic dominates. The scores are then summed to provide a total QI which is plotted against the storage period expressed in equivalent days in ice. This overcame the problems with alternative methods which were not systematic, or ignored important parameters, or gave greater weight to one factor over another, or were descriptive in nature.

The key factor controlling rate of change is temperature, and work funded with Fishing Industry Research Trust Account (FIRTA) grants (FIRTA was a forerunner of FRDC) over 25 years ago, demonstrated that the rate of change in seafood between minus 1.5^{o}C and about +15^{o}C could be calculated by a simple equation. The relationship led to the development of the concept of icedays (or icehours) so that any time period and temperature in the range up to 15^{o}C could be converted to their equivalent days in ice. Thus if the temperatures of the seafood over its storage history were known then this history could be converted to Icetime expressed in days or hours, as distinct from clocktime. So, catches with different histories could be converted to the one standard time basis – Icetime- and shelf-lives and quality grades could be expressed in these same standard terms.

From its initial development in Tasmania, the Quality Index Method is now the method of choice in research and industry, particularly in Europe. In 2002 an FRDC Working Party (project 2002/243) recommended revision and extension of the QI scheme to the currently important commercial species.

Initially, six species were chosen Atlantic Salmon (*Salmo salar*), cooked Black Tiger Prawns (*Penaeus monodon*), Goldband Snapper (*Pristopomoides multidens*), Sea Mullet (*Mugil cephalus*), Snapper (*Pagrus auratus*) and Tiger Flathead (*Neoplatycephalus richardsoni*) to cover a wide geographic range, different harvest methods and a range of fish types to show the broad applicability of the technique. These schemes were published in a QI manual in 2006.

The project moved on to a second phase in which schemes for another 8 species namely Barramundi (*Lates calcarifer*), cooked King Prawns (*Melicertus plebejus*), Pink Ling (*Genypterus blacodes*), Redthroat Emperor (*Lethrinus miriatus*), Saddletail Snapper (*Lutjanus malabaricus*), Scaly Mackerel (*Sardinella limuru*), Silver Warehou (*Seriolella punctata*) and Yellowtail Kingfish (*Seriola lalandi*) were completed and an updated QI manual incorporating all 14 species was produced in 2009.

The work was carried out by researchers from Queensland, Victoria, Western Australia and Tasmania supported by the Quality Assurance staff at SFM in New South Wales. It involved training a panel at each location and constructing a QI scheme for each species that evaluated the changes in the various attributes of each species such that the scores were linear over the storage period (at 0^{o}C) up to over 20 days in some cases. Photographs were taken throughout the storage trials to act as an aid and for publication in the QI manual. The panels then used the final schemes to evaluate two, or three, separate catches of each species. The results were tested statistically for agreement and plotted as standard graphs of QI score versus equivalent days in ice. Final sets of typical photographs that illustrated changes in the important attributes during storage were collated for the QI manual.

The key to setting up a QI scheme is to have fish available (in season and being caught) and to obtain them soon after they are caught, allowing time for them to be landed and brought to one of the centres as speedily as practical at a time when the panel is available. These logistics could not always be met at the planned time but were eventually overcome by persistence. Originally, Spanish Mackerel was in the list and a trial scheme was developed but had to be abandoned as, although they were in season, insufficient numbers were being caught.

Final schemes for Snapper and Goldband Snapper were tried out in commercial premises and presentations have been made to industry meetings, including SSA, at international and Australian Conferences and have been part of presentations on several occasions. The technique was also used to develop a scheme for Australian Sardines that has been used to good effect in FRDC Project 2002/236 'Optimising at-sea post-harvest handling procedures for the pilchard (*Sardinops sagax*)' in noting differences between handling and temperature treatments.

The QI schemes are designed to be useable by all partners in the seafood supply chain from fishermen to retailers. They can also be used by researchers and consultants to assist industry in improving supply chain performance.

Sydney Fish Market has used the technique to set freshness standards in product specifications for raw materials to be used in their range of Market Pride products. The outcome for the consumer is the benefit that it makes it possible to buy branded reliable product that is uniformly at the same standard. The Coff's Harbour fishermen's cooperative, who have been given some training in freshness assessment and the Quality Index method through this project, have started branding fish with no QI demerits as 'Coff's Premium' using gill tags to distinguish it from other product in the marketplace.

Further input is now required through some mechanism, potentially the Oceanwatch Seanet extension officers, to disseminate the QI scheme and manual to relevant persons in industry to facilitate the further adoption of the tool by the Australian Seafood Industry.

KEYWORDS: Quality Index, post-harvest changes, chilled storage, Australian seafoods

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Dr Allan Bremner is thanked for all the tireless work he has put into this project over the years, including helping draft the initial project application, various versions of the QI manual and this final report.

1. BACKGROUND

1.1 General

A myriad of various schemes for grading seafoods and for, ostensibly, evaluating their 'quality' and 'freshness' have been developed over the years in different countries, by different research organizations and in different companies, cooperatives and markets. Individual companies and individual buyers have used their own schemes most of which were never formally recorded but passed on by practice and word of mouth. Most of these informal approaches did the job well enough, but the information was never in a form in which it could be passed on outside of the immediate circumstances and be recorded in ways that were both convenient and in which the results could be immediately understood. Few developers considered the characteristic that a scheme should possess beyond meeting the immediate use.

When a scheme is developed, consideration must be given to why it is required, what advantages it has over existing schemes, its accuracy and precision, whether it fits a need, what it will be used for, the circumstances in which it will be used, its robustness in different hands, its adaptability to changing circumstances, its potential in meeting future requirements, its communication value, its ease of use, its cost, its likelihood of adoption, its consistency with known theory and thus its predictive capacities.

The Torry Research Station in Aberdeen, Scotland was a leading technology institute that did consider many of the aspects and they developed a scheme which became widely adopted (Shewan et al. 1953) known as the Torry scheme. The main scheme was developed to deal mainly with cod and related gadoid whitefish but others were also developed for fatty fish.
The scheme was based on the results from their studies that during chilled storage fish went through a number of changes that could be broken down into discrete steps to which descending scores were given as the fish was stored from catch (score of 10) through to rotten (score 1) with 4 being about the limit at which it could reasonably be acceptable for human consumption. The major deficiencies in this scheme were that:-

- considerable training by experts was required for the panellists
- the schemes were not very applicable to the wide variety of orders and species used in commerce and as food by much of the Southern hemisphere and most of Asia,
- it is more logical to estimate demerit points as it is changes away from the ideal (recently caught fish) that are measured and observed, and
- there was no evidence that it gave the correct result when the temperature of the fish was not held constant at 0°C (this is very often the case) i.e. the scheme itself has temperature kinetics of change that are different from that of the fish itself and it may under- or over- estimate the score.

James and Olley 1971, at the CSIRO Tasmanian Food Research Unit (TFRU) plotted the rates of change versus the time taken for shark to spoil reported in the literature and discovered it was not a straight line, as had been commonly assumed, but that spoilage was slowed more than anticipated in the chill range near 0^oC. Further reviews of the literature results for chemical, bacterial, organoleptic and physical spoilage of herring, cod, halibut, prawns, scampi, and beef resulted in the concept of the relative spoilage rate derived by dividing the rate of spoilage at any temperature by the rate at 0^oC (Olley and Ratkowsky 1973a,b). The concept of relative spoilage rate meant that the storage period of seafoods with any known time-temperature history could be expressed on the common basis as equivalent number of days in ice, icetime, or icedays.

Spoilage in chill stored seafoods is mainly caused by bacteria and attention turned to establishing their temperature response Ratkowsky et al. (1982). Their response could be modelled using the square root form of the equation
$\sqrt{r} = 1+0.1t$ where r is the relative rate and t is degrees Celsius.
Or, more usefully as $r = (1+0.1t)^2$ (Bremner, Olley and Vail 1987).

This equation was found to apply not only to spoilage by psychrotrophic bacteria but to degradation of ATP, to changes in myoglobin as well as to changes in bulk properties. This neat equation demonstrates that in comparison with 0^o C, seafoods deteriorate twice as fast at 4^oC, four times as fast at 10^oC and about six times as fast at 16^oC. This means that comparative storage lives can be expressed in terms of ‘Icedays’, that is, as ‘equivalent days in ice’. If a product is known to have a usable shelf-life of 12 Icedays then at 4^oC it will only have 6 days, at 10^OC it will have 3 days and at 16^o C only 2 days. This vividly demonstrates the dramatic effects of temperature and the extreme importance of ensuring fish are chilled to a temperature of 0^oC and maintained at it. The equation thus provides an excellent means of evaluating seafoods if temperature is measured along with storage period and as long as the units are traceable.

At the same time a scheme was developed by the TFRU which overcame the disadvantages of other schemes and which was designed to be capable of integrating time temperature effects.

1.2 The Quality Index Technique

Seafood is assessed using the scoring scheme outlined on the species specific QI score sheets, which can be found in this manual. These have a scientifically predetermined number of scoring parameters which ALL must be assessed for the system to work correctly. The scores for each individual parameter are then added to determine the total QI score for the product being assessed.

The parameters are scored using a demerit process, with a small scoring range usually 0, 1, 2 or 3. A sufficient number of parameters have been chosen, based on experimental results, to cover the range of the most important indicator attributes for the particular species; not too many and not too few. In this way no particular attribute dominates the overall result and the choices between the scores are thus based on substantial differences.

A typical example is that of the shape of the eyes for which only three scores are necessary; Convex with a score of 0, Flat or slightly sunken with a score of 1, and Sunken with a score of 2. These definite changes are close to being unequivocal and this promotes consistency between assessors and minimises the need for extensive training.

To reiterate the scores of each parameter are added to provide the total, which is the Quality Index itself. The fundamental principle of the QI technique is that all the schemes are developed to provide a straight-line relationship between the total QI score and the equivalent period of storage in ice at 0ºC (known as icedays).

By comparing the QI score attained with that species' icedays graph the number of icedays elapsed since capture can be determined. A straight line drawn across from the score will intersect the figure line, and a perpendicular line dropped from this intersection will cross the lower axis at a value for equivalent icedays. Thus the total time-temperature history can be expressed in icedays, irrespective of actual temperatures and clock time elapsed. Note that the number of icedays is often not the same as actual clock time. This is due to any time spent by the product at temperatures above 0ºC at some point prior to the QI assessment. By the same process if the users know where the appropriate shelf-life for their usage is on the continuum, the remaining shelf-life in icedays can be readily calculated.

Experience with the development of QI has indicated that the parameters, and the scores, used in the schemes need to be tailored to each species, although there is a high degree of similarity in the final schemes. More detail on fish spoilage, icedays, shelf-life and the development of the QI scheme approach can be found at the back of this manual. As well as a comprehensive list of references on the subject, for those interested in understanding more about the scientific principles regarding fish spoilage that underpin the development of the quality index technique.

2. NEED

At the workshop meeting in Hobart in 2002 (FRDC project 2002/243) a working group comprising a wide variety of stakeholders from industry, fishing industry councils, service providers, SSA and government organizations endorsed that;

> 'An agreed quality index has enormous advantages in monitoring every aspect of the seafood chain from catch through to final point of sale. Properly used, a quality index can help eliminate inefficiencies, provide standard material, minimize waste, provide control records, improve image, diagnose faults, predict shelf-life, reduce disputes and enhance market confidence in the products'

They considered that there was an urgent need in the marketplace for adoption of a recognized, readily understandable, rapid, practical, yet scientifically-based quality index. The need is critical as the industry moves inexorably towards electronic transfer of information, electronic trading (such as Sydney Fish Market's SFMLive ™ trading platform), remote buying, and increasing exports to demanding and discriminating markets. It has also proved valuable in sorting out procedures, suppliers, selection of batches and in QA for the development of new consumer products from under utilized species.

The index is in a form that is readily understood and which can gain wide acceptance domestically and be recognized internationally to provide the industry with advantages in meeting consumer requirements through:-

- Accurate grading
- Estimation of elapsed storage life
- Prediction of remaining shelf-life
- Increasing buyer certainty
- Better management of the supply chain
- Ease of resolving conflict
- Use in training and education.

Straightforward grading schemes, that differentiate product into grades such as; A, B & C are common but provide only limited information, are weak in estimating the history of the product and at predicting likely remaining shelf-life. Although grading is apparently simple, disputes commonly arise, particularly about material that is close to the borderline between different grades. The Quality Index technique overcomes these deficiencies and met the above requirements. It focuses directly on the attributes of seafood that deteriorate during storage.

3 OBJECTIVES

1. To develop quality index (QI) schemes for the initial 6 nominated species – Snapper, Tiger Flathead, Black Tiger Prawns, Goldband Snapper, Atlantic Salmon and Sea Mullet
2. To validate the initial 6 QI schemes and investigate their application in appropriate commercial supply chains
3. QI Manual produced on 6 validated QI schemes
4. Develop QI schemes for 8 additional species - King Prawns, Scaly Mackerel, Silver Warehou, Pink Ling, Barramundi, Yellowtail Kingfish, Saddletail Snapper and Redthroat Emperor
5. Updated QI manual with 14 species produced

There were two other original project objectives that were cancelled in agreement with FRDC;

A. To undertake a cost/benefit analysis of the QI schemes on appropriate selected supply chains.

B. To assess the potential for the commercialization and industry adoption of QI schemes and describe a strategy to achieve this.

These were cancelled due to the difficulties in carrying them out before the scheme has been fully developed and rolled out to industry. Thus putting the focus firmly on QI scheme development in this project.

4 METHODS

The Quality Index approach was chosen since it systematically measures changes in seafoods during storage through visual, tactile and olfactory observation in a manner that is consistent with known microbiological, chemical, biochemical and bulk processes in a way that integrates time and temperature effects (Bremner et al. 1987, Hyldig et al. 2007).

The steps involved for each species were:-

Materials

- Make decisions on which research provider was best suited geographically to deal with the species
- Ascertain a source for the species either a vessel, skipper or receival depot to get them to the lab, as soon after catch as possible
- Determine timing for each species to account for seasonal abundance and general availability and to develop a contingency plan as availability almost always varies.
- Establish reliable packaging and transport mechanisms
- Obtain sufficient material for training and for three subsequent trials proper.
- Each batch usually consists of 40 fish, – 5 fish per assessment and 8 assessments over the course of the shelf life period. Thus up to 160 fish are needed to develop a scheme. Using Barramundi as an example, a reasonable sized fish (1 – 1.2 kg) were selling wholesale for $9kg (for trials you often have to pay a bit more than this due to the handling issues that you are asking suppliers to do). But even at $9. That's $1440 to 1728 for the fish and there are also fish transportation costs to add.

Laboratory

- Set out a plan to cover the work taking into account availability of species and personnel
- Recruit and train a panel that are reliably available over the several month period for repeat trials required for each species.
- Familiarise the panel and researchers with the species, do exploratory round table discussions and select a suitable vocabulary and number of attributes in which definite changes can be seen and described (this approach has parallels in ethology and animal behaviour studies).
- Develop standard photographic procedures
- Consolidate the scheme and ensure panelists are in agreement in its use.
- Conduct two -three validation trials, collate data and do preliminary analyses
- Engage consulting statistician and fully analyse data using multivariate techniques.
- Write report and submit to PI.

4.1 Research providers and approach

Schemes were developed by four different research providers as identified in the results section for each species and Table 4.1.1. Each laboratory followed the same general principles and mainly the approach outlined above but the experiments had to be tailored to meet the circumstances, availability of personnel and the facilities. The reports from each therefore follow different formats.

Consequently, the sections covering materials (catch, transport and storage), methods (panel composition, number of trials, whether cooked samples were tasted), data analysis (statistical methods, acceptance and rejection of individual trials) and conclusions are not combined as occurs in usual reporting formats, but are presented under the banner of each species.

Table 4.1.1 Research Providers

Laboratory	Leader	Species
Innovative Food Technologies, DEEDI (formerly QDPI&F), Hamilton, Brisbane, QLD	Sue Poole	Barramundi, Goldband Snapper, Black Tiger Prawns (cooked), King Prawns (cooked), Saddletail Snapper, Scaly Mackerel, Sea Mullet, Yellowtail Kingfish
Dept. of Food Science and Marketing, Victoria University of Technology, Werribee, VIC - substituted for CSIRO Food Science Australia who withdrew from project.	Jayanthi Weerasinghe, formerly of Food Science Australia, as consultant	Snapper, Tiger Flathead,
National Centre for Marine Conservation & Resource Sustainability, Australian Maritime College, University of Tasmania, Beauty Point, TAS	Dr Felicia Kow	Atlantic Salmon, Pink Ling, Silver Warehou,
Curtin University of Technology, School of Public Health, Perth, WA.	Dr Hannah Williams	Redthroat Emperor

4.2 Guidelines on QI Scheme application

These guidelines in the QI Manual apply mostly to whole fish, but in some instances fish that have been gutted can be assessed by the same scheme. In this case the total score is restricted and the slope of the line is slightly different.

Different attributes are assessed for different species, although a large degree of overlap occurs.

4.3 Notes on the attributes (refer to the section in the QI Manual pages 8-12)

APPEARANCE AND TEXTURE

Skin
The whole external surface including fins should be examined. Skin colour and the fading of coloured spots or stripes can be important indicators in many species. The appearance can be affected by the medium of storage and fish that have been immersed in RSW, slurry or other media may have lost scales and colour.

Mucus
Some species have natural mucus, whilst others produce it on storage. This has been taken into account during the formation of the schemes.

Odour
This is best assessed by smelling along the spine of the fish. If the fish has been laying on the assessment surface for some time (15 minutes) it should be turned over and smelled on the under surface.

Blood on gill flap
The spread of blood on the gill flap (opercula) can be an important criteria for fish such as sea mullet and Australian salmon. Storage of the fish in liquid media such as chilled seawater may wash some of this blood away.

Texture and firmness
This is assessed by pressing firmly, but not too vigorously, with a finger into the central back portion of the fish and then judging how fast the flesh recovers. Only fish in rigor should be given a score of 0. Pre-rigor fish is soft and recovers only slowly but if it is known to be pre-rigor, a score of 0 should be given.

Belly
Firmness is judged by stroking with the fingertips or by pinching between the fingers.

EYES
The eyes should not be touched in the assessment. Don't assess an eye that is physically damaged.

Cornea
Assess the colour and the clarity

Form
The form of the eye should be judged by looking from both above and slightly to the side. Eyes generally score 0 for convex, 1 for flat and 2 for sunken.

Colour
Look directly into the eye to judge the colour.

GILLS
The operculum (gill cover) must be lifted to assess the gills without touching them.

Colour
The colour of the gills may vary on the different sides of the fish and both should be assessed. Different species may vary in the way they change colour; some tend towards greyness, some towards brown.

Odour
Should be assessed on the open gill.

Mucus
The mucus colour is often an important indicator of change.

OTHER PARAMETERS

Viscera
In some schemes the gut can be opened to examine the state of the viscera. In general, these schemes prepared here have been designed to be non-invasive and opening the gut cavity is not required

Abdomen
Note that the assessment does not include workmanship. Although ragged cuts are undesirable they are not a feature that relates to storage.

Colour of blood
The colour of the blood in the abdomen and its viscosity can be a good indicator
The colour of the flesh also may be evaluated as it changes during storage towards a yellow-brown or grey appearance.

Odour
Where applicable the abdomen should be held open to assess the smell

Cut Surfaces
The colour of cut surfaces is another indicator on some species.

5 RESULTS

The trials were conducted in four separate laboratories over a period of time. Each species is reported here individually including detail of materials, method e.g., composition of panels, analysis of data methods and results and consequently, although the overall strategy was the same, there were differences in approach which are reflected in the reports for the individual species. These minor differences do not affect the major output, the QI Manual.

5.1 Atlantic Salmon (*Salmo salar*)

Trials conducted by Dr Felicia Kow at Australian Maritime College (AMC), University of Tasmania Beauty Point,Tasmania.

Farmed HOGG (Head on gilled and gutted) Atlantic salmon (*Salmo salar*) was used for this investigation.

5.1.1 Methods

Sensory assessment included – visual, odour and texture parameters for all possible features specific to the species product form. Eight to nine experienced seafood assessors were used at each time to ensure that assessment data from a total of 5 assessors were available for analysis throughout the trial. Five separate fish were assessed at each sample time and samples were taken 8 times throughout the storage period.

Pilot investigations were done in which fish with a known harvest-handling-storage history were obtained and stored in melting ice. Ice time was calculated using the Ice Time Calculation Method (Olley, J. 1978). At regular short intervals (2-3 days), the fish were assessed for their sensory characteristics and relevant descriptors were listed for each stage throughout storage (some of this information was available from previous works conducted by the Danish Institute for Fisheries Research).

A score sheet and panel training was developed and all assessors reached consensus on what score a particular parameter achieves at which intensity and agreed that the descriptors selected for the index were relevant. Two full trials were then completed and completed fish samples were obtained at point of harvest, assessed where possible and transported rapidly to the seafood labs at Beauty Point, Tasmania. Transport containers included temperature data loggers to capture storage history. Data loggers were placed immediately after harvest to monitor the core temperature of fish throughout the entire storage period. Full assessment of 5 fish was carried out 8 times throughout subsequent iced storage of the product.

During these trials, the definitive points of visual change were noted pertinent for photographic records. Also during this phase, the score for flavour of cooked samples was estimated by 4 assessors using the Torry Scheme (Table 5.1.1).

Table 5.1.1 Torry score sheet for cooked lean fish

Odour	Flavour	Score
Initially weak odour of sweet, boiled milk, starchy, followed by strengthening of these odours	Watery, metallic starchy. Initially no sweetness but meaty flavours with slight sweetness may develop	10
Shellfish, seaweed, boiled meat	Sweet, meaty, characteristic	9
Loss of odour, neutral odour	Sweet and characteristic flavours but reduced in intensity	8
Woodshavings, woodsap, vanillin	Neutral	7
Condensed milk, boiled potato	Insipid	6
Milk jug odours, reminiscent of boiled clothes	Slight sourness, trace of "off" – flavours	5
Lactic acid, sour milk, TMA	Slight bitterness, sour, "off" – flavours, TMA	4
Lower fatty acids (e.g. acetic or butyric acids) decomposed grass, soapy, turnipy, tallowy	Strong bitterness, rubber, slight sulphide	3

5.1.2 Results and discussion

Temperatures were well maintained and ranged around 1°C throughout the two full trials and storage periods were converted to equivalent days in ice.

The QI scheme was developed in preliminary trials and then used to assess samples in on two carefully controlled trials (Table 5.1.2)

A linear relationship between QI and equivalent days in ice was evident (Figure 5.1.1) described by the equation:-

Quality Index = 0.7854xdays in ice -1.2865 (R^2= 0.8194)

5.1.3 Estimated Remaining Shelf Life

The limit for shelf-life was assessed by four people based on bitterness of cooked meat was estimated as 23 days. Based on the averages of the linear relationship of the above two trials and the end use day, the remaining shelf life was estimated (Table 5.1.3).

5.1.4 Comparison of QI scores with Torry scores for cooked fish flavour

The plot of the scores for flavour versus storage period resulted in a negative linear relation (R^2 =0.8942) and an indicative rate of change in flavour score of about -0.74 units per day slightly less than the rate of change of QI score at +0.79 per day. This inverse relation demonstrates clearly the value of the QI method as a rapid non-destructive approach that could deal with a far greater number of samples per day than the Torry method

5.1.5 Conclusion

Atlantic Salmon in this form has a remarkably long shelf-life at 0°C of about 23 days. The QI reflects well the progressive change in flavour that occurs in chill-stored salmon and this reinforces its use. It's utility is obvious.

Table 5.1.2 QI scheme for Atlantic Salmon (Head on, gilled and gutted)

Quality Parameters		Description	Score
Skin	Colour/ appearance	Pearl-shiny all over the skin	0
		The skin is less pearl-shiny	1
		The fish is yellowish, mainly near the abdomen	2
	Mucus	Clear, not clotted	0
		Milky, clotted	1
		Yellow and clotted	2
	Odour	Fresh seaweedy, neutral	0
		Cucumber, metal, hay	1
		Sour, dish cloth	2
		Rotten	3
	Texture	In rigor	0
		Finger marks disappear rapidly	1
		Finger leaves mark over 3 seconds	2
Eyes	Pupils	Clear and black, metal shiny	0
		Dark grey	1
		Matt, grey	2
	Form	Convex	0
		Flat	1
		Sunken	2
Fin (caudal fin)	Colour	Translucent, slightly pink	0
		Dark and opaque	1
	Edge	Moist and smooth with frills intact	0
		Moist and smooth with frills broken	1
		Dry and comb-like frills	2
Flesh	Colour	Fresh orange	0
		Pale orange	1
		Pale yellowish orange	2
		Yellow discoloured	3
Abdomen	Blood in abdomen	Blood red/not present	0
		Blood more brown, yellowish	1
	Odour	Neutral	0
		Cucumber, melon	1
		Sour, fermenting	2
		Rotten/rotten cabbage	3
Quality Index			0-23

Figure 5.1.1 QI scores versus equivalent days in ice for Atlantic Salmon

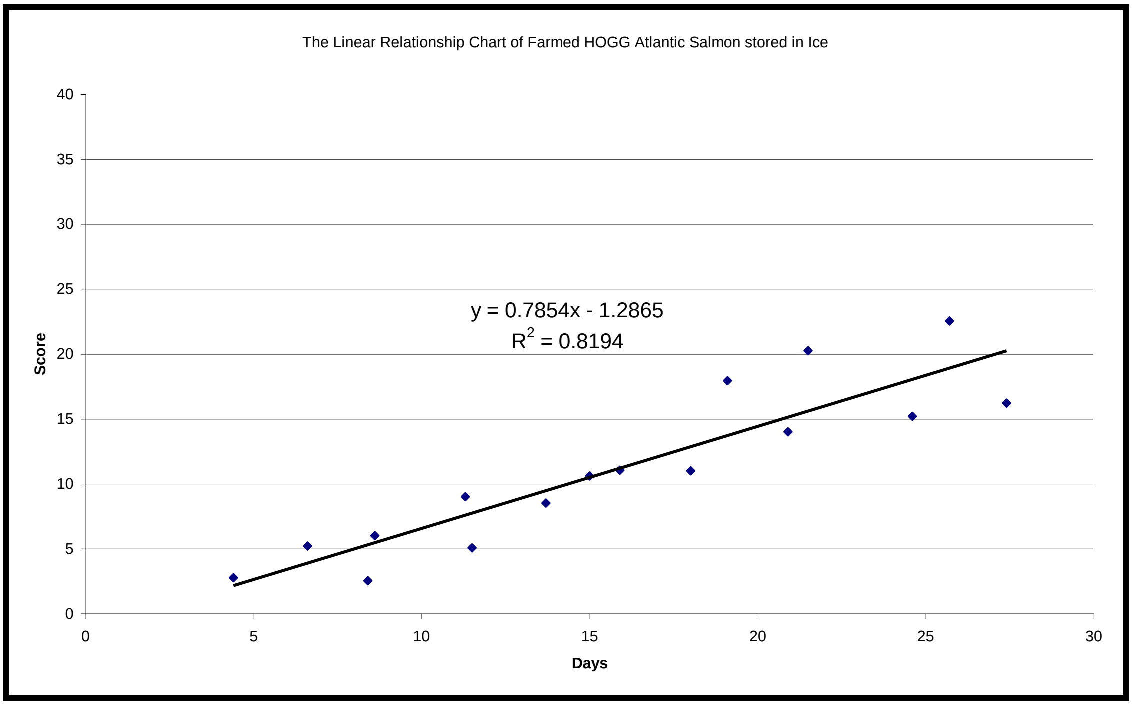


Figure 5.1.2 QI scores versus flavour scores for cooked samples of flesh of Atlantic Salmon

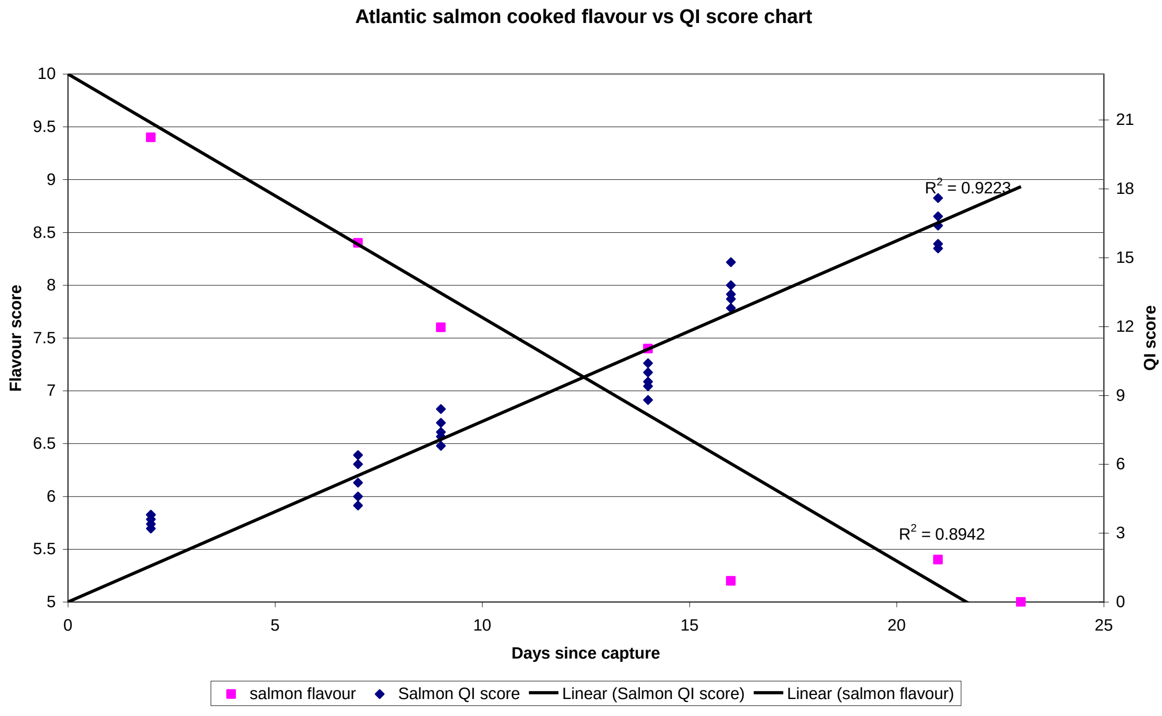


Table 5.1.3 Estimated remaining shelf-life for Atlantic Salmon held at 0°C

Quality Index	Storage time in ice (days)	Remaining Shelf life (days)
1	3	20
2	4	19
3	5	18
4	7	16
5	8	15
6	9	14
7	11	12
8	12	11
9	13	10
10	14	9
11	16	7
12	17	6
13	18	5
14	19	4
15	21	2
16	22	1
17	23	0

5.2 Barramundi (*Lates calcarifer*)

Trials were conducted by Sue Poole, John Mayze, John Nagle, Paul Exley, Stephanie Kirchhoff and Steve Nottingham, Innovative Food Technologies, DEEDI (formerly QDPI&F), Hamilton, Brisbane and Ron Wong a visiting Senior Research Scientist from New Zealand Institute for Crop & Food Research Limited.

5.2.1 Preliminary trial fish

The preliminary trial was carried out with fish obtained as close to harvest as possible and then stored whole (gut in) in ice to observe typical changes in attributes over time. From these observations, specific descriptors were agreed as describing the particular attributes at any point of storage

- fish were harvested from a plastic lined pond on a farm in north Queensland (Kula Park, Mount Molloy)
- the ponds contained potable bore water that was pH neutral
- ponds had low stocking density and predation covers to minimise the stress to animals
- fish used for assessment were harvested then transferred to a purge tank for 1 hour before being ice-slurried in a salt brine until a core temperature 0.2°C was attained
- fish were packed and air freighted to Brisbane arriving the next day
- whole (gut in) fish were stored in free draining melting ice (0^{o}–1^{o}C) in insulated lidded bins (250L Xactics) which were stored in a temperature controlled environment (22°C room)

5.2.2 Pilot trial and assessment trial fish

The pilot trial was undertaken to train the assessors in the meaning of each descriptor used for the different attributes of the fish and to confirm agreement that they were appropriate and universally understood.

- fish were harvested from a earth-bottom pond from a farm in north Queensland (Molloy Barramundi, Mount Molloy)
- pond water is exchanged 2-3 times a week
- fish used for assessment were harvested straight into ice-slurry (no purge) and held for 2 ½ – 3 hours
- fish were packed and air freighted to Brisbane arriving the next day
- whole (gut in) fish were stored in free draining melting ice (0^{o}–1^{o}C) in insulated lidded bins (250L Xactics) which were stored in a temperature controlled environment (22°C room)
- assessment trials were carried out with 3 separate batches of fish from different harvests
- Three separate trials were carried out to provide the quality index assessment data to build the model.
- 5 randomly selected individual fish were used for each assessment
- each fish was assessed separately under standardised evaluation conditions on a stainless steel table at 22^{o}C under fluorescent lighting

- fish were assessed in a random order
- 8-10 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the pilot trial on the specific parameters by which barramundi was to be assessed
- assessors made individual judgements independently and their performance was analysed statistically

5.2.3. Statistical data analysis

Averages at each time period were calculated based on the assessor's average of the five fish and the fish average over the assessor's. This allows comparison of the variability between fish and between assessors. Data was graphed to readily identify outliers and observe trends.

5.2.4 Combining of data from the separate trials

For each trial the average Quality Index (QI) for each assessment day was calculated and the regression lines were plotted together to allow easy visual comparison between trials. The four characteristics of any linear equation fitted to data are: goodness of fit; slope of regression line; the intercept; range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and the data could then be pooled from all trials to obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

5.2.5 Assessor variation and fish variability

The assessor average for each trial on each day was plotted to show variation between scores across the storage time. It also showed if there was any interaction between assessors and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between assessors and fish, then the plots can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance (AOV) in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and each assessor and fish were considered as two factors. This gives an overall measure of assessor differences and fish differences and more importantly, any interaction between fish and assessor.

5.2.6 Predicted and measured using partial least square regression

This was based on analyses similar to those by (Sveinsdottir *et al*, 2002, 2003) for Atlantic salmon. Unscrambler software was used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). PLS1 option was chosen with full validation and no weighting but using the inverse model, so X was QI and Y was days. Since QI is the sum of *n* parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter 't' comes from the AOV regression.

5.2.7 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system, so as to be complementary to that system. Parameters for assessment were selected from those gained from previous experience of the spoilage pattern of ice-stored barramundi. The parameters were observed during storage with appropriate descriptors discussed and defined at all stages of the preliminary storage trial.

Early assessment sheets included "grey/silver" as the colour description for skin but observation of fish from different sources indicated that colour was very dependent on the physical grow-out conditions. Colour varied from a black to bright silver according to grow-out conditions e.g. earth pond, lined pond, recirculation tank or wild caught. In order to make the quality index (QI) sheet applicable to all barramundi (aquaculture or wild caught) colour descriptors were removed and replaced with "bright" and "iridescent".

Odour was another descriptor that was dependent on grow-out conditions. Variations in just-harvested fish included "weedy", "muddy", "earthy", "clean" and "fresh-water". Descriptors for this parameter were modified to account for this variation at time "0".

Eyes can range from clear black to slightly opaque depending on whether the fish are cooled in salt or fresh-water slurry. Scoring descriptors for this parameter were modified accordingly. Seemingly, contrary terms of "concave" or "bulging" are included to describe the eye form. Both terms are relevant but are an either /or choice – the bulging caused frequently by physical storage in ice with that eye facing downwards.

Gills also range from bright red to dark red dependant on salt or fresh-water slurry. Scoring descriptors were modified to include both descriptors at time "0".

Describing these parameters this way when fish are expected to be perceived as 'perfect' (highest quality) allows flexibility of the scoring system to cope with variations in farm grow-out and post-harvest handling techniques.

Table 5.2.1 provides the final QI scheme and lists the quality attributes for physical and visual parameters, including odour.

Table 5.2.1. Quality Index scheme for Barramundi

Quality Parameter		Description	Score
Skin	Colour/ appearance	Bright, iridescent	0
		Loss of brightness or matt	1
	Scales	Intact and firm	0
		Removable from dorsal region	1
		Loose or easy to pull out	2
	Slime	Clear / slightly cloudy or milky	0
		Cloudy brown under pectoral fin	1
	Odour	Freshwater pond	0
		No smell	1
		Spoilage odour	2
	Texture of flesh	Firm (anterior dorsal), bounces back when pressed	0
		Slightly soft, finger mark disappears slowly	1
	Rigor	In-rigor	0
		Post	1
Eyes	Form	Convex	0
		Flat	1
		Concave or bulging	2
	Cornea/jelly	Clear	0
		Cloudy	1
		Fully opaque, burst / blood	2
	Pupils/Iris	Pupil: dull black / transparent / iridescent / orange Iris: white / silver/bronze	0
		Pupil: cloudy, white / grey Iris: cream	1
		Pupil: cloudy, white / grey Iris: fully burst / bloody	2
Gills	Colour/ appearance	Dark red / bright red	0
		Dark red-brown or some discolouration, brown edges	1
		Brown &/or discoloured / bloody	2
	Mucus	Clear / transparent	0
		Cloudy beige	1
		Brown on gill edge	2
	Odour	Wet grass / weedy / fresh pond water	0
		Not so fresh, no odour	1
		Off odour	2
		Spoilage	3
Quality Index			0-21

Pilot trial

Assessors were trained in applying the QI parameter scores to barramundi in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with barramundi throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category and hence the aptness and clarity of the descriptions for each quality attribute was confirmed.

Scores were given for each quality attribute according to descriptions, ranging from 0 to a possible maximum of 3, where 0 implies "perfect", highest quality. At each storage time, the attritibute ratings were summed and noted as the QI score of that assessor for each fish. All the parameter scores were totalled for each assessor and for each fish. The totals were then averaged to provide the final QI score at that storage time. The end of storage life was noted as the point where barramundi was rejected (considered rotten) on physical parameters. This occurred prior to the cooked flesh being considered objectionable. This phenomenon occurred repeatedly and was judged to be the case by all assessors. It has also been observed to hold true in other storage life trials undertaken by the researchers (Poole *et al*, 1991 and unpublished data) with various other species.

Assessment trials

In each of the 3 trials, 5 individual fish (whole, gut in) were assessed on each sampling day. The QI was calculated for storage time and graphed against storage days to illustrate relationship. The final QI score for a sampling time was based on an average of all fish assessed in each trial to allow for biological variation between fish.

Comparing the data from each trial and the individual trial graphs (Fig. 5.2.1) it was clear that the regression lines attained were similar. Analysis gave the assessor average for each fish and provided the mean with the standard deviation of 5 fish (not shown for reason of graph clarity). The variation between fish across trials was comparable and no unusual pattern is exhibited in different trials. Therefore, the data for all trials show a similar rate of deterioration of the barramundi with time stored in ice

Regression analyses comparing slopes and intercepts from the separate trials showed that the data is poolable and therefore Figure 5.1.2 is based on 15 fish at each assessment time. The pooled data for barramundi shows a high correlation between QI score and number of days the fish were stored in ice, with an R^2 of 0.970 (R^2 for individual trials were 0.982, 0.958 and 0.965 respectively for trials 1, 2 and 3).

QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored in ice, with fish at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axes origin (0, 0) which was only attained in one of the three trials.

Figure 5.2.1. Quality Index scores for all three trials of barramundi stored on ice.

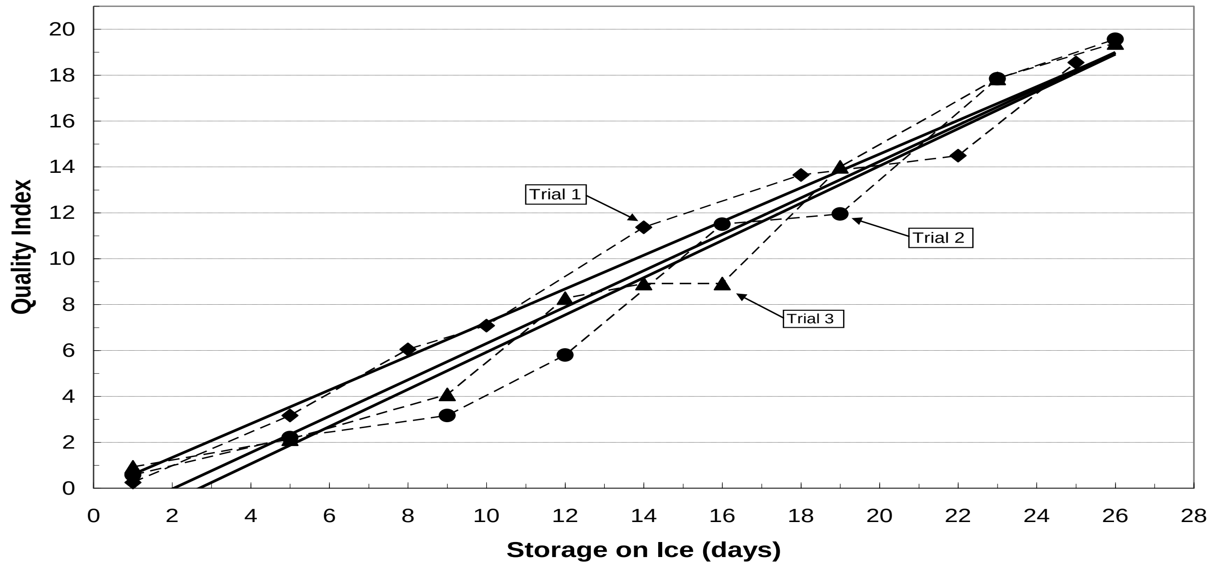
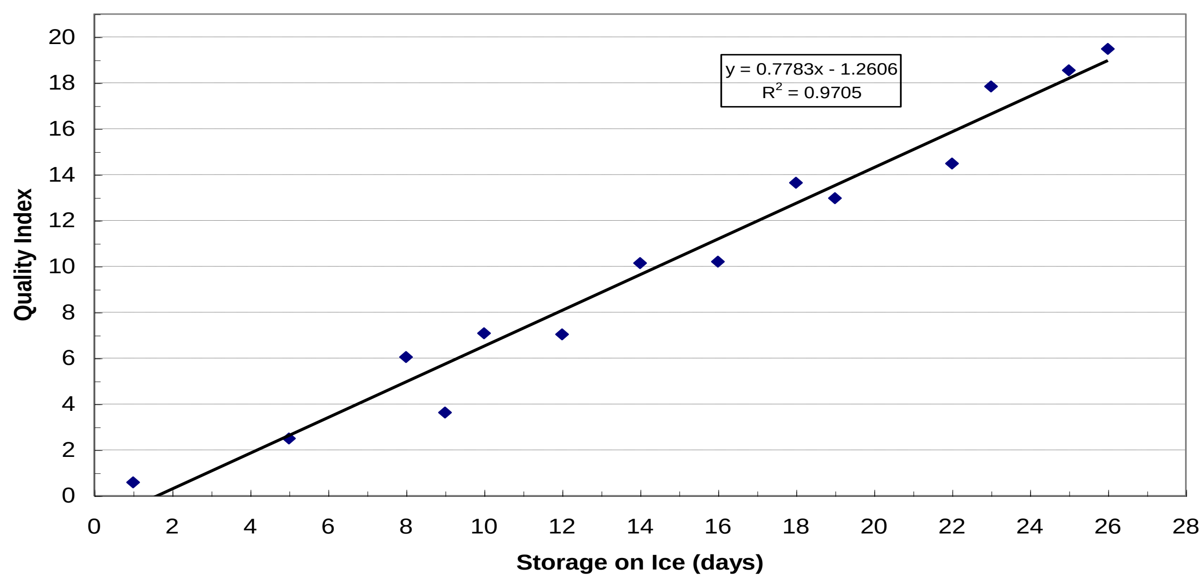
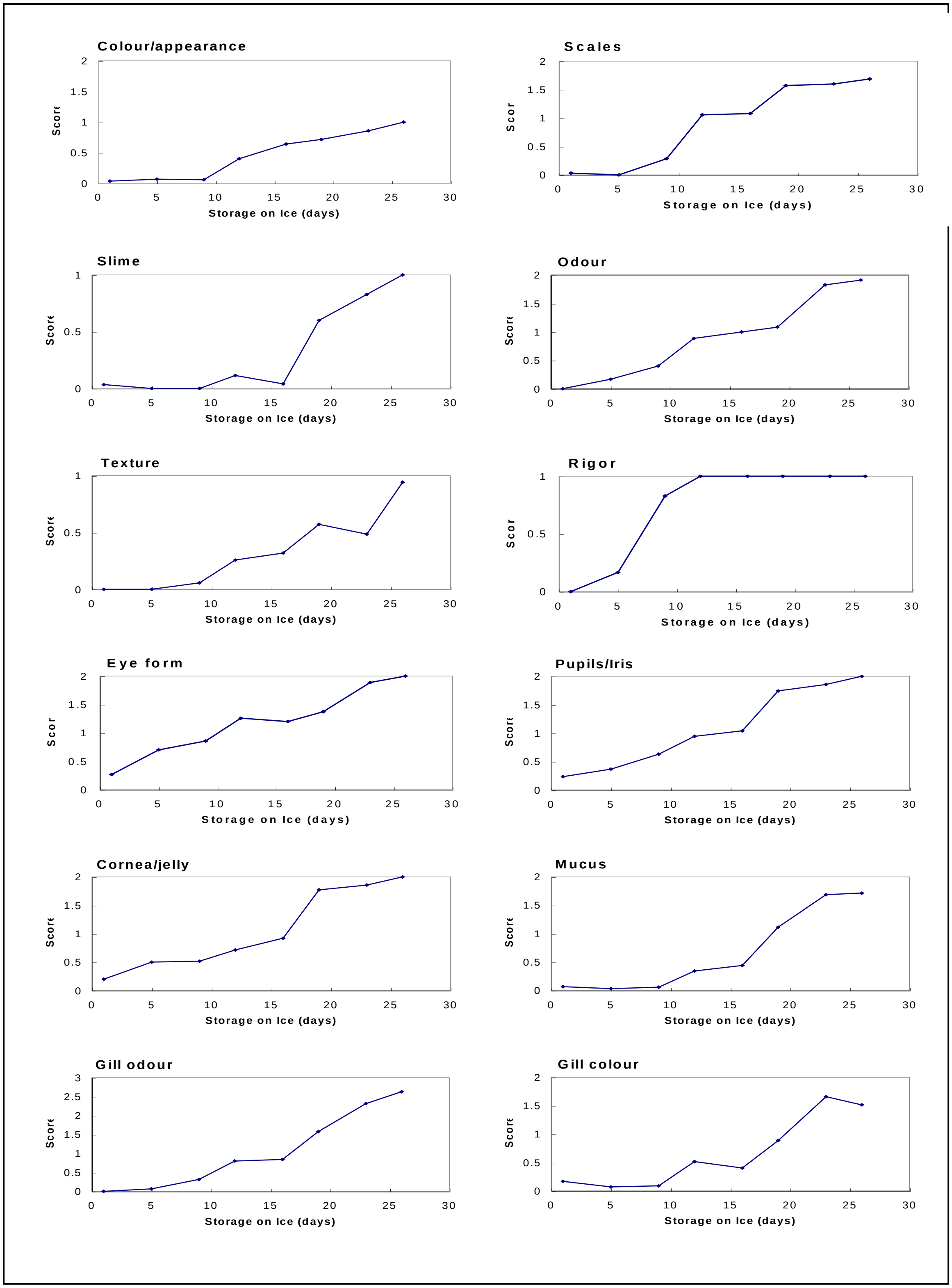


Figure 5.2.2. Quality Index for pooled data (trials 1-3) showing scores averaged across fish and assessors.



The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials. Increase in score for each parameter over storage time is depicted in Figure 5.2.3. Of the 12 parameters selected all but rigor demonstrated direct relevance with time, indicated by steadily increasing in score over time. Rigor, commonly used as an indicator of freshness, is a unique parameter in that it resolves to completion early in storage with no further change occurring.

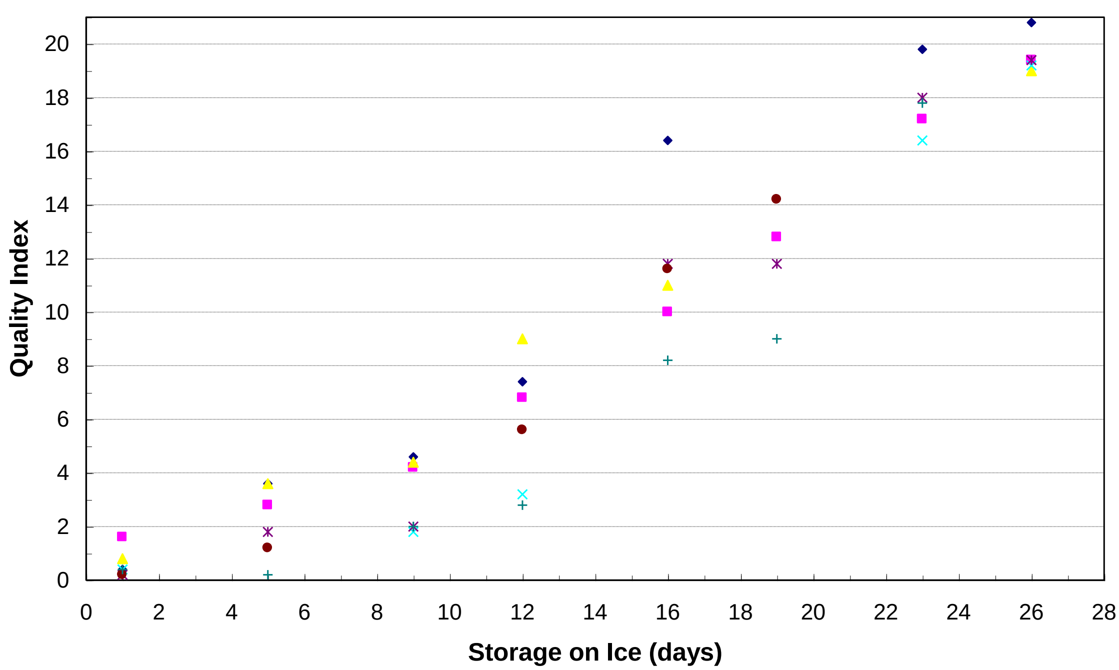
Figure 5.2.3. Scores for individual assessment attributes over time (taken from Trial 3)



There was variation in the QI obtained by different assessors for each trial, however each assessor was consistent over the storage period. Analysis showed that variation between assessors increased during the mid phase of storage (Fig 5.2.4) and that assessors were in better agreement when the fish were very fresh and at the end of storage life. Where large variation between assessors occurs it may be that individual interpretation of parameter descriptors is the cause. This can be overcome with more training of assessors, but is also likely to be typical of assessments by industry personnel. In trial 2 and 3 the variation remained reasonably constant over storage time of the fish and this is likely to have occurred due greater variation of attributes during this storage period dictated by the specific spoilage rate of an individual fish. It is also possible that in trials 2 and 3 assessors are more familiar with the spoilage pattern of barramundi and experienced in the QI scheme. i.e. they were more trained than for trial 1.

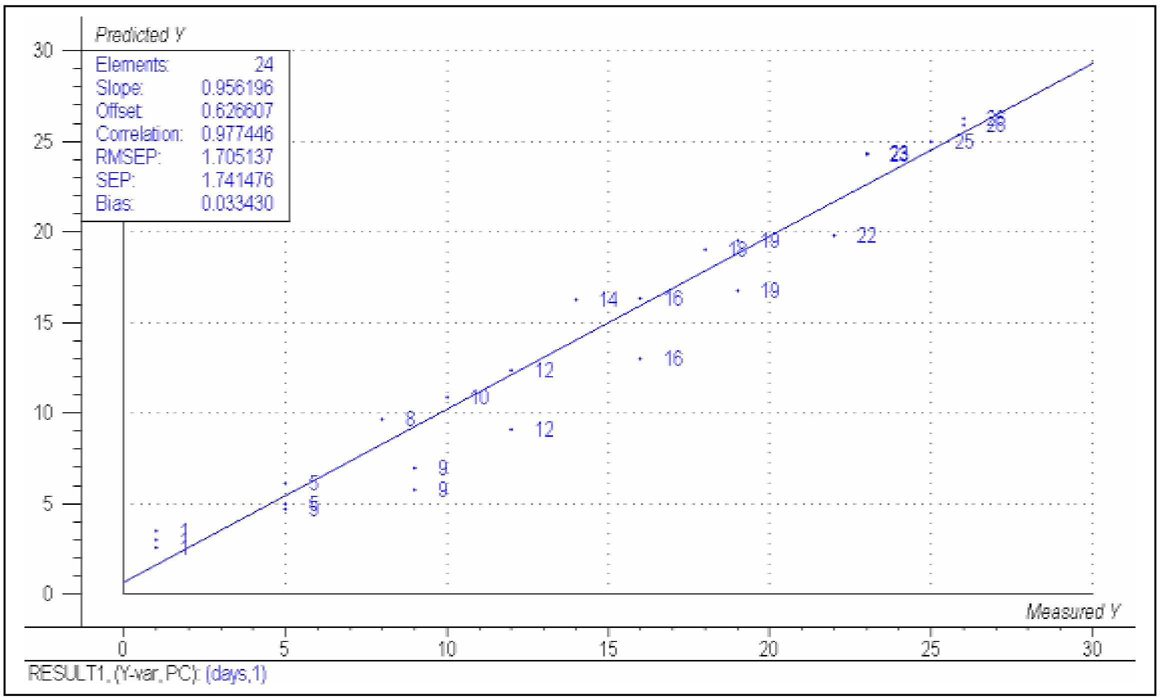
There were significant (P<0.05) QI score differences between fish at assessment times in trial 2 only (data not depicted here). For trials 1 and 3, variation between individual fish were not significant. In all 3 trials, there was no significant (P>0.05) interaction between fish and assessor scores. This means that each assessor's average score is different but consistent across fish.

Figure 5.2.4. QI scores given by individual assessors during storage of fish in ice (data from Trial 2).



Predictability of QI was analysed using partial least square “inverse” regression model (PLS) with full validation and this also gave a (SEP) standard error of prediction value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis, the QI of barramundi could be used to predict the storage time with an accuracy of ± 1.7 days (Fig 5.2.5, the numbers associated with data points on the graph indicate days of storage of fish in ice).

Figure 5.2.5. Standard error of performance of the barramundi QI scores.



5.2.6 Conclusion

The QI score sheet with the descriptors given can be used to assess fresh chilled barramundi sourced from any growing conditions including both wild harvest and aqua-cultured product. The QI score can predict the days of equivalent ice-storage with an accuracy of ± 1.7 days. The panel considered that the maximum chill-storage period for barramundi was at a QI score about 21 relating to around 26 equivalent days in ice at 0ºC. This remarkably long storage life has been noted for other tropical species.

5.3 Black Tiger Prawns (*Penaeus monodon*)

Trials were conducted by Sue Poole, John Mayze, John Nagle and Steve Nottingham, Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton, Brisbane.

Black tiger prawns were harvested specifically for preliminary trial work from aquaculture ponds at Prawns North (Townsville, Qld). Prawns were those remaining in the ponds after harvesting season was finished and therefore were a mix of sizes and maturity. Prawns were not graded but those of similar large size were selected for trial work. Immediately post-harvest (pond-side), prawns were immersed in ice slurry ($0^o – 1^oC$). Prawns were stored overnight in ice slurry prior to cooking next morning, as is usual practice at Prawns North, hence prawns were held green for ~18h. They were not dipped in metabisulphite. Prawns were cooked under usual farm practice and cooled briefly with potable water and placed in a freezer for a short time to chill. Prawns were transported by airfreight and received in Brisbane ~8h later and stored as freighted in a 2^oC cold room. No temperature records were logged during on-farm handling or transport stages. The first assessment of the prawns was carried out ~24h after cooking.

5.3.1 Pilot and Trial 1 prawns

Trials had to be conducted out of season and consequently, green prawns from the previous season, individually quick frozen, were procured from Prawns North (Townsville). These prawns had been handled green similarly to those used in the prelim trial with the only difference being that after harvest the green prawns had been stored overnight in a brine (2.5-3% NaCl) slurry (0^o-1^oC) for ~18h prior to freezing. Prawns were transported in frozen state to Brisbane. Visual assessment at IFT showed that they looked to be of good quality in the frozen state. Prawns were thawed overnight at 2^oC prior to cooking at IFT and their quality still looked good with no melanosis evident. It is estimated that the total time held green in a chilled and thawed state was ~36-40h (inclusive of green on-farm and thaw time at IFT). Completely thawed prawns were cooked at IFT under standard conditions using the prawn cooking meter to determine cooking end-point (meter developed at IFT under a FRDC supported project). Prawns were then chilled in an ice slurry and, when cold (1^o-2^oC), stored on ice in covered draining baskets. Prawns were stored throughout the trial in a 2^oC cold-room and re-iced each day using fresh ice.

5.3.2 Trial 2 and Trial 3 prawns

Prawns for Trials 2 and 3 were also from Prawns North handled under similar conditions as above (usual farm practice) but not frozen. Prawns were cooked on farm under commercial conditions according to usual on-farm practice which includes an overnight (18-20h) brine slurry step and then chilled as for prawns used in the preliminary trial. Prawns were air-freighted to Brisbane. For Trial 2, the prawns were received ~8h later and stored as freighted in a 2^oC cold room. Prawns for Trial 3 were received some 20-24h after despatch from Prawns North farm as they sat overnight in the Air Express chiller in Townsville due to a flight delay caused by a plane breakdown. Hence Trial 3 prawns were received at IFT ~25-30h after cooking and no temperature fluctuation records are available for the time the prawns were held at Townsville airport. For both, Trials 2&3 the first assessment of the prawns was carried out ~24-34h after cooking.

Preliminary analysis of results and QI score graphs obtained from these 3 trials showed that the rates of deterioration of the cooked prawns were very different between trials and as these trials were intended to be replicates, it was considered prudent to conduct more trials. Prawns for these further trials were obtained locally (as the new harvesting season had started) and therefore the long and uncontrollable transport steps were deleted.

5.3.3 Trial 4 and Trial 5 prawns

Prawns for Trial 4 and 5 were obtained as green chilled prawn from Gold Coast Marine Hatcheries at Jacob's Well an hour south of Brisbane. Prawns were harvested straight into ice slurry (0^{o}-1^{o}C) and transported directly to IFT. Time held green prior to cooking was ~ 6h. Prawns were removed from the slurry and cooked immediately under standard conditions using the prawn cooking meter to determine cooking end-point. Prawns were then chilled in an ice slurry and, when cold (1^{o}-2^{o}C), stored on ice in covered draining baskets. Prawns were stored throughout the trial in a 2^{o}C cold-room and re-iced each day using fresh ice. To achieve similarity with previous trials, the first assessment of prawns for these trials occurred the following day (~24h from cooking).

A summary of pertinent handling factors for prawns from different trials is given in Table 5.3.1.

Table 5.3.1. Summary of prawn handling for different trials.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Season phase	After end (frozen green)	End (prawns remaining in ponds)	End (prawns remaining in ponds)	Beginning of next	Beginning of next
Source	Prawns North	Prawns North	Prawns North	Gold Coast Marine Hatcheries	Gold Coast Marine Hatcheries
Size	30 – 40 's	~ 30 – 40 's	~ 30 – 40 's	~ 20 – 30 's	~ 20 – 30 's
Immediate post-harvest handling	Ice slurry pond side (4-5h) O/N brine slurry (~18h)	Ice slurry pond side (4-5h) O/N brine slurry (~18h)	Ice slurry pond side (4-5h) O/N brine slurry (~18h)	Ice slurry pond side (4-5h)	Ice slurry pond side (4-5h)
Time green prior to cook	36 – 40h	~20h	~20h	~6h	~6h
Transport time	Frozen	Post cook ~8h	Post cook- ~20h	Green ~2h	Green ~2h
Where cooked	IFT	On-farm	On-farm	IFT	IFT
Time from cook to first assessment	24h	24h	24h	24h	24h

5.3.4 Trial Samples

Within each trial, five prawns from each batch were randomly selected for each assessment time and each prawn coded with a random 3 digit number for identification. Prawns were assessed individually under standardised evaluation conditions on a stainless steel table at 22°C under white fluorescent light. Additional prawns (randomly selected) were provided to each assessor for taste testing, hence the prawn assessed for flavour and texture was not the same as the five assessed visually.

5.3.5 Assessors

Six to eight assessors were used for each assessment selected for their expertise and experience in sensory assessment of prawns. Additionally, all assessors were trained in the pilot trial on the specific parameters by which the prawns were to be assessed. Assessors made individual judgments independently and their performance was analysed.

5.3.6 Statistical data analysis

Averages at each time period were calculated based on the panellists average of the five prawns and the prawn average over the panellists. This allows comparison of the variability between prawns and between panellists. Graphs were made of each of these to detect outliers and look at trends.

5.3.7 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartletts test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.3.8 Panellist variation and prawn variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also showed if there was any interaction between panellists and time. Assuming prawns were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and prawn, then the plotted graphs can also show variation between individual prawn at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and prawn were considered as two factors. This gives an overall measure of any panel member differences and prawn differences and more importantly, any interaction between prawns and panel member.

5.3.9 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so X was QI and Y was days. Since QI is the sum of n parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter ‘t’ comes from the AOV regression.

5.3.10 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system so as to be complementary to that system. Parameters for assessment were selected from observation of spoilage changes during the preliminary trials and those attributes mentioned by Hanpongkittikun *et al* (1995). Initially, assessment parameters chosen also included attributes known to be commonly used in assessing overall quality of cooked prawns, such as:

- the shell hardness - relates to moult stage and influences spoilage rate
- degree of flesh shrinkage (between shell and body flesh) – indicates overcooking
- melanosis visible in cooked prawn– is a function of pre-cook handling
- state and colour of the hepatopancreas – dictated by cooking procedure and pond water quality and feed

Early trials showed that scores for most attributes chosen did increase over time and this was reflected in the QI attained, however a few did not change over time. Considering the change for each attribute individually, it was noted that the parameters listed above maintained a similar score over the storage period in all trials. For example, the scores given for rating the hepatopancreas did not change for cooked prawn and, as the score relates to factors other than spoilage or deterioration of the cooked prawn, this is not surprising.

Shell hardness, flesh shrinkage and extent of melanosis are similarly affected parameters and relate to immediate post-harvest handling of the green prawn rather than to deterioration of the cooked product. Hence it was concluded that these attributes are not influenced by storage but are predetermined prior to or at cooking.

It was noted during this preliminary trial that with all parameters included the QI score attained at point of rejection (as established by taste test) was well below the maximum which should be attained at this point. As the maximum QI score involved parameters that did not change with storage time of cooked prawn, it was decided to drop these attributes from the list. Following much discussion with assessors, degree of melanosis was subsequently re-instated as a pertinent parameter.

This was on the basis of, although dictated by pre-cook handling, extent of blackening around the head and appendages is a universally recognised measure used for determining prawn quality. It was agreed that this attribute should be assessed, but its weighting be reduced to melanosis present or absent only. Consequently, a shortened assessment sheet was developed from this preliminary trial based on only those attributes that changed with storage time.

Table 5.3.2 shows the QI scheme and lists the quality attributes for physical and visual parameters, as well as odour, flavour and texture. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 2, where 0 implies "perfect". For any storage time, the scores were summed and all attributes summarized and noted as the Quality Index. The end of storage life was confirmed by taste testing the prawns.

Quality of cooked product is very dependent on pre-cooking handling practices and the significance of this was strongly evidenced with different batches of prawns received for trial work. Some prawns were of untypical quality being the last remaining in the ponds at the end of the season. The ponds were dragged specifically for the trial and hence harvesting practice was 'tougher' and more damaging physically to the prawn than usual. This was evident when the prawns were cooked for assessment trials by exhibition of black scarring of shell integuments and some tissue. Additionally, the prawns were not purged prior to death and so traces of dark weed/feed was obvious in the cephalothorax area of the prawns which led to some confusion during assessments related to melanosis. Consequently, the prawns rated a quite high initial QI score on day 1 of storage.

Table 5.3.2 QI scheme for Black Tiger Prawns (cooked)

Quality Parameter	Description	Score
Colour/appearance	High sheen, distinct banding, bright & iridescent	0
	Dull, opaque.	1
	Pink sheen	2
Head	Firmly attached	0
	Slightly drooped or loose	1
	Loose, membrane broken	2
Eyes	Bright black	0
	Dull black, charcoal	1
	Sunken	2
Melanosis	No melanosis	0
	Melanosis present	1
Gills	White	0
	Slight grey or pink tinge	1
	Dark grey	2
Odour	Fresh sea	0
	Neutral	1
	Stale, musty, off	2
TASTE		
Flesh texture	Springy, firm, crisp	0
	Firm, chewy, tough	1
	Soft	2
Flesh flavour	Fresh prawn flavour	0
	Bland, neutral	1
	Stale, off	2
Quality Index		**15**

5.3.11 Display and analysis of results

Figure 5.3.2 shows the different relationships obtained between QI and storage time for all 5 trials. The regression lines for Trials 1 to 5 appear to be linear but are not similar, exhibiting differing slopes and intercepts. Hence, the four characteristics for stating that the relation between the variables was the same in each trial are not satisfied, so the data is not poolable statistically. This implies there is a different rate of change in demerit score with days across trials. Prawns between trials are not spoiling at the same rate and some are starting and finishing at different levels.

The differences are likely explained by the variation in handling conditions occurring prior to cooking which affect the quality of the prawn at cooking (noted as time zero – the beginning of storage time for cooked prawns). As well, the cooking process itself varies by operator and it is noted that prawns for Trials 1, 4 & 5 were cooked at IFT whereas those for trials 2 & 3 were cooked on-farm in Townsville.

Trial 1 was conducted with prawns that had been frozen green (IQF) and therefore the length of time the prawns were held green (raw) prior to cooking is longer than for other trials due to thaw time (36-40h as compared to 20 or 6h for the other trials). This may explain the high day 1 score (QI =4) for this trial.

Obtaining different slopes and intercepts using the same QI scheme on repeated occasions for the same species is not unique to our trials with cooked prawns however. Nielsen and Hyldig (2004) reported variable regression lines with lower slopes and higher Y-intercepts when repeating QIM evaluations with herring compared to those attained in the study developing the QIM used (Jonsdottir, 1992). The authors suggest this was related to different handling and storage methods used for the herring trials.

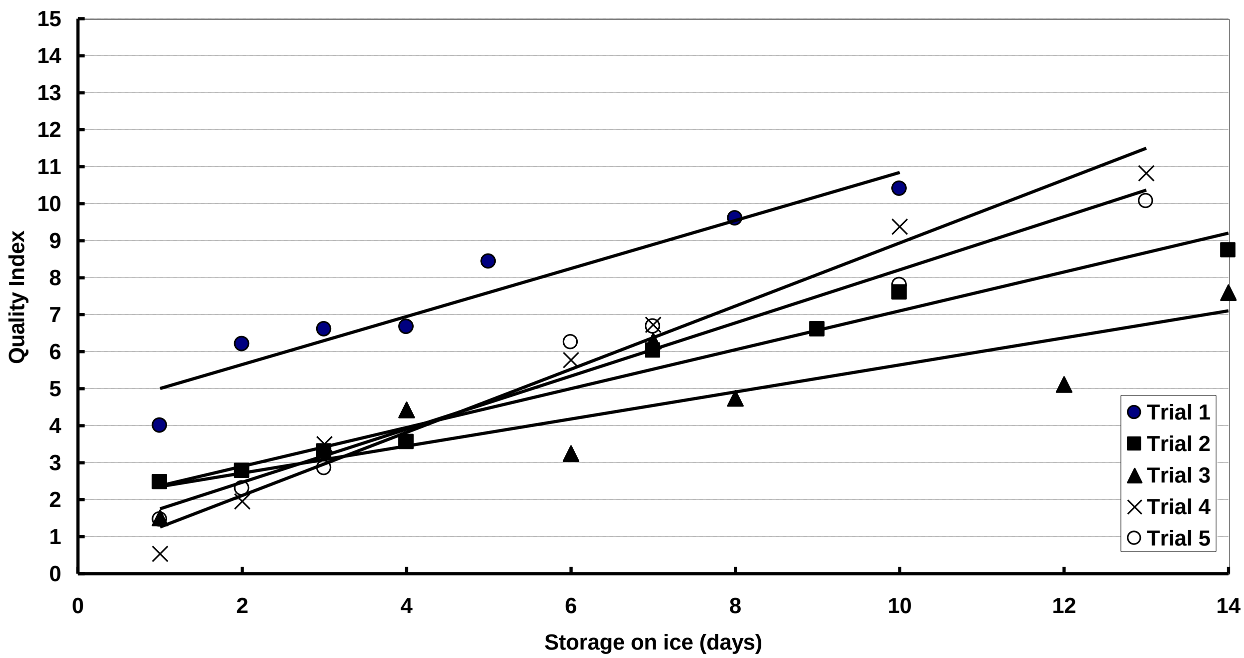
The R^2 values (Table 5.3.3) for trials 2, 4 and 5 data indicate very high correlation between QI score and number of days prawns were stored in ice. QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored, with product at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axes origin (0,0). For trials 1, 2 and 3 the offset (y intercept) is high showing that the starting QI score for these prawns reflects the pre-cook handling rather than storage time of prawn.

Table 5.3.3 Linear regression equations from all trials (sorted on best correlation).

	Equation	R^2
Trial 4	y = 0.8535x + 0.406	0.980
Trial 2	y = 0.5335x + 1.763	0.975
Trial 5	y = 0.7180x + 1.035	0.972
Trial 1	y = 0.6489x + 4.355	0.918
Trial 3	y = 0.3658x + 1.986	0.682

For practical use, a graph has been drawn using data averaged across trials 4 and 5 (Fig 5.3.3.). This is not statistically valid but depicts a functional QI that considers the greatest rate of spoilage, hence can be regarded as worst case scenario against which quality of others prawns can be assessed. The data from these two trials was selected on the basis that the slopes of the regression lines most closely approximate the theoretical straight line used as the assumption for QI schemes. Additionally, data demonstrated high correlation (R^2) between QI score and days prawns were stored on ice.

Figure 5.3.2 Quality index scores for all 5 trials of cooked prawns stored in ice.



Comparing trials, the rate of QI score increase – in rate order, low to high – was: trial 3, 2, 1, 5 and 4. The different rates achieved are concerning and the cause(s) of the variation needs to be established as, if real and inherent to cooked prawns, a QI scheme for such product could be dysfunctional in practise. It is worth emphasising that it is likely the overall prawn quality and its spoilage rate is influenced far more by pre-cooking handling and the cooking procedure itself than storage time.

It is of note that the melanosis parameter remains low scoring until day 7, after which storage time there is a significant increase in melanosis present. In none of these trials were the green prawns dipped in metabisulphite to inhibit blackspot occurring as the handling procedures prior to cooking minimised the prawn's exposure to air and oxygen is necessary for the enzymatic reaction of melanosis to occur. All prawns were stored on ice after cooking hence in the presence of available oxygen, however a satisfactory cooking time/temperature regime will denature the enzyme responsible for melanosis.

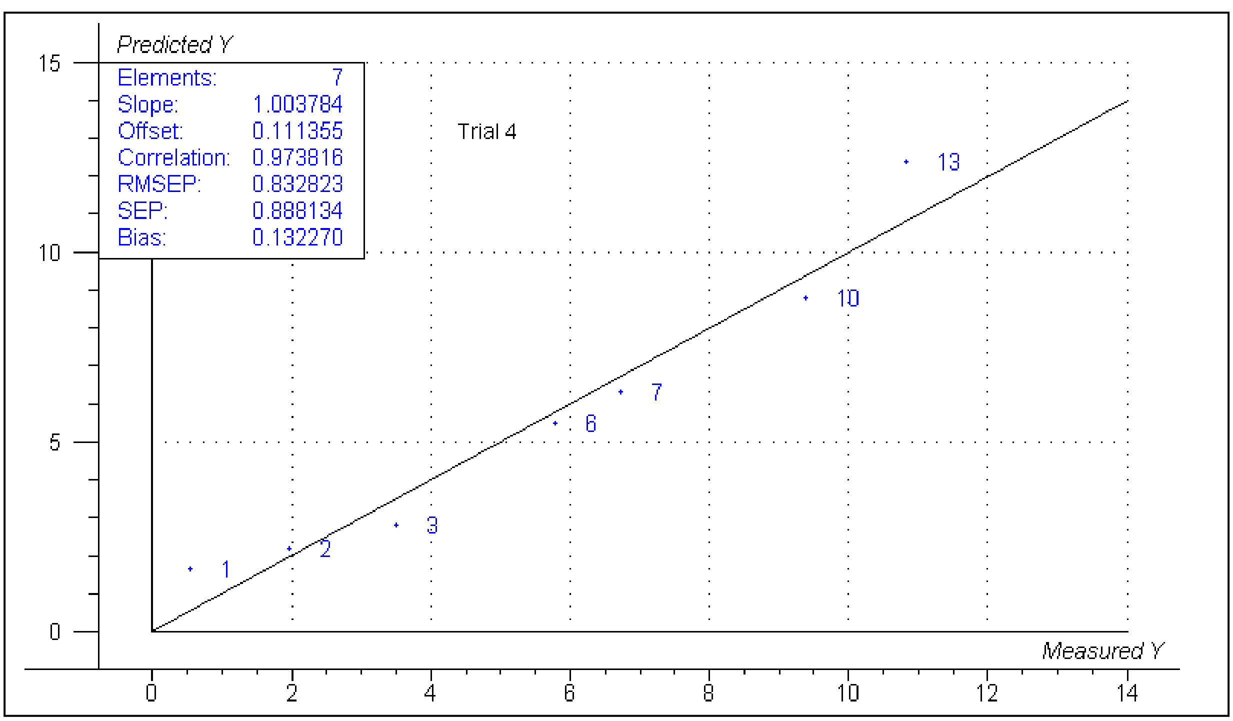
Analysis of assessor performance) looked at the average scores given by each assessor for all prawns assessed at a particular time. There was variation in the QI attained by different panel members for all trials and at all times but assessors were consistent individually. The range of scores given at any assessment time was fairly wide for most trials especially at the rejection point. Only in trials 4 and 5 was there a tight range shown at the first day of storage. Trial 3 showed anomalous results with the variability in the 6 to 8 day period being very high, related to the differing rate of change perceived by some assessors.

The variation between individual prawns within any one trial was demonstrated to be low which is in contrast to the casual observation of a batch of prawns. Trial 1 showed greatest variability between prawns in the early stages of the trial (these prawns were originally frozen IQF which may introduce variability due to thawing rates prior to cooking) whereas all other trials showed great consistency of quality among prawns for at least the first 7 days storage. In general, the variation in prawn variability on a particular assessment day seems similar across trials.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the 5 trials. For the purpose, time was used as a blocking factor and assessor and prawn were considered as two factors. This gives an overall measure of any assessor differences and prawn differences and more importantly, any interaction between prawn and panel member. For all trials there were significant differences between the overall QI score across all times given by each assessor and, for Trials 2 and 4, there was also significant ($P<0.05$) prawn QI score differences. However in both these trials there was no significant ($P>0.05$) interaction between prawns and assessor scores, indicating that each panel member is using a different part of the scale but is consistent across prawns. This implies that assessors were consistent individually in the scores each gave but not similar one assessor to another and hence suggests more training is required for agreement on judgements.

Predictability of QI was analysed using partial least square regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 8 quality parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. Data from Trial 4 is presented in Figure 6. Considering all trials separately, the QI of prawns can be used to predict the storage time in ice with an accuracy of ±1.1, 0.65, 1.9, 1.1, or 0.85 days respectively for Trials 1, 2, 3, 4, or 5. When trials 1 and 3 are omitted from calculations due to their outlying data, the average prediction for prawn quality by QI is ±0.87 days.

Figure 5.3.3. Standard error of performance of the prawn QI scores (data is from Trial 4)



5.3.12 Discussion and Conclusion

Handling practices of green prawns dictate the quality of the prawn at cooking point therefore the time zero QI score attained. Several attribute parameters commonly involved in adjudging prawn quality are dictated prior to cooking and do not change during storage after cooking. The outcome of this is that prawns may not achieve a QI of 0 immediately post-cooking and if such parameters are included in the overall QI scheme they will skew the apparent rate of deterioration.

Therefore for cooked product, a QI scheme should be developed using only those parameters that change with time during storage. As a tool for assessing quality, QI schemes for cooked seafood products have their limitations due to the fact that many 'typical' parameters frequently used to ascertain quality of that product are not relevant as they do not change over time.

A suitable QI scheme for cooked Black Tiger Prawns has been developed and published in the QI Manual.

5.4 Goldband Snapper (*Pristopomoides multidens*)

Trials were conducted by Sue Poole, John Mayze, John Nagle and Steve Nottingham Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton, Brisbane.

5.4.1 Preliminary trial fish

- fish were harvested from reef waters off the Qld coast near Rockhampton
- whole (gut in) fish were spiked, bled and stored in ice slurry (0^{o} – 1^{o}C)
- fish used for assessment were caught <24hr prior landing
- trucked from Rockhampton to Brisbane in a refrigerated truck, packed in ice in bins, therefore assumed fish 2 days old on receival at Cardinal Seafoods, Brisbane
- fish were picked up and transported to the lab in ice
- then stored in melting ice in insulated lidded bins (250L Xactics)
- temperature was monitored throughout storage trial

5.4.2 Pilot and assessment trial fish

- harvested by drop line (60-80m) from the Timor reef fishery 200km NE of Darwin
- whole (gut in) fish, (not spiked or bled) were stored onboard in an ice slurry (0^{o} – 1^{o}C)
- fish were from the last day's catch
- landed in port 24hrs later
- transported to NT Fish (Winellie, Darwin)
- packed out with 4-5 loggers included per box
- air-freighted to Brisbane and transported to lab
- stored in melting ice in insulated lidded bins (250L Xactics)
- temperature during storage was monitored

5.4.3 Samples

- 5 fish randomly selected for each assessment time
- each fish was coded with a random 3 digit number for identification
- each fish was assessed individually under standardised evaluation conditions on a stainless steel table at 22^{o}C under white fluorescent light

5.4.4 Assessors

- 6-8 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the pilot trial on the specific parameters by which gold band snapper was to be assessed
- assessors made individual judgements independently and their performance was analysed

5.4.5 Statistical data analysis

Averages at each time period were calculated based on the panellists average of the five fish and the fish average over the panellists. This allows comparison of the variability between fish and between panellists. Graphs were made of each of these so outliers could be spotted and trends examined.

5.4.6 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartlett's test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.4.7 Panellist variation and fish variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also showed if there was any interaction between panellists and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and fish, then the plotted graphs can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly, any interaction between fish and panel member.

5.4.8 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from Excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so X was QI and Y was days. Since QI is the sum of n parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter 't' comes from the AOV regression.

5.4.9 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system so as to be complementary to that system. Parameters for assessment were selected from those gained from previous experience of the spoilage pattern of ice-stored gold band snapper. Table 5.4.1 shows the QI scheme and lists the quality attributes for physical and visual parameters, as well as odour. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 3, where 0 implies "perfect". For any storage time, the scores were summed and all attributes summarized and noted as the Quality Index. The end of storage life was confirmed by taste testing of cooked (microwaved, as is) fillet flesh.

It was noted that the gold band snapper were rejected and considered "rotten" on physical parameters (visual and odour quality attributes, especially of the gills) before the cooked flesh from the same fish was rejected by off-flavour. This phenomenon occurred repeatedly and was judged to be the case by all assessors. It has also been observed to hold true in other storage life trials undertaken by the researchers (Poole *et al*, 1991 and unpublished data) both with gold band snapper and several other tropical reef species.

5.4.10 Pilot trial

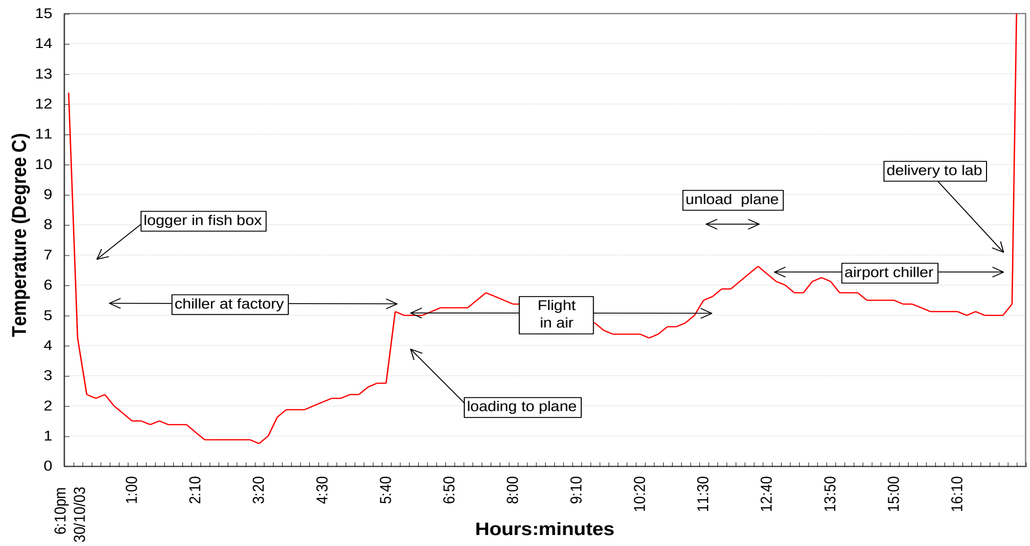
Assessors were trained in applying the quality index parameter scores to gold band snapper in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with gold band snapper throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category. During this trial the aptness and clarity of the descriptions for each quality attribute was confirmed.

Temperature of the fish was monitored from pack out in Darwin throughout transport to Brisbane (Fig 5.4.1). Graph shows the average of 4 temperature loggers positioned in one box. As illustrated the temperature of the fish during transport varied over a 5.5°C range, from 1°C in the factory chiller to a peak maximum for a very short time when the plane was unloaded in Brisbane. Significantly, with respect to spoilage rate of the fish, the temperature was between 4°C and 6°C for a total of 11 hours during air-freighting. To determine whether this elevated temperature over the period affected spoilage rate of the fish significantly, the model equation for spoilage of tropical fish (Dalgaard and Huss, 1997) was applied to the data. Calculations were made for each short time interval where the temperature changed and, although it is noted that the model has not been validated for fluctuating temperatures, the overall result indicated that during the 17 hours of transport the gold band snapper had a spoilage rate of 1.1 days. When analysing the data from the trials (see Assessment trial section) it was noted that the variation between fish and also between assessors far exceeded the slight increase in spoilage rate over the short transport period and so was not considered further. The temperature throughout storage in ice was monitored also and ranged from 0° – 1°C .

Table 5.4.1. Quality Index scheme for Gold Band Snapper

Quality parameter		**Description**	Score
Skin	**Colour /appearance**	Distinct yellow bands (when evident in fish >1kg). Bright &/or iridescent.	0
		Yellow bands less distinct. Loss of brightness &/or iridescence.	1
		Yellow bands not obvious. Dull &/or matt. Pink tinge on ridge or head.	2
	Scales	Intact and firm	0
		Easy to pull out	1
		Loose, falling out	2
	Slime (if present)	Clear	0
		Slightly cloudy	1
		Milky or opaque	2
	Odour	Fresh sea	0
		Neutral	1
		Not so fresh or cabbage or sour	2
		Off or rotten	3
	Texture of flesh	Firm, bounce when pressed	0
		Finger mark disappears slowly	1
		Finger mark remains over 3 seconds	2
Eyes	**Form (ignore popped or bulging)**	Convex	0
		Flat	1
		Sunken	2
	Cornea/jelly	Clear	0
		Cloudy or pink, orange tinge	1
		Fully opaque	2
	Pupils	Shiny jet black	0
		Dull black, slightly translucent, patchy	1
		Cloudy, grey	2
	Iris	White, pale gold, silver	0
		Pink, orange tinge	1
		Fully orange, burst	2
Gills	**Colour /appearance**	Red	0
		Dark red-brown &/or some discolouration	1
		Brown &/or discoloured	2
	Mucus	Transparent	0
		Milky	1
		Brown	2
	Odour	Fresh sea	0
		Not so fresh, stale	1
		Sour, vegetable, meaty, chemical	2
		Rotten	3
Quality Index			**0-26**

Figure 5.4.1 Temperature profile of consignment of fish



5.4.11 Assessment trials

Assessment trials were carried out with 3 separate batches of fish. In trial 1, assessments were carried out on 8 individual fish at each sampling time due to early miscommunication at the harvest point (Darwin) of the numbers of fish required for each trial. In the next assessment trials, 5 individual fish were assessed on each sampling day.

The QI was calculated for storage time and graphed against storage days to illustrate relationship. The QI was based on an average of all fish assessed within a trial to allow for biological variation between fish. It is seen from the separate trial graphs that early QI scores (up to day 7 or 8) were similar between trials however, from that day on the results from trial 2 (Fig. 3) conform to an exponential regression fit, whereas trials 1 (Fig. 5.4.2) and 3 (Fig.5.4.4) show the expected linear relationship. There was no obvious reason which explained the different shaped curve obtained in trial 2, although it is suggested that the continued lower QI scores in trial 2 may be caused by fish being stored in a 'too cold' ($\leq 0^oC$) ice slurry immediately post-harvest. Such onboard handling practice variances are common occurrence within the fishery and usually dependent on boat equipment and skipper/crew experience. As confirmation of this trial data's validity was unable to be undertaken, the data was not considered further within the analyses.

Comparing the data obtained from trials1 and 3, statistical analysis (using 2-tailed F test) proved that both regression lines had the same order of accuracy (were not significantly different P>0.01). However, the slopes and intercepts are different between the trials and hence statistical criteria are not met sufficiently to allow 'pooling' of the data from both trials. Differences in regression line slope was also observed by researchers using the QI method on Atlantic salmon (Sveinsdottir *et al*, 2002).

Figure 5.4.2 QI for trial 1 showing scores averaged across fish and assessors (bars indicate standard deviation)

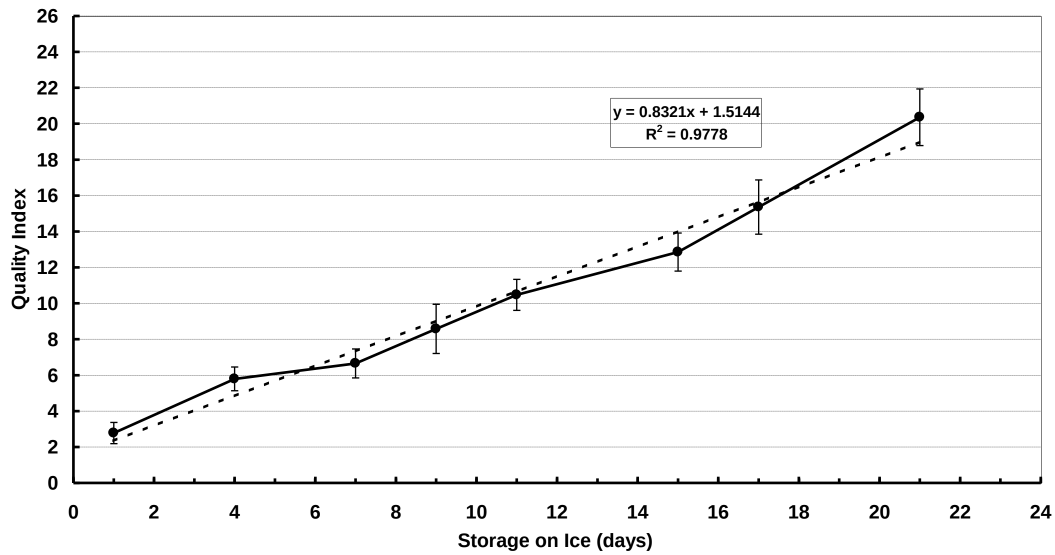


Figure 5.4.3. Quality Index for Trial 2 showing scores averaged across fish and assessors with bars indicating standard deviation

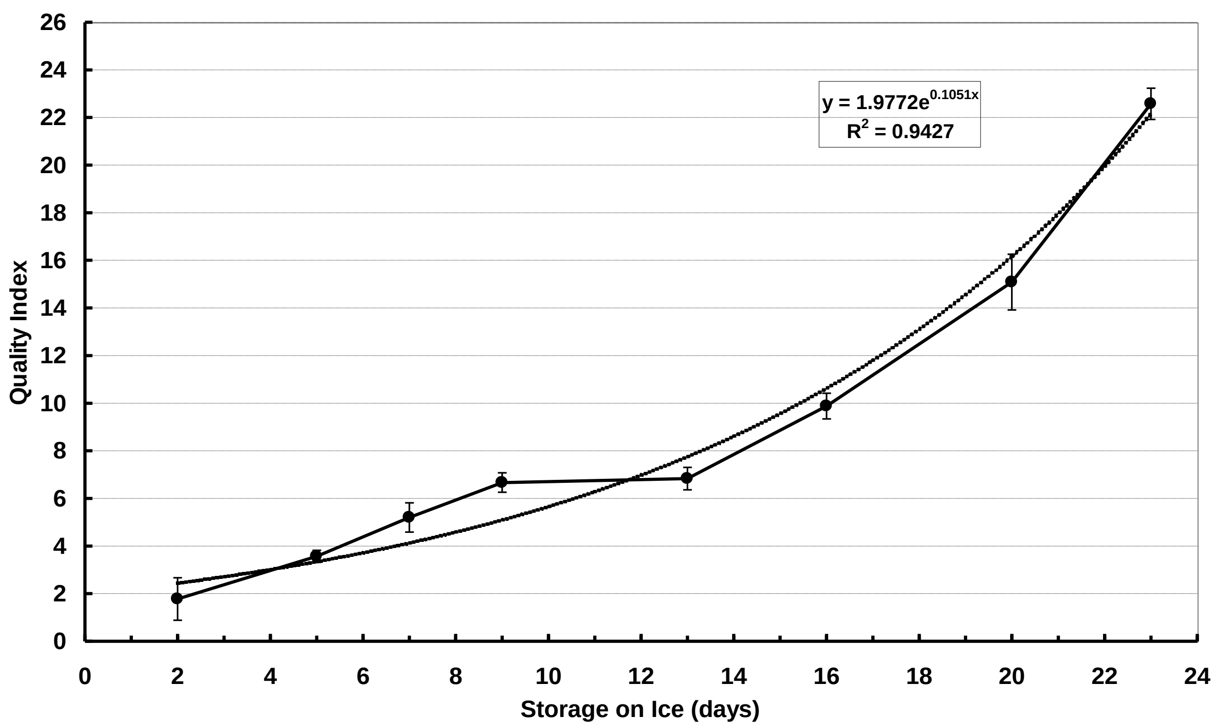
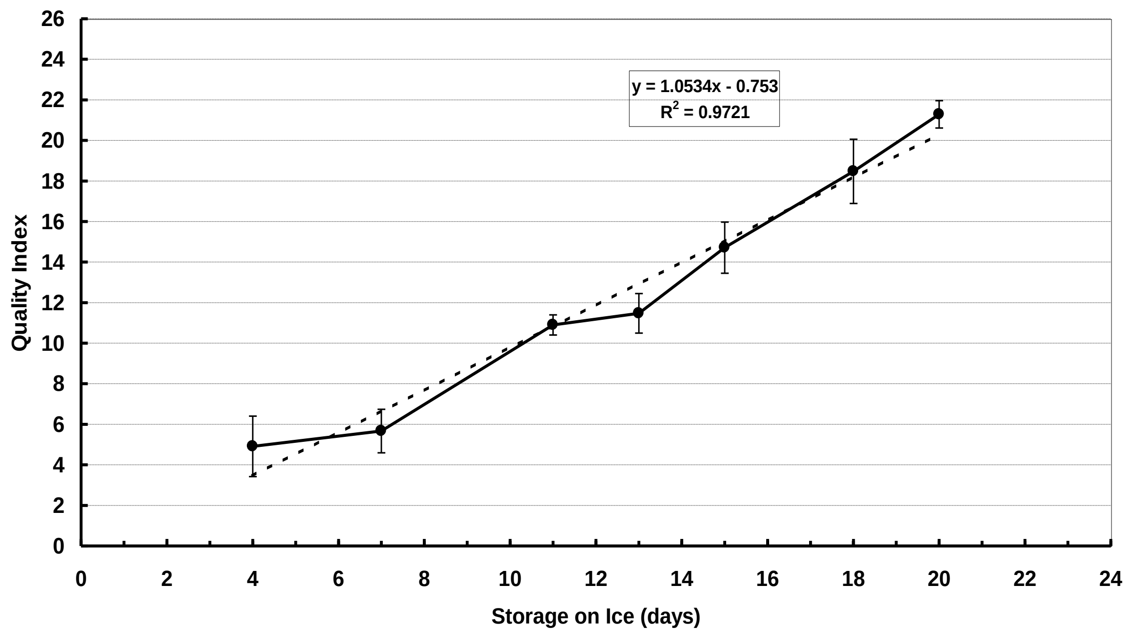


Figure 5.4.4. Quality Index for Trial 3 showing scores averaged across fish and assessors with bars indicating standard deviation.

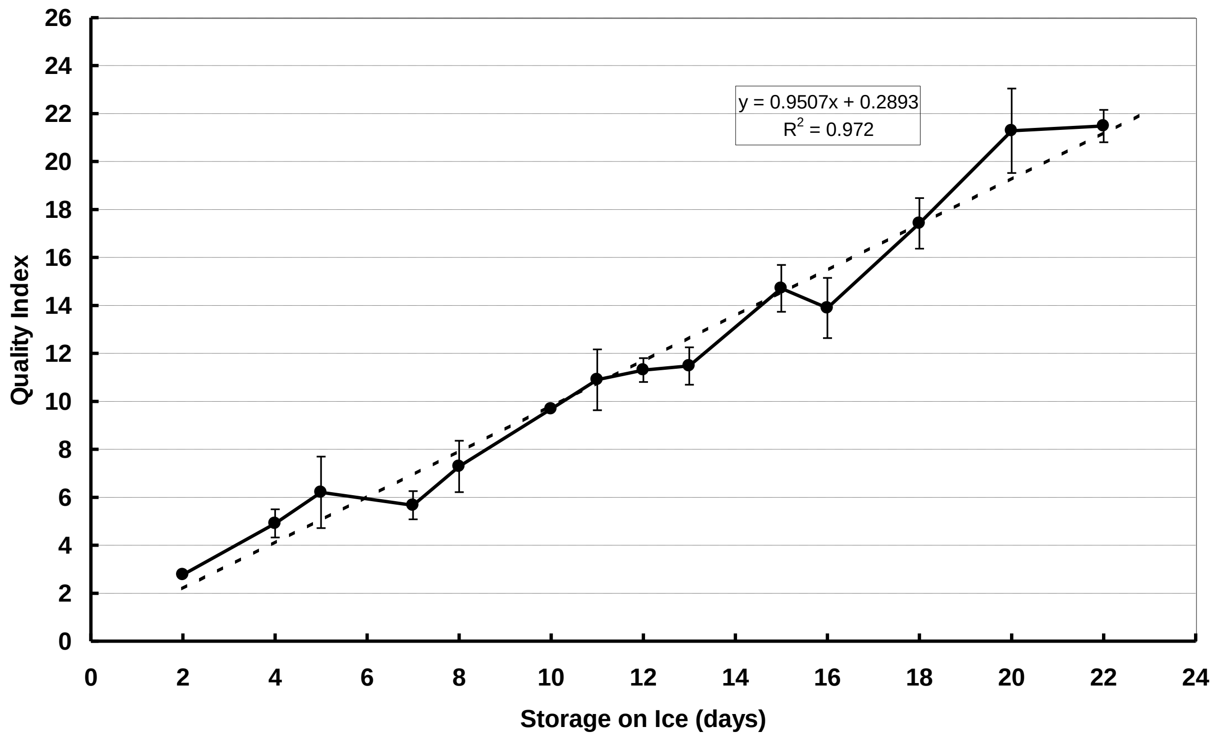


For trials 1 and 3 there was high correlation between QI score and days fish were stored in ice, with R^2 of 0.978 and 0.972 respectively. QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored, with fish at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axes origin (0,0), which was not attained in these trials. If the line is forced through the origin, the correlation between QI and days stored is lower and the slope changes.

In no trial did the QI reach the maximum possible and yet the fish were stored to rejection point and a little beyond. It is suspected that this occurs due to assessors being individually reluctant to use the extreme points within a parameter category. This is a frequently observed phenomenon (Steve Nottingham, pers.comm.) and should not detract from the usefulness of the data obtained. Interestingly, similar occurrences are reported in many QIM schemes sighted (see Sveinsdottir *et al*, 2002: reached 17 of maximum possible of 24; Sveinsdottir *et al*, 2003: 19 of max 22; Andrade *et al*, 1997: sardine: 24 from max 30; horse mackerel: 18 from max 29; Atlantic mackerel: 26 from max 29).

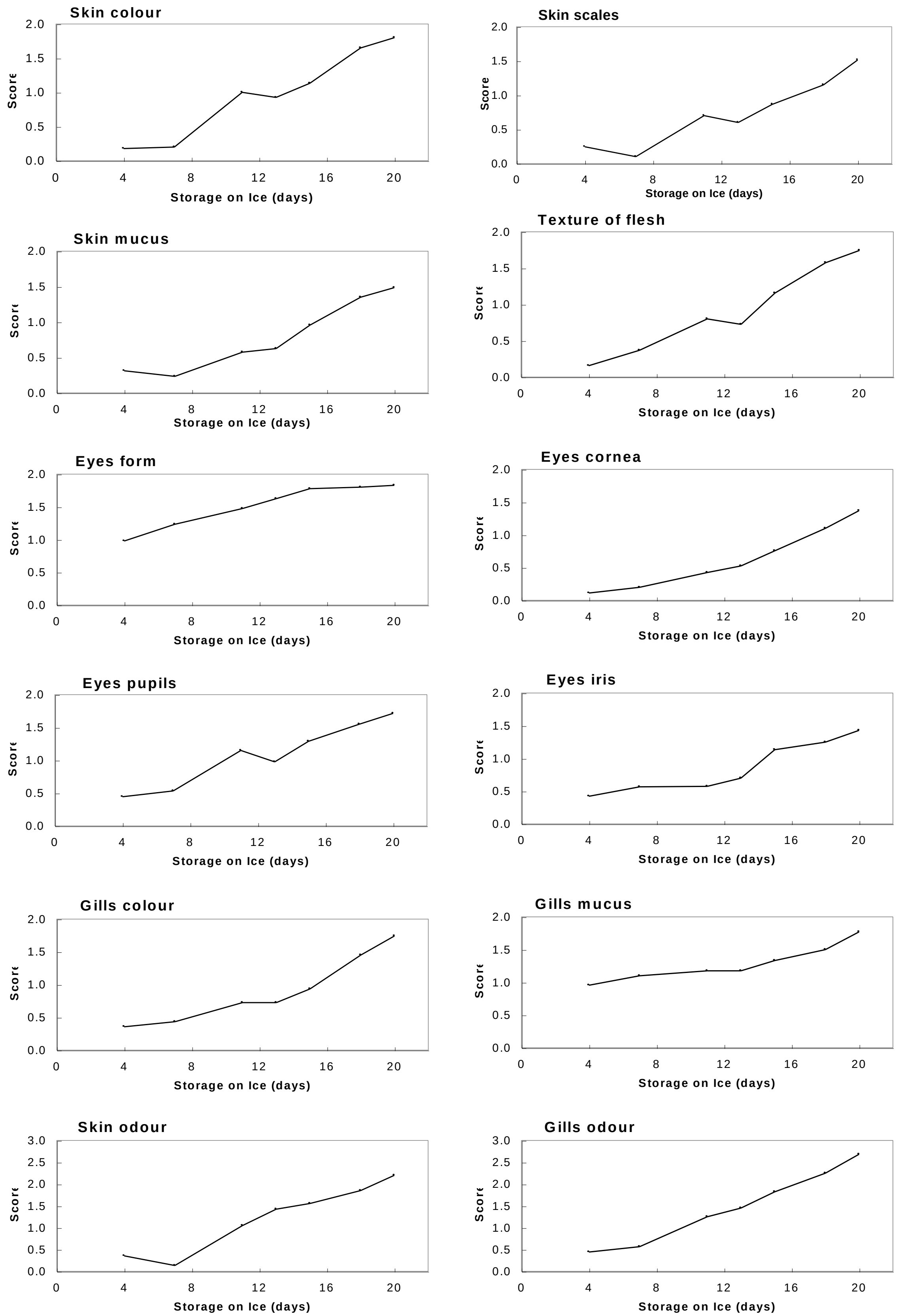
For practical use, a graph has been drawn using data averaged across trials 1 and 3 (Fig 5.2.5). This is not statistically valid but depicts a functional QI.

Figure 5.4.5. Quality Index for averaged data from Trials 1 and 3.



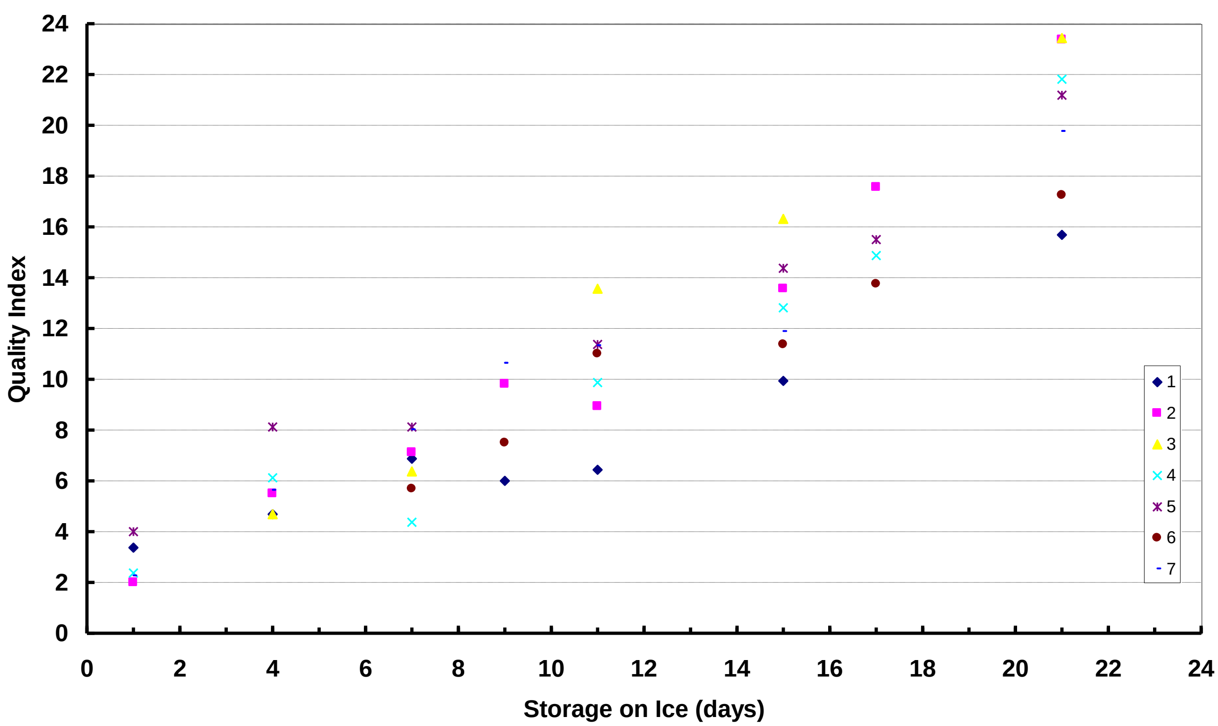
The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials and their worth is also shown in Figure 5.4.6 where scores given for each increased over time. A couple of parameters, namely the yellow banding (skin colour) on the head and body and the eye cornea varied greatly between individual fish. It is considered likely that such differences result from handling differences at point of harvest, for example varying time from capture to slurry immersion, different slurry temperatures.

Figure 5.4.6. Scores for individual assessment attributes over time (taken from Trial 3)



There was variation in the QI obtained by different assessors for each trial, however each assessor was consistent over the days assessment occurred. Trial 1 data showed that variation between assessors increased as storage time increased (Fig 5.4.7), indicating that assessors were in better agreement when the fish were very fresh. Near the end of storage life, individual assessor interpretation of parameter category was of greater importance, illustrated by greater variation between assessor scores. This may be overcome with more training of assessors, but is also likely to be typical of industry personnel assessments. In trial 3 (not depicted here), the variation remained reasonably constant over storage time of the fish and this is likely to have occurred due to assessors being more familiar with the spoilage pattern of gold band snapper and experienced in the QI scheme during this last trial (ie they were more trained than for trial 1).

Figure 5.4.7. QI scores given by individual assessors during storage of fish in ice.



The trial assessment results were analysed using partial least square regression (PLS) with full validation which provides a predictability of QI. The standard error of prediction (SEP) is also generated evaluates the precision of the predictability. Since the QI is the sum of 12 quality parameters assessed, the SEP can be assumed to be normally distributed and a 95% confidence interval estimated. The PLS regression analysis showed that the QI for gold band snapper predicted storage time on ice with an accuracy of ±1.65 days in Trial 1 and ±1.75 days in Trial 3 (Figures 5.4.8 & 5.4.9 respectively). Given that Trial 1 data was generated from 8 fish as opposed to 5 fish in Trial 3, it could be expected that predictive accuracy is better for trial 1, as demonstrated.

The precision of predictability for any QI correlating to days stored on ice for gold band snapper is very good and compares favourably with the predictability of researchers with other species. For Atlantic salmon, storage time was predicted by the QI ±2 days when 3 fish were assessed (Sveinsdottir *et al*, 2002), however greater accuracy was achieved (±1.4 days) when 5 fish were assessed in the QIM (Sveinsdottir *et al*, 2003).

Figure 5.4.8 Standard error of performance of the QI scores in Trial 1.

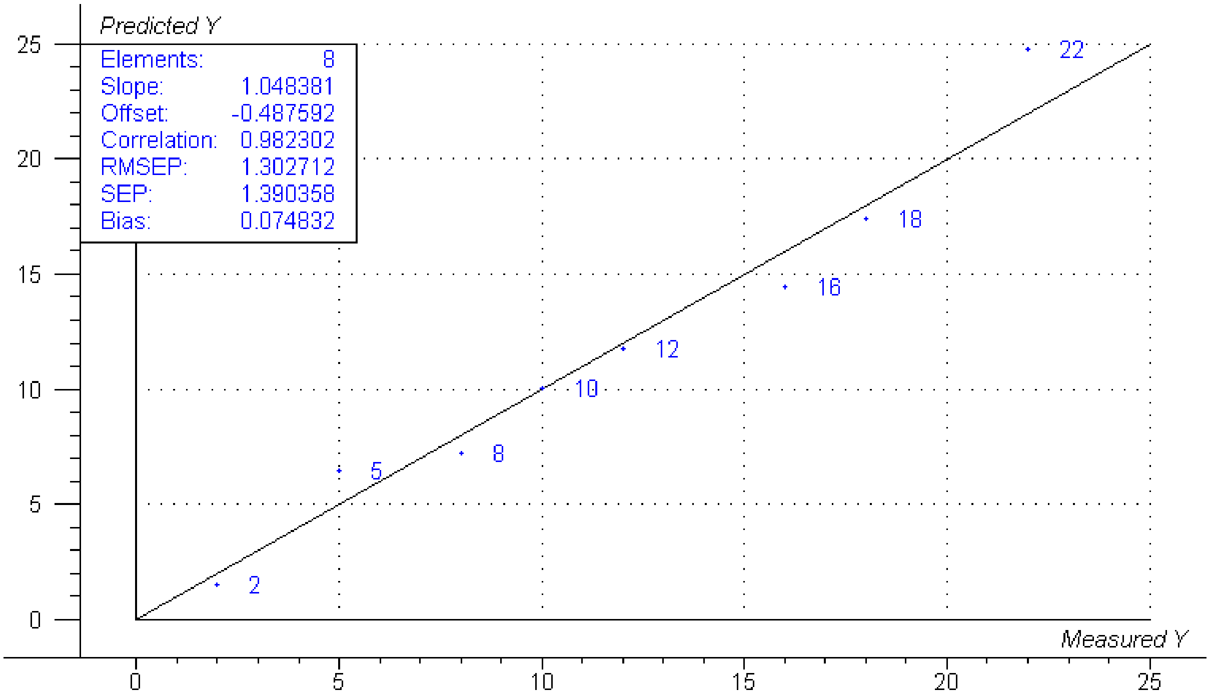
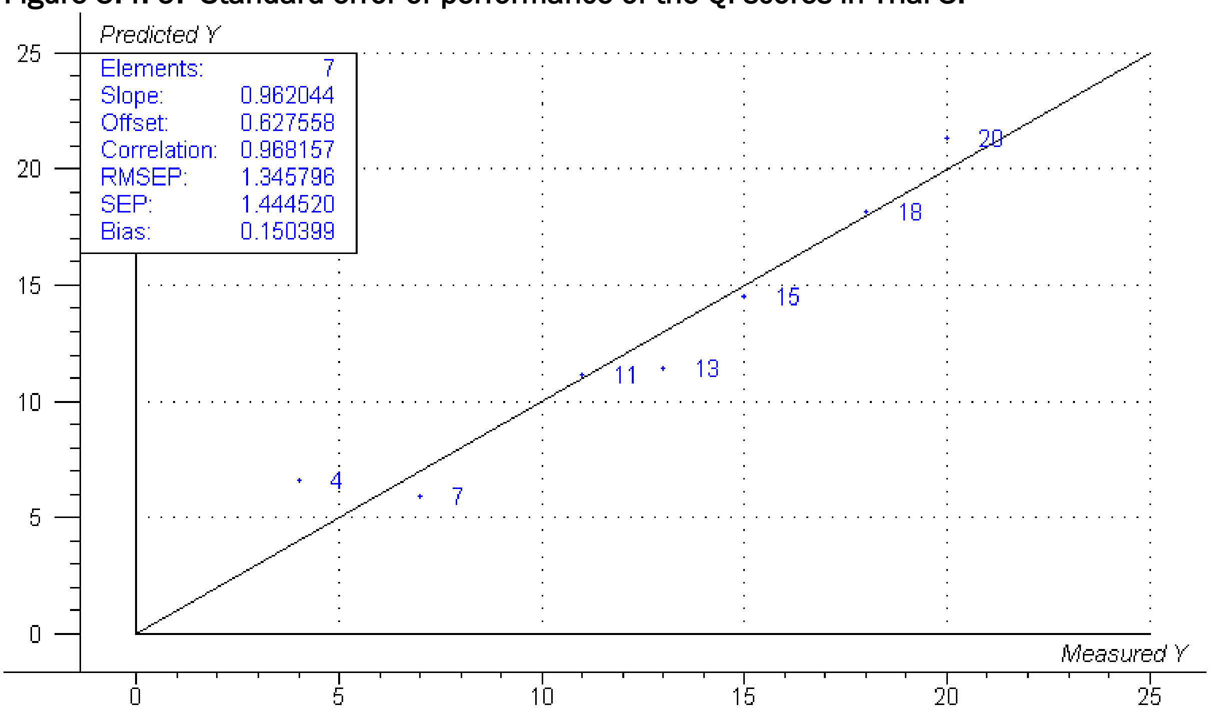


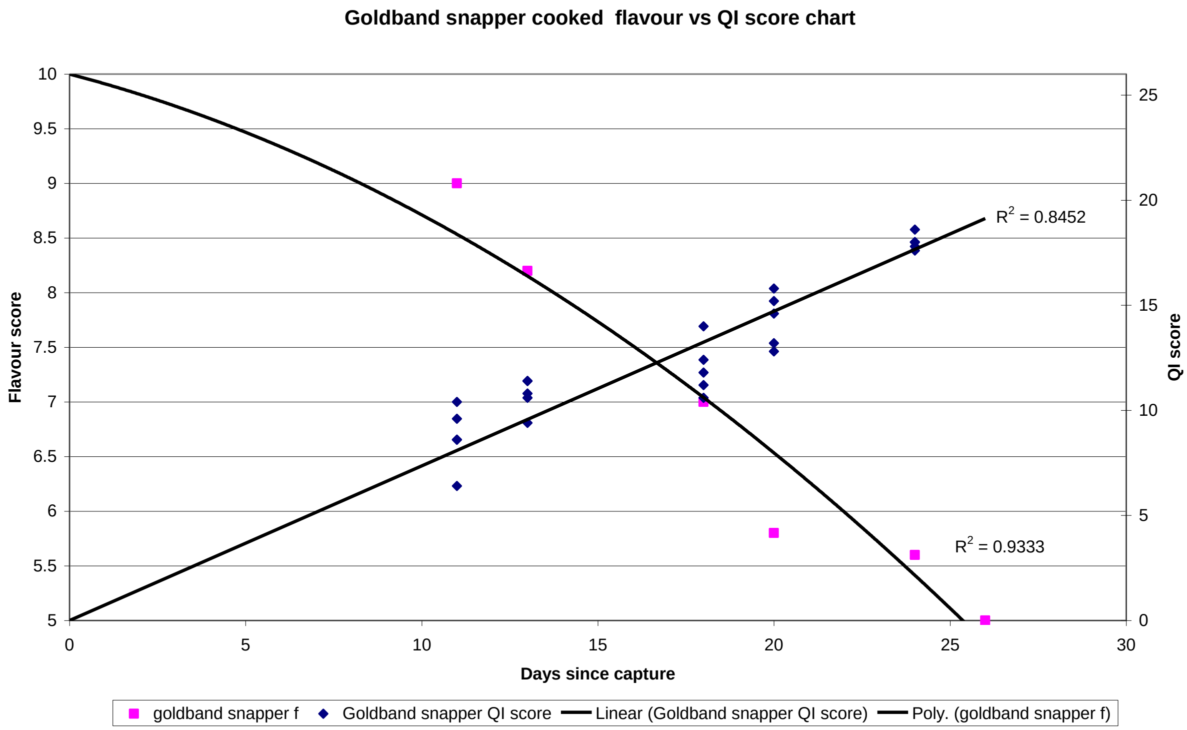
Figure 5.4. 9. Standard error of performance of the QI scores in Trial 3.



5.4.12 Comparison of cooked flavour scores, QI scores and Icedays.

The plot of the Torry scheme scores for cooked flavour resulted in a curvilinear relationship with both QI and Icedays (Figure 5.4.10).

Figure 5.4.10 Comparision of Torry cooked flavour scores and QI scores plotted versus Icedays for cooked flesh of Goldband Snapper (*Pristipomoides multidens*)



5.4.13 Conclusion

A practical QI scheme and graph of QI score versus days on ice for Gold Band Snapper has been developed, tried in practice and is published in the QI Manual.

5.5 King Prawns (Cooked) (*Melicertus plebejus*)

Trials were conducted by Sue Poole, John Mayze, Carlo Paulo and Steve Nottingham Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton , Brisbane.

5.5.1 Preliminary trial prawns

The preliminary trial was carried out with prawns obtained as soon after landing as possible and then stored in flaked ice to observe typical changes in attributes over time. From these observations, specific descriptors were determined and agreed as describing the particular attributes at any point of storage.

- all prawns used were harvested from inshore waters off Northern NSW and were from the last catch of the night (early morning)
- prawns were cooked onboard according to commercial practice
- separate batches used in different trials were from different prawn trawlers
- prawns were <12hr from harvest prior to assessment
- cooked prawns were landed at Clarence River Fisherman's Co-operative, packed in ice in foam polystyrene boxes and couriered to IFT, Hamilton by refrigerated truck
- at receival, prawn temperature was noted (1^0C)
- prawns were then transferred and stored in melting ice in draining lidded bins held in a temperature controlled environment (2°C room)
- temperature of the prawns during storage was recorded to monitor required holding temperature. Prawns were checked daily and re-iced as needed.

5.5.2 Pilot and assessment trial prawns

The pilot trial was undertaken to train the assessors in the meaning of each descriptor used for the different attributes of the prawns and to confirm agreement that descriptors were appropriate and universally understood. Prawns used were obtained, handled and stored as for the preliminary trial.

5.5.3 Samples for assessment

Three separate trials were carried out to provide the quality index assessment data to build the model. Photographic records were obtained each day of assessment.

- 50 prawns were randomly selected for each assessment time and each assessor rated 5 individual prawns
- each lot of prawns were coded with a random 3 digit number for identification
- each prawn was assessed individually under standardised evaluation conditions in booths in the sensory evaluation unit

5.5.4. Assessors

- 8-10 assessors were used for each assessment

- assessors were selected for their expertise and previous experience in sensory assessment of prawns
- additionally, all assessors were trained in the pilot trial on the specific parameters by which the prawns were to be assessed
- assessors made individual judgements independently and their performance was analysed

5.5.5. Statistical data analysis

Statistical analysis was undertaken using various methods and analysing for the effect of different variables. Averages at each time period were calculated based on the panellists' average of the five prawns and the prawns' average over the assessors. This allows comparison of the variability between prawns and between assessors

5.5.6 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartlett's test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.5.7 Assessor variation and prawn variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also shows if there was any interaction between panellists and time. Assuming prawns were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and prawns, then the plotted graphs can also show variation between individual prawns at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and prawns were considered as two factors. This gives an overall measure of any panel member differences and prawn differences and more importantly, any interaction between prawns and panel member.

5.5.8 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from Excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so *x* was QI and *y* was days. Since QI is the sum of *n* parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter *t* comes from the AOV regression.

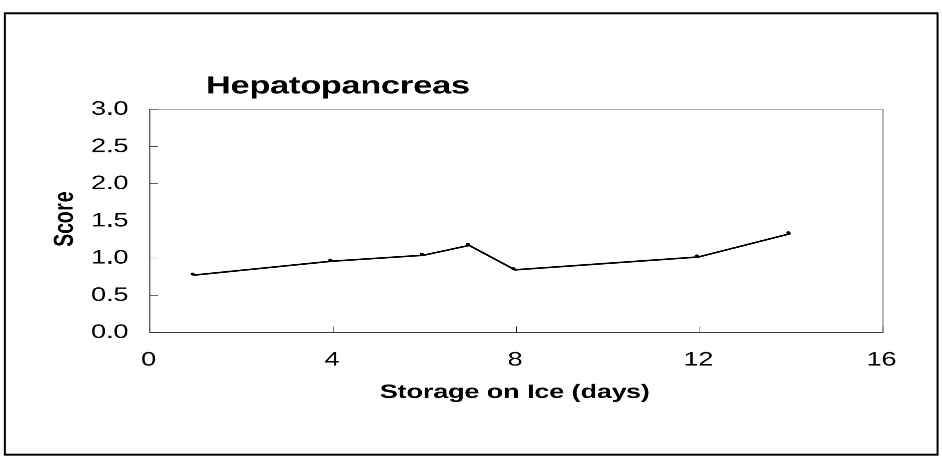
5.5.9 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system so as to be complimentary to that system. Parameters for assessment were selected from observation of spoilage changes during the preliminary trials and those attributes mentioned by Hampongkittikun *et al* (1995). Initially, assessment parameters chosen included attributes commonly used in assessing overall quality of cooked prawns, such as:

- the shell hardness - relates to moult stage and influences spoilage rate
- degree of flesh shrinkage – indicates overcooking
- melanosis visible in cooked prawn – is a function of pre-cook handling
- state, colour of the hepatopancreas – dictated by cooking procedure

Early observations showed that scores for most attributes chosen did increase over time and this was reflected in the QI attained, however at the point of rejection (as established by taste test) the QI score was well below the maximum which should theoretically occur at this point. Looking at the change for each attribute individually, it was evident that the parameters listed above were not changing with time, their given score remaining the same throughout the trial (example depicted in Figure 5.5.1).

Figure 5.5.1. Example of attribute taken out of assessment sheet.



Hence it was concluded that these attributes are not influenced by storage but are pre-determined prior to or at cooking. Consequently, these attributes were dropped from the list and a shortened assessment sheet developed based on only those attributes that changed with storage time.

Table 5.5.1 gives the final QI scheme developed for King prawns and lists the quality attributes for physical and visual parameters, as well as odour, flavour and texture. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 2 (3 in the case of flavour) where 0 implies “perfect”. For any storage time, the scores were summed and all attributes summarized and noted as the Quality Index. The end of storage life was confirmed by taste testing the prawns as this is common practice with wholesale and retail buyers.

5.5.11 Pilot trial

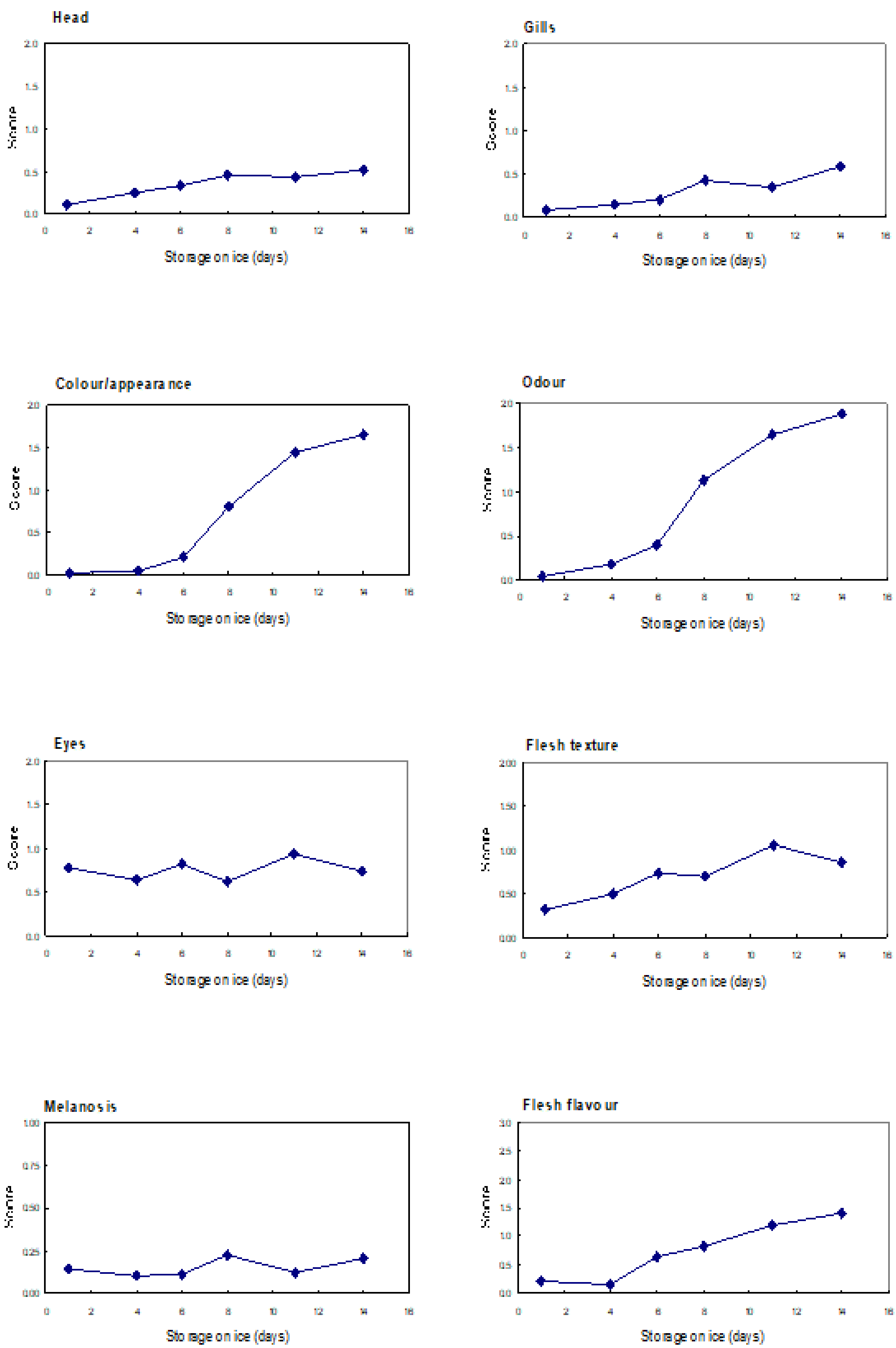
Assessors were trained in applying the quality index parameter scores to the prawns in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with prawns throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category. During this trial, the aptness and clarity of the descriptions for each quality attribute was confirmed. Further observation of the ‘dropped’ attributes were made as well, to establish agreement by assessors that the particular attributes, while related to overall quality of the prawn, were inappropriate for the QI scheme as they did not change with storage. The parameters finally chosen for assessing the prawns were demonstrated to be effective and weighted proportionately. Increase in score for each parameter over storage time is depicted in Figure 2.

The melanosis parameter did not change over storage time indicating that the prawns were cooked to a temperature effective in inactivating the phenyloxidase enzyme responsible for blackening. Of the other attributes, only two reached their maximum score – those of ‘colour/appearance’ and ‘odour’. For the other attributes assessed, there was an increase in score with storage time but not to full demerit. It is suggested that this arises from the cooked nature of the prawns where microbial load has been severely reduced and contamination of bacteria capable of spoilage is introduced only from the storage ice. This conclusion is supported by the prawn flesh flavour not attaining “rottenness” while the odour did. For King prawns handled under conditions as in this trial, eye shape nor colour changed with a trend but rather varied between individual prawns.

Table 5.5.1. Quality Index Scheme for King Prawn

Quality Parameter		Description	Score
	Colour/appearance	high sheen / bright & iridescent	0
		dull	1
		faded / pink sheen	2
	Shell feel	smooth	0
		sandpaper	1
	Head	firmly attached	0
		slightly drooped or loose	1
		loose / membrane broken	2
	Eyes	dull black / charcoal / evenly bulbous	0
		mottled / slightly sunken	1
		dull / mottled / sunken	2
	Melanosis	no melanosis	0
		melanosis present	1
	Gills	white / pink tinge	0
		slight grey	1
		dark grey	2
	Odour	fresh sea	0
		neutral / slightly off	1
		stale / musty / off / ammonia	2
Taste	**Flesh texture Initial bite**	springy / firm	0
		slightly soft	1
		soft	2
	Flesh texture After chewing	springy / firm	0
		soft	1
		tough / chewy / fibrous	2
	Flesh flavour	fresh prawn / sweet	0
		bland / minimal prawn flavour	1
		no flavour	2
		off flavours	3
Quality Index			**0-19**

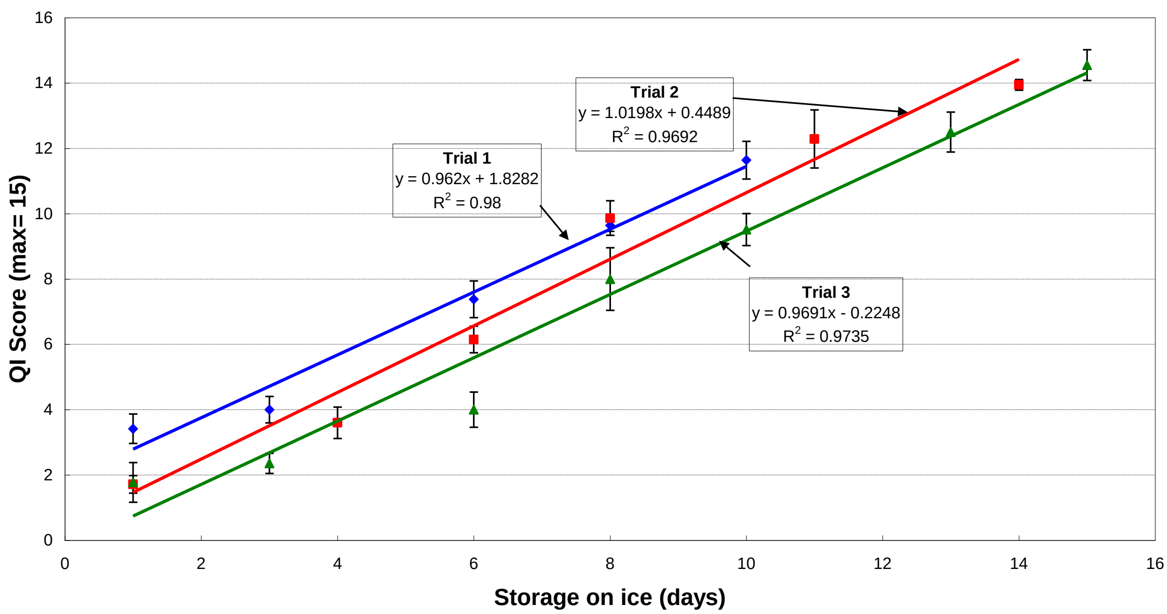
Figure 5.5.2. Scores for individual attributes over time (taken from one trial only)



5.5.12 Assessment trials

In all trials, 5 individual prawns were assessed by each assessor on each sampling day (n=50) hence the data set is strong and allows for biological variation between prawns. The QI was calculated for each storage time and plotted against days stored in ice to illustrate relationship (Figure 5.5.3).

Figure 5.5.3. Quality index scores over time for 3 separate trials.



From Figure 3 it is seen that data from the separate trials produce regression lines that are similar. Regression analysis illustrates that data from all trials is poolable and that QI can be significantly predicted by the day. A graph combining all data could be prepared and compared to the theoretical trend line using a chosen QI for end of shelf-life at around 15 days.

However, a significant effect of trial was observed. This effect could come from different sized datasets between trials:

- trial 1 - 5 assessments between day 1 and day 10
- trial 2 - 6 assessments between day 1 and day 14
- trial 3 - 7 assessments between day 1 and day 15

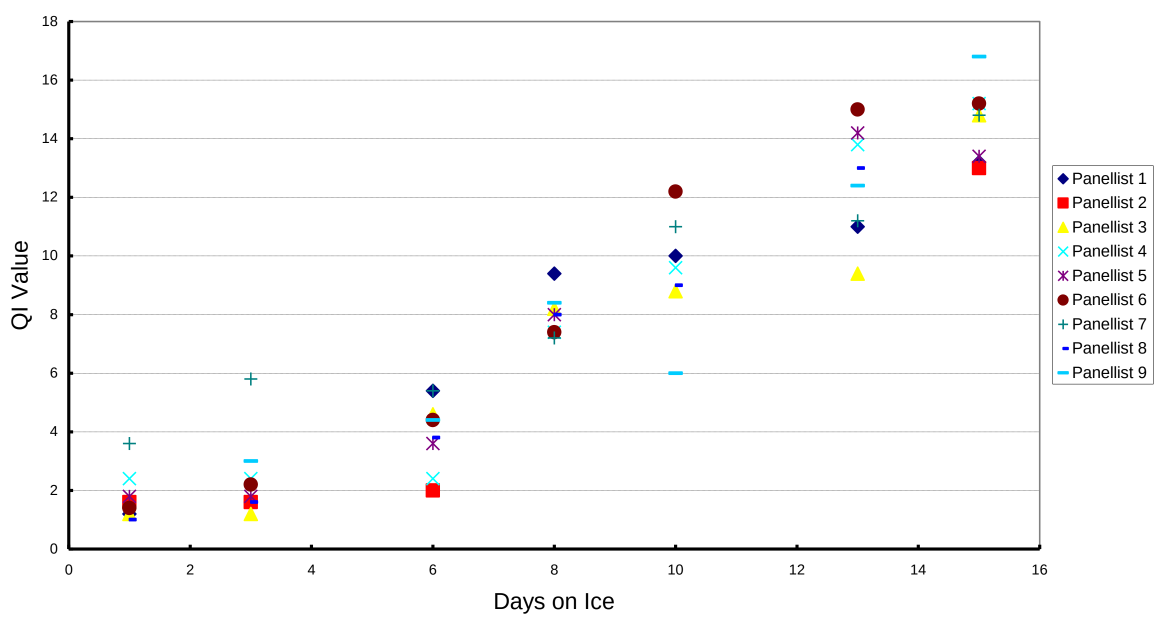
It is observed that prawns in trial 1 had a high initial QI on day 1 compared to trials 2 and 3 and were rejected by assessors sooner than for the latter trials. This would suggest that prawns in this trial were not handled according to industry best practice immediately post-harvest. The trial data was retained within the analyses because the rate of spoilage of these prawns was similar to that of other trials as indicated by the slope of the regression line

(Fig.3). In previously reported studies with cooked prawns (farmed black tiger prawns, Poole *et al*, 2003), the effect of pre-cooking treatment and handling of prawns was noted as strongly dictating the rate of spoilage of product during ice-storage. It is interesting to note that despite different QI starting points at day 1, the rate of spoilage was similar for all trials. Considering prawns for trials originated from different boats, this suggests that there is a common best practice handling happening within this fishery, of which the skippers can be proud. The nature of cooked product storage is indicated by QI scores not increasing very much during the first 3-4 days of storage. This is likely due to cooking temperatures reducing microbial load severely and inactivating enzymes within the prawn flesh.

5.5.13 Assessor variation and consistency

Depiction of variation between assessors (Figure 5.5.4) present the average for each panel member across all fifty prawns assessed at a particular time. Only those panel members present for at least 50% of all assessments were included.

Figure 5.5.4. QI scores given by individual assessors during storage of prawns in ice (data taken from trial 3)

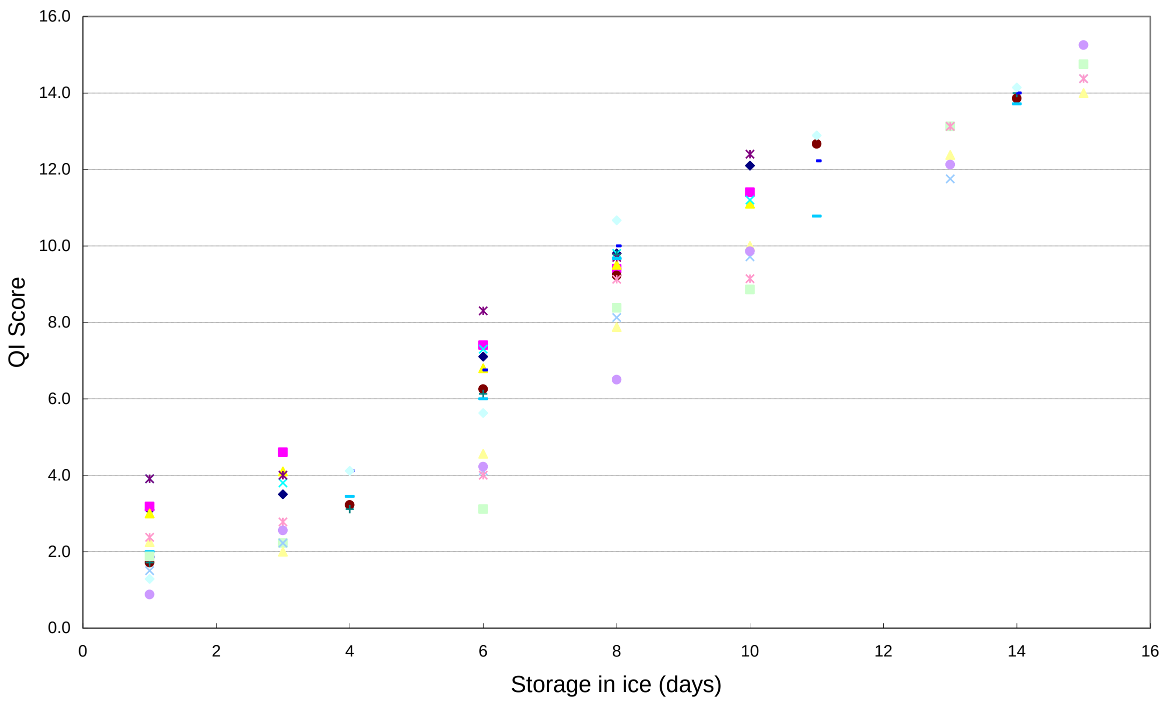


The variation in the QI obtained by different assessors across all trials was similar for all trials with least variation on day 1. However, assessment scores were consistent for any one assessor indicated by an individual always assessing high or always assessing low. Variation between assessors on any one sampling day was greater in these cooked prawn trials than is observed for ice-stored fish trials. This is likely due to individual assessor preference in flavour on a particular day and/or results from a greater number of prawns sampling at each sampling time compared to fish trials.

5.5.14 Variability between prawns

Data depicted in Figure 5.5.5 uses the average of all assessments for each prawn and presents the mean with the standard deviation at each sampling time.

Figure 5.5.5. Variation in QI for all prawns assessed (from all trials)



The variation across trials was comparable but it is still interesting to note that:

- for the first assessment (day 1) for each trial, the prawn variation is above the regression line
- for the second assessment for the three trials and even the third assessment session for trial 3, the prawn variation is below the regression line

This suggests that a regression line is not the best model to represent the deterioration of these prawns. Spoilage of any seafood product in ice is unlikely to follow a straight-line model and in fact is usually sigmoidal due to its biological nature. However, QI scheme development is based on an assumption of straight lie relationship between demerit score and days stored in ice hence it is not expected that data points will fit the trend exactly. For these trials, the regression equation for each trial yields similar values and a similar trend with a close correlation between QI score and days in ice (r^2 of 0.98, 0.97, and 0.97 respectively for trials 1, 2 and 3).

5.5.15 Analysis of variance comparing variation between fish and assessors

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the 3 trials. For the exercise, time was used as a blocking factor and panel member and prawn were considered as two factors. This gives an overall measure of any panel member differences and prawn differences and more importantly any interaction between prawn and panel member. Note however that as each panellist assessed five different prawns, this analysis is not as powerful for estimating the panel performance and consistency.

For all trials there was no significant difference between the overall QI score across times for the prawns. Also in all 3 trials, there was no significant (P>0.05) interaction between prawns and panel member scores. This means that each assessor's average score is different but they are consistent across all prawns.

5.5.16 Predicted and measured using partial least square regression

Predictability of QI was analysed using partial least square "inverse" regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis the QI of King prawns can be used to predict the storage time with an accuracy of ± 1.3 days. (Figure 5.5.6, the numbers associated with data points on the graph indicate days of storage of fish in ice).

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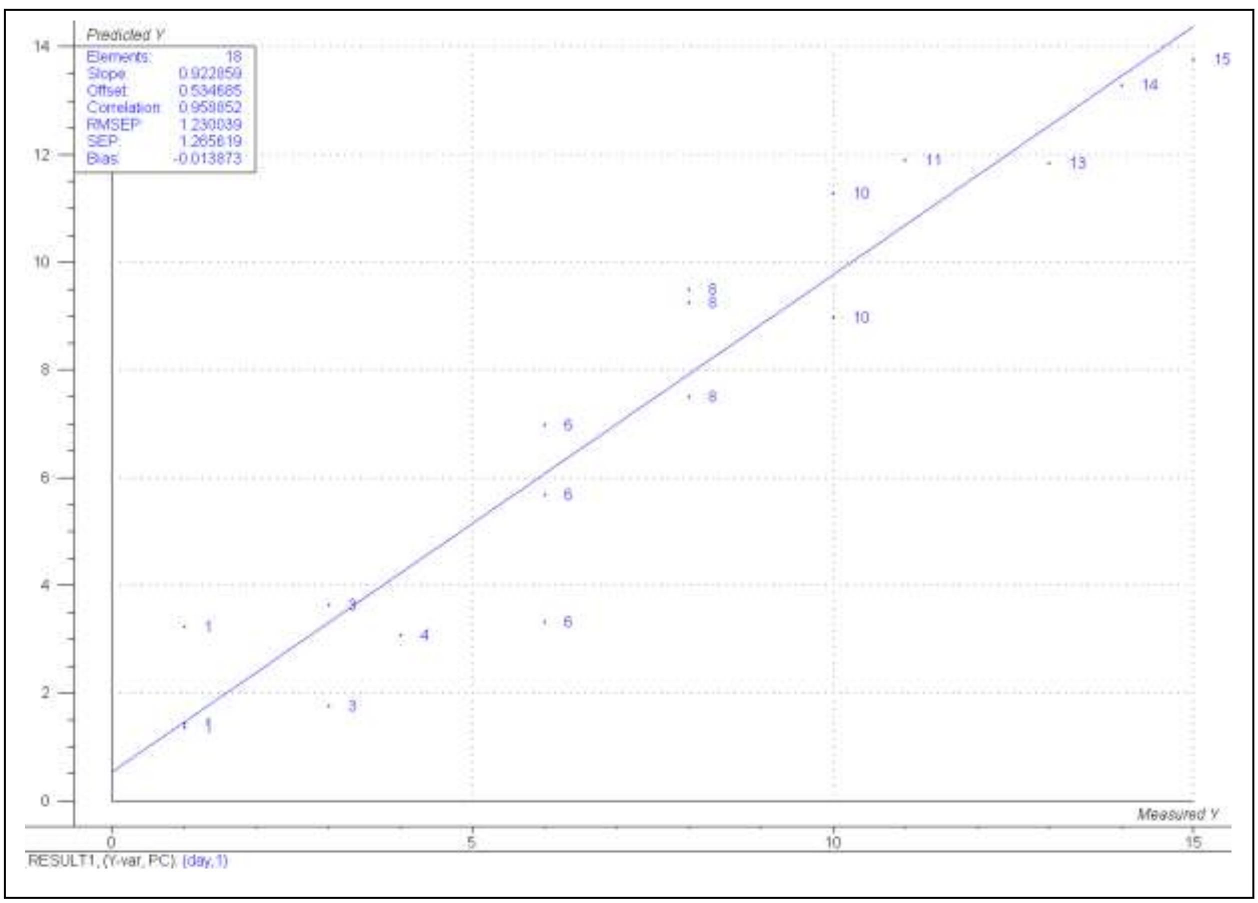
Figure 5.5.6. Standard error of performance of King prawn QI scores.



5.5.17 Conclusion

Data from trials 1, 2 and 3 were pool-able thus giving one regression line and 95% confidence intervals to predict storage time with an accuracy of ± 1.3 days. This is based on a total of 18 assessments within 3 trials and assessors judging 5 different prawns at each time.

5.6 Pink Ling (*Genypterus blacodes*)

This trial was done by Dr Felicia Kow and students at the Australian Maritime College (AMC), Beauty Point, Tasmania.

The Pink Ling batches used in the assessments were in the head-on, gill-in, gutted state. Sensory assessment included visual, odour and texture parameters for all possible features specific to this species product form. Experienced seafood assessors, 6 to 11, were used at each time to ensure that assessment data from a total of 6 assessors were available for analysis throughout the trial. A total of five separate fish were assessed at each sample time and samples were taken 8 times at 2 to 3 days intervals, throughout the storage period.

5.6.1 Pilot investigations

Fish with a known harvest-handling-storage history have been obtained and stored in melting ice. Ice Time was calculated using the Ice Time Calculation Method (Olley, J 1978). At regular intervals (2-3 days) the fish were assessed for their sensory characteristics and relevant descriptors were listed for each stage throughout storage. The score sheet developed from this pilot investigation is presented in Table 5.6.1. Further, electronic images were capture at each corresponding stage.

A minimum of 40 fish samples for the two full scale trials were obtained at point of harvest, assessed where possible and transported as soon as possible to the seafood labs at Beauty Point, Tasmania. Transport containers included temperature data loggers to capture storage history. In fact these data loggers were place immediately after the fish have been landed to monitor the core temperature of fish throughout the entire storage period. Full assessment of 5 fish was carried out 8 times throughout subsequent iced storage of the product as mentioned above. It is to be noted that the assessments involved all assessors to reach consensus on what score a particular parameter achieves and at which intensity and to agree/confirm that the descriptors selected for the index were relevant and correct.

Photographs were taken at the definitive points of visual change.

5.6.2 Results

The temperature and sensory records for the first and second trials are shown in Tables 5.6.2 and 5.6.3 respectively. The data obtained from these two Tables have been used to prepare the linear relationship chart (Fig. 5.6.1) showing that $y = 1.183x + 0.747$ with $R^2 = 0.948$.

The end use day assessed by three people based on odour of fish and bitterness of cooked meat was estimated as 15 days. Based on the averages of the linear relationship of the two trials and the end used day, the remaining shelf life was estimated and presented in Table 5.6.4.

Table 5.6.1 Quality index for Pink Ling (*Genypterus blacodes*) –head on, gills on, gutted (HOGOG)

Quality Parameters		Description	Score
Skin	Colour/ appearance	Bright pink/orange	0
		The skin is less shiny	1
		Dull, pattern faded, light orange near mouth	2
	Mucus	Clear, not clotted	0
		Milky, clotted	1
		Yellow and clotted	2
Skin	Odour	Fresh sea-weedy,	0
		Neutral	1
		Sour	2
		Rotten	3
	Texture*	In rigor	0
		Finger marks disappear rapidly	1
		Finger leaves mark over 3 seconds	2
Caudal fin	Colour	Pink	0
		Pale or grey	1
Flesh	Colour	Light pink translucent	0
		Creamy	1
		Pale yellowish	2
		Yellow /light brown	3
Gills	Colour	Bright pink	0
		Slightly discoloured	1
		Discoloured, dark pink	2
	Mucus	Transparent	0
		Milky, clotted	1
		Yellow, clotted	2
	Odour	Fresh sea-weedy	0
		Neutral	1
		Sour	2
		Rotten	3
Abdomen	Blood in abdomen	Blood red/not present	0
		Blood more brown, yellowish	1
	Odour	Fresh, sea-weedy	0
		Neutral	1
		Sour	2
		Rotten	3
Quality Index			**0-23**

*Texture assessed at the interception of anus and lateral line.

Table 5.6.2. Average temperature and mean sensory score records of Pink Ling for the first trial

Date	Temp ^{0}C / 24Hr	Equivalent days in ice (ice time)	Actual Sampling Day	Equivalent Sampling Days in ice	Sensory scores
15-Aug	-1.3	0.7		0.7	
16-Aug	-0.8	0.8		1.5	
17-Aug	-0.6	0.9	3	2.4	5.2
18-Aug	-0.4	0.9		3.3	
19-Aug	-0.3	0.9		4.2	
20-Aug	-0.2	1	6	5.2	10.8
21-Aug	-0.2	1		6.2	
22-Aug	-0.3	1	8	7.2	13.2
23-Aug	-0.2	1		8.2	
24-Aug	-0.1	1	10	9.2	14.6
25-Aug	-0.1	1		10.2	
26-Aug	0	1		11.2	
27-Aug	0.1	1	13	12.2	19.4
28-Aug	0.3	1.1		13.3	
29-Aug	0.5	1.1	15	14.4	21.4
30-Aug	0.7	1.1		15.6	
31-Aug	0.8	1.2	17	16.8	23.4
1-Sep	0.6	1.1		17.9	
2-Sep	0.7	1.2		19.1	
3-Sep	0.5	1.1	20	20.2	25.2
	Total			**20.2**	

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Table 5.6.3. Average temperature and mean sensory score records of Pink Ling for the second trial

Date	Temp ^{0}C / 24Hr	Equivalent days in ice (ice time)	Actual Sampling Day	Equivalent Sampling Days in ice	Sensory scores
9-Oct	-1	0.8		0.8	
10	-1.8	0.6		1.4	
11	-2	0.6		2.0	
12	-1.7	0.6		2.8	
13	-1.3	0.7		3.5	
14	-1	0.8		4.3	
15	-0.3	0.9	7	5.2	9.4
16	-0.2	1		6.2	
17	-0.2	1	9	7.2	9
18	-0.2	1		8.2	
19	-0.2	1	11	9.2	10.7
20	-0.1	1		10.2	
21	-0.1	1		11.2	
22	-0.1	1	14	13.2	13.9
23	-0.1	1		14.2	
24	-0.1	1	16	15.2	16.5
25	-0.1	1		16.2	
26	-0.1	1	18	17.2	17.6
27	0.1	1		18.2	
28	0.4	1.1		19.3	
29	0.7	1.2	21	20.5	22.2
30	0.5	1.1		21.6	
31	0.3	1.1	23	22.7	25.1
	Total			**22.7**	

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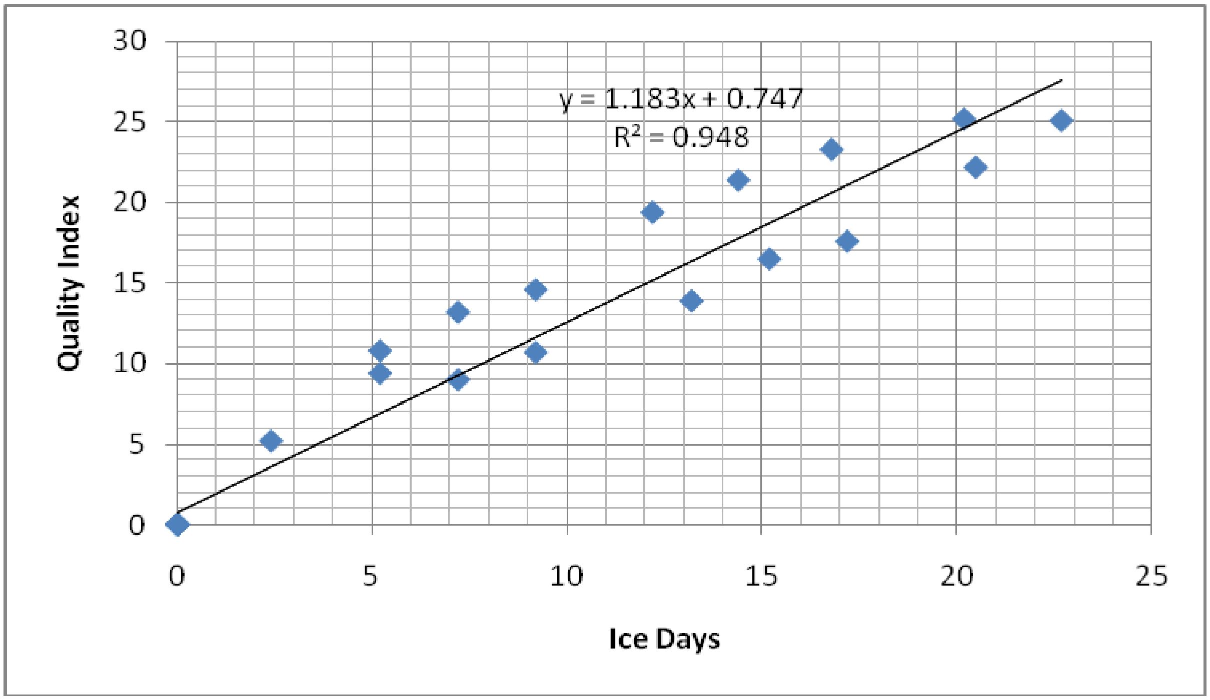
Table 8.6.4. Estimated remaining shelf life for Pink Ling when the end used day is 16 Ice Days

Quality Index = 1.183 x days in ice + 0.747 (R^2 = 0.9480)

Quality Index	Storage time in ice (days)	Remaining Shelf life (days)
1	0	16
2	1	15
3	2	14
4	3	13
5	4	12
6	4	12
7	5	11
8	6	10
9	7	9
10	8	8
11	9	7
12	10	6
13	10	6
14	11	5
15	12	4
16	13	3
17	14	2
18	15	1
19	15	1
20	16	0

Fig.5.6.1 Linear relationship chart for Pink Ling (*Genypterus blacodes*) –head on, gills on gutted (HOGOG)



5.6.3 Conclusion

The QI scheme for Pink Ling (*Genypterus* blacodes) has been developed and is included in the QI Manual.

5.7 Red Throat Emperor (*Lethrinus miniatus*)

This work was done by Philip Anthonisen as part of the requirement for a BSc. Honours (Food Science and Technology) at Curtin University of Technology, WA, under supervision of Dr Hannah Williams and Dr Satvinda S. Dahliwal.

5.7.1 Fish, handling and transport

The Red Throated Emperor (0.8kg to 4kg) were caught in the Indian Ocean outside Geraldton and Kalbarri in the months April to September 2006 by commercial fishing boats using hand lines. The fish was then brain-spiked and then put in ice brine slurry. As soon as possible after the catch the fish was delivered to Geraldton Fish Market or Perth situated Kai Fish and transported to Curtin University of Technology, Perth. The fish were delivered by trucks or by couriers, which ever was the fastest, and when the fish was needed. Whole fresh Red Throated Emperor was received from either Geraldton or Kalbarri within 3 days of capture. At the laboratory, the fish was stored on ice in polystyrene boxes which were self-draining, in a refrigerator at 0 to 1°C. The ice was replaced daily. The flaked ice was supplied by Seafood Enterprise in South Fremantle. A total of 156 fish were used for the development of the QI for Red Throated Emperor together with 2.2 tonnes of flaked ice.

5.7.2 Assessments

The panellists were all staff or post-graduate students from Curtin University, and had experience in sensory evaluation. The laboratory facilities, sensory evaluation room, and analytical equipment were made available through the School of Public Health at Curtin University of Technology. The ISO guidelines for sensory evaluation of fish, panel training and facilities were followed .The method is based on the QIM scheme by Eurofish in the Netherlands (Martinsdottir et al., 2001).

5.7.3 Preparation of whole fish

For the QI scheme training and sensory evaluation during the shelf-life study, whole fish were placed on a clean white cutting board at room temperature, in a fully ventilated room.

5.7.4 Preparation and evaluation of cooked fillets

To prepare the cooked fish sample, fish from each of the storage conditions were filleted then cut into pieces 2 cm by 2 cm and cooked in a microwave oven for 20 seconds on high power (1800W). The cooked samples were served immediately to the panelists for evaluation on a modified Torry scoring scheme (Table 5.7.1).

Table 5.7.1 Modified Torry scheme for cooked whitefish

Score:	Odour:	Taste:
10	Initially weak odour of boiled cod liver, fresh oil, starchy followed by strengthening of the odours	Watery, metallic, no sweetness at the start but meaty flavour with slight sweetness may develop.
9	Shellfish, seaweed, boiled meat, cod liver	Oily, Sweet, meaty, characteristic
8	Loss of odour, neutral odour	Sweet and characteristic flavours but reduced in intensity
7	Wood shavings, wood sap, vanillin	Neutral
6	Condensed milk, Boiled potato	Insipid
5	Milk jug odours, boiled clothes-like	Slight sourness, trace of “off”-flavours, rancid
4	Lactic acid, sour milk, TMA	Slight bitterness, sour, “off”-flavours, TMA, rancid
3	Lower fatty acids (e.g. acetic or butyric acids) decomposed grass, soapy, turnip, tallow	Strong bitter, rubber, slight sulphide, rancid

5.7.5 Preliminary scheme

The fish was observed every day by two people from the day received, until the fish was considered spoiled. Based on these observations, the parameters were suggested and described. Each description received a score from 0 to 3 where 0 corresponded to very fresh fillets. The scores then increased according to spoilage with a maximum score of 3 for each parameter. A preliminary QI scheme for the sensory evaluation of fresh whole Red Throated Emperor was then developed. Previous research by Martinsdottir et al. (2001) showed that the number of fish evaluated for each storage day should be based on the size of the fish used due to the biological variation between individual fish. So, for small fish, e.g. sardines, five fish per storage day are evaluated and for bigger fish, e.g. snapper, three fish per storage day are evaluated (Martinsdottir et al., 2001).

6-8 panellists participated in six training sessions. In the first three sessions, the panel used the scheme developed during the preliminary trial of the Red Throated Emperor. The panel leader explained how the scheme is used and how to evaluate each quality parameter. Then, the panellists evaluated the fish for themselves. The panellists had an opportunity to ask questions regarding the evaluation at any time during the session. After each session, the panel leader and the panellists discussed the scheme and the panel leader made changes to the scheme according to panellist's suggestions. The panellists were notified about these changes at the next session. Before the last training session, the QI scheme for fresh whole Red Throated Emperor was completed.

A further three sessions were then conducted and three whole fish from different storage days were evaluated in each session. The storage day was given on a note next to each fish for the two first sessions. In the last session, the notes only showed randomised three-digit numbers and at the end of the session, the panellists were informed about the storage time. The storage periods of the fish inspected were 3,8 and 16 days then 7, 12,19,23 days and 3, 8 and 19 days respectively. There were no significant differences in results between the panelists (one-way ANOVA).

Table 5.7.2 The Final QI scheme for Redthroat Emperor

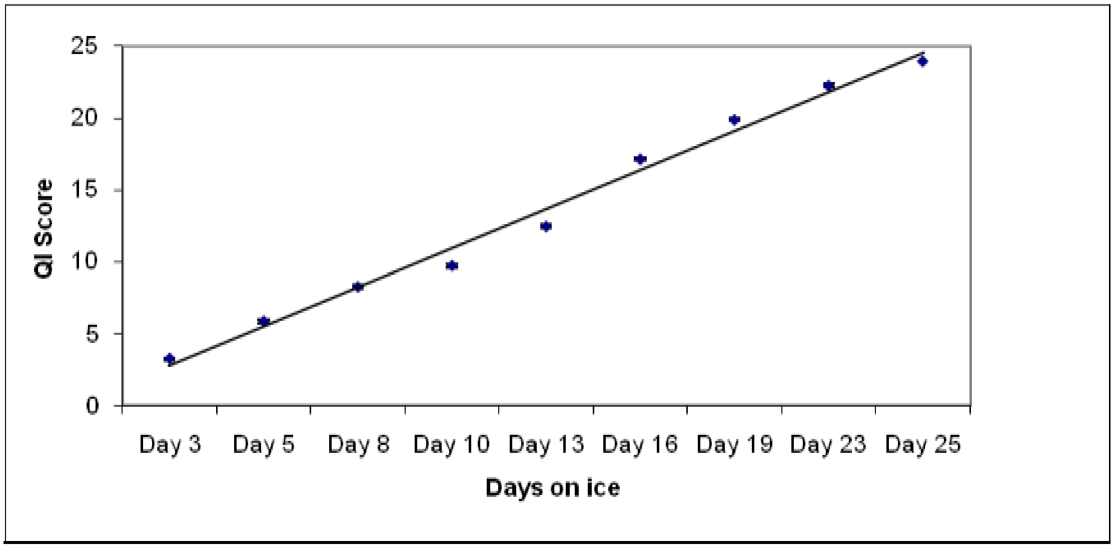
Quality Parameter		Description:	Score:
Skin/body:	**Colour / appearance:**	Fresh & bright, red all over (distinctive red head and along the lateral line) or green all over (distinctive green head and lateral line).	0
		Not so fresh and bright starting to loose the main colour (red/green)	1
		Starting to go grey	2
		Grey, dull, boring to look at	3
	Slime:	Clear, not clotted	0
		Milky, white	1
		Yellow	2
	Odour:	Fresh sea smell, neutral	0
		Metal, hay, cucumber	1
		Dish cloth, sour	2
		Rotten	3
	Texture:	In rigor	0
		Finger marks disappears rapidly	1
		Finger leaves mark over 3 sec	2
	Tail or caudal fin:	Fresh & bright red	0
		Starting to lose colour, going pale	1
		Changing colour to purple/greenish	2
Eyes:	**Pupils:**	Clear and black	0
		Cloudy	1
		Grey, milky	2
	Form:	Convex	0
		Flat	1
		Sunken	2
Gills:	**Colour:**	Fresh, blood red/pinkish	0
		Pale red/pink	1
		Starting to go brown	2
		Brown	3
	Mucus:	Transparent	0
		Milky	1
		Orange/brown	2
	Odour:	Fresh, seaweed	0
		Metal, cucumber	1
		Sour, mouldy	2
		Rotten	3
Total Quality Index Score:			0 - 24

5.7.6 Validation trials

Three validation trials using the scheme were done in which three fish stored for three different periods were evaluated. The periods were 3, 5 and 23 days; 8, 10 and 19 days; and 3,13 and 16 days. The results were based on the average of 6-7 panellists and the QI was linearly related to storage period in ice (R^2 = 0.979) fitted by the relationship QI = 0.740x + 0.957 where x is days in ice.

The mean scores are plotted in Figure 5.7.1

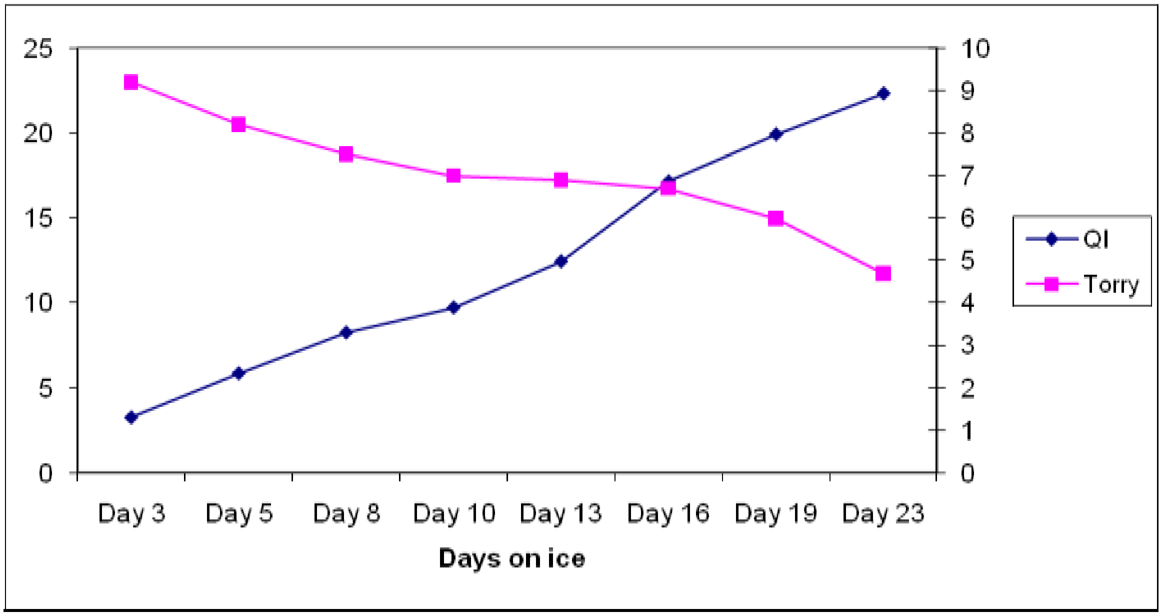
Figure 5.7.1 QI scores for chill-stored Redthroat Emperor



5.7.7 Evaluation of cooked fish flesh using modified Torry scoring scheme

This panel also evaluated samples from the fish in the validation trials with fish served in random order at two sessions each day of the sensory evaluation at 2 sessions. The results obtained on cooked samples of fish stored for 3, 5, 8, 10, 13, 16, 19 and 23 days were plotted versus compared with QI. There was good agreement between the QI and the Torry scores although there was less error in the QI results.

Figure 5.7.2 Torry scores and QI versus Torry versus storage period.



5.7.8 Further comparative analyses on the flesh of stored fish

Additionally a number of other analyses were done on the stored fish; total viable counts (TVC), Enterobacterial count (EBC), total volatile nitrogen (TVB-N), trimethylamine (TMA), pH, texture and colour index using a Minolta Colormeter.

The TVC increased linearly from log 2.1cfu/g after 3 days to log5 cfu/g after 23 days and was well correlated with QI (R^2 = 0.877). Similarly the EBC rose linearly from log 1.5 cfu/g to log 3.1 cfu/g and was highly correlated with QI score (R^2 = 0.948). The TVC was relatively low for a fish stored 23 days since catch but this is commonly found as fish from warm waters have few psychrotrophic organisms that can grow at chill temperatures unless they are contaminated from handling and storage materials.

The TVB-N results correlated well with QI scores (R^2 = 0.923). Levels remained reasonably low and were still about 6 mg/100g after 19 days chill storage. The same was true of TMA which correlated highly with QI (R^2 =0.923) and after 19 days chill storage levels were about 5 mg/100g. Concomitantly with TVC, TVB-N, TMA and the pH increased in level in a similar linear fashion with period of chill storage and, too, were highly correlated with QI score (R^2= 0.871). Effectively these four parameters measure the result of the same phenomenon, namely growth of bacteria which produce alkaline compounds that TVB-n, TMA and pH all measure directly or indirectly.

Force relaxation was measured on dorsal samples (3 per fish) after deformation by plunger in a TA-XT2i texture analyzer. The calculated force was highly correlated with QI and decreased with increasing period of storage.

A colorimeter was used to measure the CIELab colour coordinates L*.a* and b* at three positions along the stored fish on the lateral line, sides of the tail and the centre of the tail. Each position showed a linear decline in value with increasing period of storage but the side of tail was most sensitive – particularly for a* (redness) and b* yellowness as they started at much higher values than the other locations. All were highly correlated with QI.

5.7.9 Conclusion

A QI scheme has been developed for, and validated, on stored Redthroat Emperor (*Lethrinus miniatus*) and has been included in the QI manual.

The results of the ancillary tests all serve to endorse the use of QI as a rapid non-destructive test method that requires no equipment or particular skills to use effectively. The results also bear out the relatively long shelf-life of Redthroat Emperor, provided it is handled correctly straight after catch and maintained at a temperature of 0^oC.

5.8 Saddletail Snapper (*Lutjanus malabaricus*)

Trials were conducted by Sue Poole, John Mayze, Paul Exley, Carl Paulo, Stephanie Kirchhoff and Steve Nottingham, Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton, Brisbane.

5.8.1 Fish

- all fish were harvested by trap from depths of 30-60m within the Timor reef fishery (200km NE of Darwin, NT)
- fish (not spiked nor bled) were from the last day's catch, <24h before landed in Darwin and were held onboard in an ice slurry (0° –1°C)
- fish were taken straight from the slurry onboard and packed for transport in foam polystyrene boxes with ice-packs
- boxes were transferred to airport freight chiller-room and held until the midnight flight to Brisbane (arriving 0530 following morning)
- fish were transported to IFT, Hamilton and fish temperature checked on arrival
- whole (gut in) fish were stored in free draining melting ice (0°–1°C) in insulated lidded bins (250L Xactics) which were stored in a temperature controlled environment (22°C room). Temperature of the fish during storage was recorded to monitor required holding temperature. Fish were re-iced as needed.

5.8.2 Development Trials

Development of the quality index scheme and data gathering involved specific phases:

5.8.3 Assessment sheet development trial

A preliminary trial was carried out with fish obtained as soon after harvest as possible (<24h) and then stored in flaked ice to observe typical changes in attributes over time. From these observations, specific descriptors were determined and agreed as describing the particular attributes at any point of storage.

- 5 fish were randomly selected for each assessment
- fish were assessed under standard evaluation conditions, presented on steel bench-top at room temperature and under white fluorescent lighting
- fish were individually assessed in random order by assessors
- discussions on each fish were chaired and agreed observations noted

5.8.4 Pilot trial

The pilot trial was undertaken to train the assessors in the meaning of each descriptor used for the different attributes of the fish and to confirm agreement that descriptors were appropriate and universally understood.

- 5 fish were randomly selected for each assessment
- fish were assessed under standard evaluation conditions, presented on steel bench-top at room temperature and under white fluorescent lighting
- each fish was displayed on its side with the best eye presented to assessors

- prior to individual assessments, group discussions were held on assessment procedures and to achieve descriptor clarification
- fish were then individually assessed in random order by assessors
- assessment of eye attributes was performed on the top eye only as presented to assessors
- fish were individually assessed in random order with assessors recording results on individual assessment sheets

5.8.5 Assessment trials (Trials 1, 2 and 3)

Three separate trials were undertaken to capture the necessary data required to develop the quality index model. To maintain consistency and unbiased independence, individual assessment of fishes were performed as per the preliminary trial with the exception of pre-assessment discussions, explanations and attribute clarifications.

5.8.6 Assessors

- 12-14 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the preliminary trial on the specific parameters by which Saddletail Snapper was to be assessed
- assessors made individual judgements independently and their performance was analysed statistically

5.8.7 Statistical data analysis

Statistical analysis was undertaken using various methods and analysing for the effect of different variables. Averages at each time period were calculated based on the panellists average of the five fish and the fish average over the assessors. This allows comparison of the variability between fish and between assessors

5.8.8 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartlett's test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.8.9 Assessor variation and fish variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also shows if there was any interaction between panellists and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and fish, then the plotted graphs can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly, any interaction between fish and panel member.

5.8.10 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from Excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so x was QI and y was days. Since QI is the sum of n parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter t comes from the AOV regression.

5.8.11 Assessment sheet development

The sheet development trial was undertaken to identify and observe the evolution of key assessable attributes that closely correlated with storage time. From these observations, specific descriptors were identified which suitably described and defined these attributes at any point of storage. The parameters were observed during storage with appropriate descriptors discussed and defined at all stages of the preliminary storage trial. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 3, where 0 implies "perfect". At each storage time, the attribute ratings were summed and noted as the QI score of that assessor for each fish. All the parameter scores were totalled for each assessor and for each fish. The totals were then averaged to provide the final QI score at that storage time. The end of storage life was adjudged to be the point when fish were rejected by all assessors as being well beyond acceptable for purchase. This sheet development process was based along very similar lines to those of the EU QIM system so as to be complementary to that system.

Early assessment sheets incorporated the overall colour of the fish as well as its lateral line, saddle colouration, fins and tail into a single assessable parameter. However, such inclusion of multiple assessable traits into a single parameter led to grading confusion. It was identified that the evolution of these attributes differed and so should not be grouped together. Table 5.8.1 provides the final QI scheme and lists the quality attributes for physical and visual parameters, including odour.

Table 5.8.1 - Quality Index scheme for Saddletail Snapper

Quality Parameter		**Description**	**Score**
Skin	**Colour / appearance**	Iridescent colour (red, pink, silver). External gill flap bright red	0
		Fading colour around belly. External gill flap pale red	1
		Colours fading all over. External gill flap patchy white	2
		Colour mostly gone with possible yellow patches / tinge. External gill flap mostly white with possible yellow tinge	3
	Fin (caudal fin)	Red, pink	0
		Faded with possible white tips	1
		Pale with yellow discolouration	2
	Mucus	None / Natural clear	0
		Cloudy	1
	Odour	Fresh sea	0
		Neutral, slightly stale	1
		Sour, natural gas	2
		Sulphur, ammonia, cabbage, off odour	3
Eyes	**Form**	Convex / Flat / Bulging	0
		Completely Sunken	1
Gills	**Colour**	Uniform red or pink when cut	0
		Discoloured / Blotchy	1
		Brown / Grey colour present	2
	Mucus	Transparent / Slightly cloudy	0
		Milky / Opaque	1
		Brown, bloody	2
	Odour	Fresh sea	0
		Not so fresh, stale	1
		Sour, vegetable, metallic	2
		Rotten, strong off odour	3
Quality Index			**0-17**

5.8.12 Pilot trial

Assessors were trained in applying the QI attribute scores to Saddletail snapper in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with saddletail throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category and hence the aptness and clarity of the descriptions for each quality attribute was confirmed. Photo records obtained at different storage times during the score sheet development trial were found of invaluable use for assisting assessments.

The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials. The appropriateness of each attribute assessed during the trials, and associated descriptors, can be graphically represented by the increasing scores for each parameter over storage time by Increase in score for each parameter over storage time as depicted in Figure 5.8.1. Of the 10 parameters selected all but rigor demonstrated direct relevance with time, indicated by steadily increasing in score over time. Rigor, commonly used as an indicator of freshness, is a unique parameter in that it resolves to completion early in storage with no further change occurring. However, it is worth including because of the universal acknowledgement of 'in-rigor' fish being of ultimate freshness.

5.8.13 Assessment trials

In each of the 3 trials, 5 individual fish were assessed on each sampling day. The QI was calculated for storage time and graphed against storage days to illustrate relationship. The final QI score for a sampling time was based on an average of all fish assessed in each trial to allow for biological variation between fish. For each trial, 9 assessments have been performed and at the same intervals. Having the same number of assessments scheduled at the same rhythm improves the consistency of the dataset, lowers the risk of session effect and improves the predictability of the model.

5.8.14 Combining of data from different trials.

From Figure 5.8.2, it is seen that data from the separate trials produce regression lines that are similar. Regression analysis illustrates that data from all trials is poolable and that QI can be significantly predicted by the day. A graph combining all data could be prepared and compared to the theoretical trend line using a chosen QI for end of shelf-life at around 19 days. Analysis demonstrated that there was no trial effect in this data most probably due to the matched assessment times. Predictably there was a day effect illustrated with QI increasing with storage time as expected.

5.8.15 Assessor variation and consistency

To determine variability between assessors, an average for each assessor's score across the 5 saddletail assessed at a particular time was calculated (an example is depicted in Figure 5.8.3). Only results for panel members present for at least 50% of the assessments were used.

The variation in the QI obtained by different assessors across all trials was similar in all trials. One assessor assessed the fish excessively high on day 3 of trial 1 and although reasons for this are unknown, data was retained. It was noted in all trials that there was less variability between assessor scores for beginning and end storage trial assessments implying universal agreement of attribute rating. In mid-storage assessments variation was greater perhaps due to individual interpretation of attribute state.

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Figure 5.8.1. Scores for individual attribute over time (data taken from trial 2)

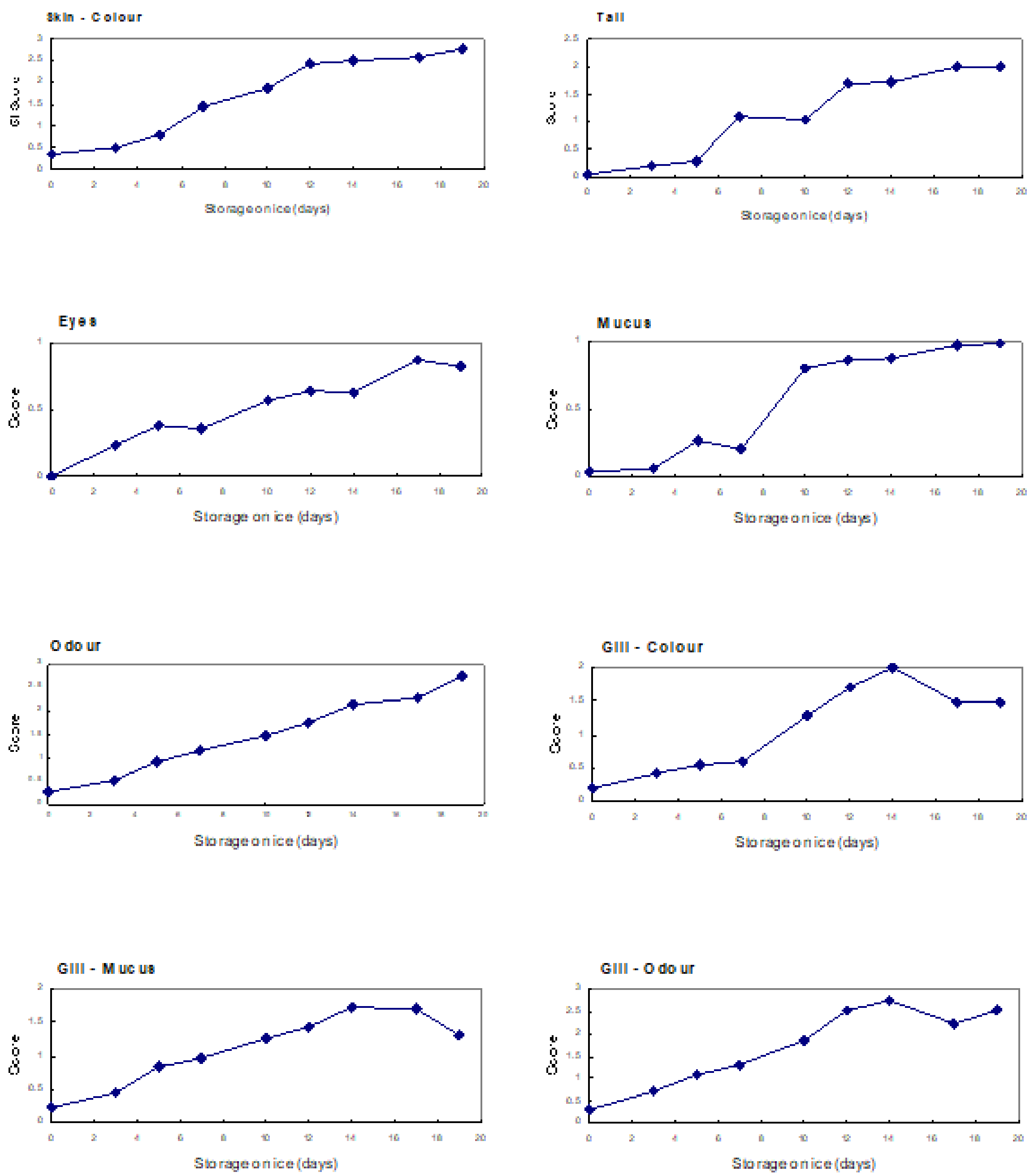


Figure 5.8.2. Quality index scores over time for 3 separate trials.

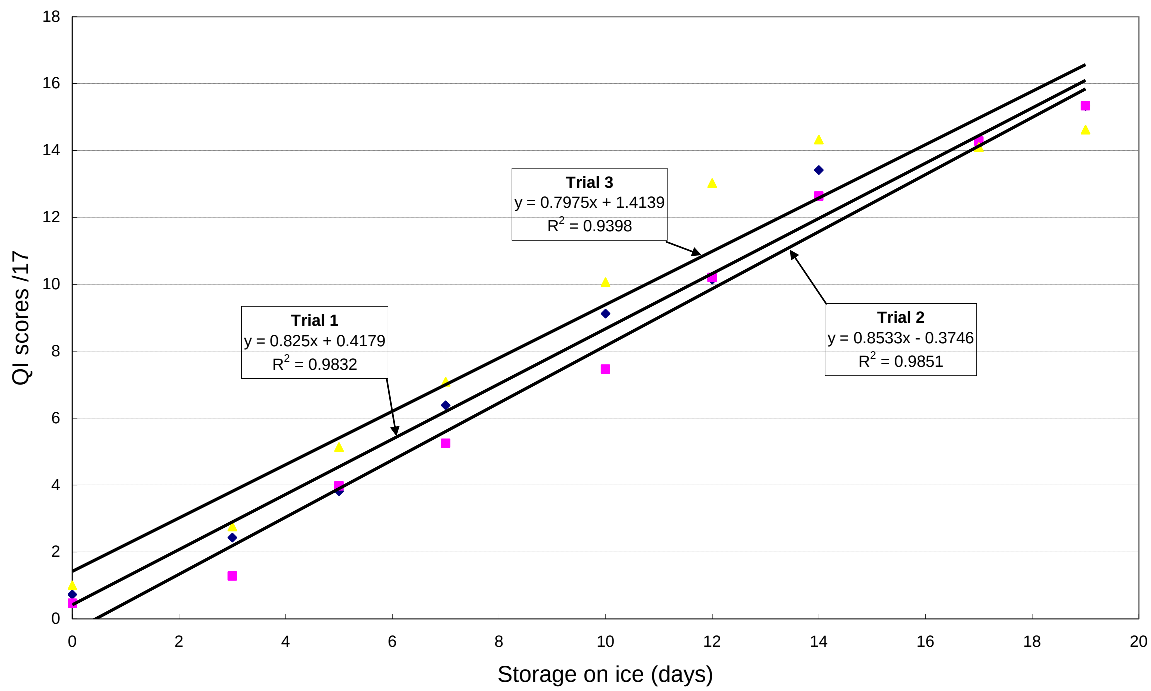
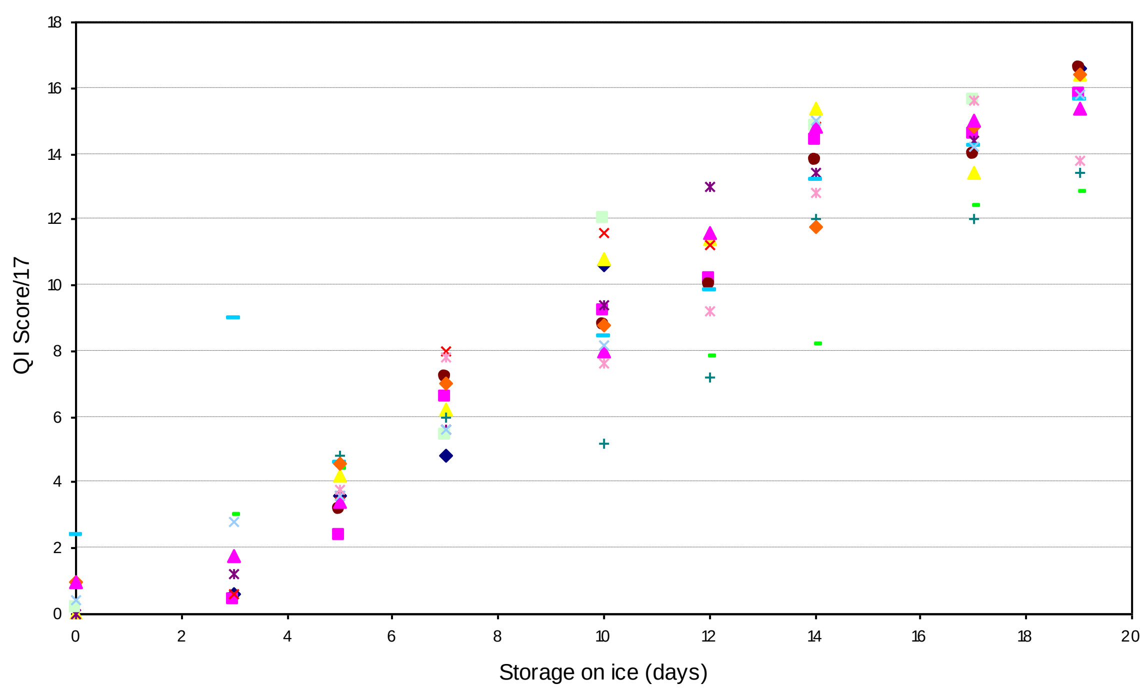


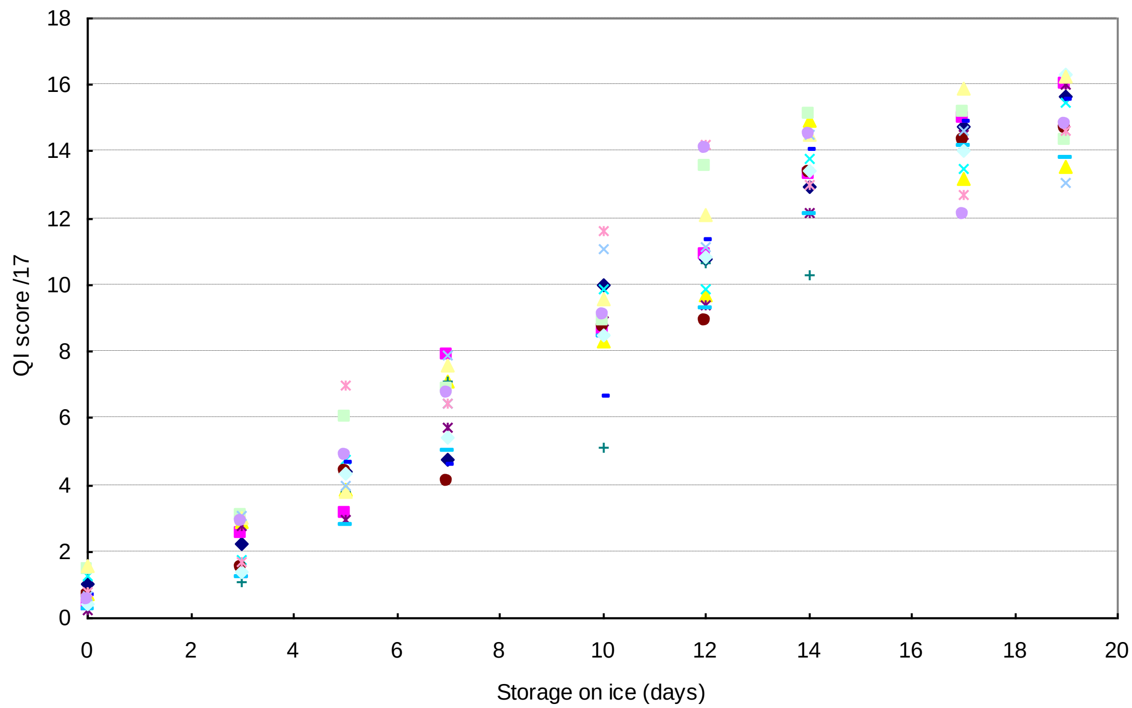
Figure 5.8.3. QI scores given by individual assessors during storage of fish in ice (data taken from trial 1)



5.8.14. Variability between individual fish

Figure 5.8.4 presents the average QI scores of the 135 fishes assessed during the study. For each session, 5 fishes were randomly selected and assessments were repeated in triplicate which gives a total of 15 fishes for each assessment point.

Figure 5.8.4. Variation in QI for each of the five fish assessed.



Limited variations between the 15 fishes were observed at the beginning of the trials (days 0 and 3) and this applied at the end of the trials (days 17 and 19). Variations between the scores are greater during mid-phase storage especially at day 10-12, however there was no obvious reason for this to be so. It is possible that delineation between attribute divisions are more difficult to determine in mid-phase storage or that at this time individual fish are spoiling with differing rates and assessors evaluation of attributes is influenced one fish to another.

8.8.15 Analysis of variance comparing variation between fish and assessors

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the 3 trials. For the exercise, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly any interaction between fish and panel member. Each panellist assessed five similar fishes within the same sessions. Fish were randomly selected and different from one session to another. This analysis can provide an interesting insight to check assessor performance and consistency.

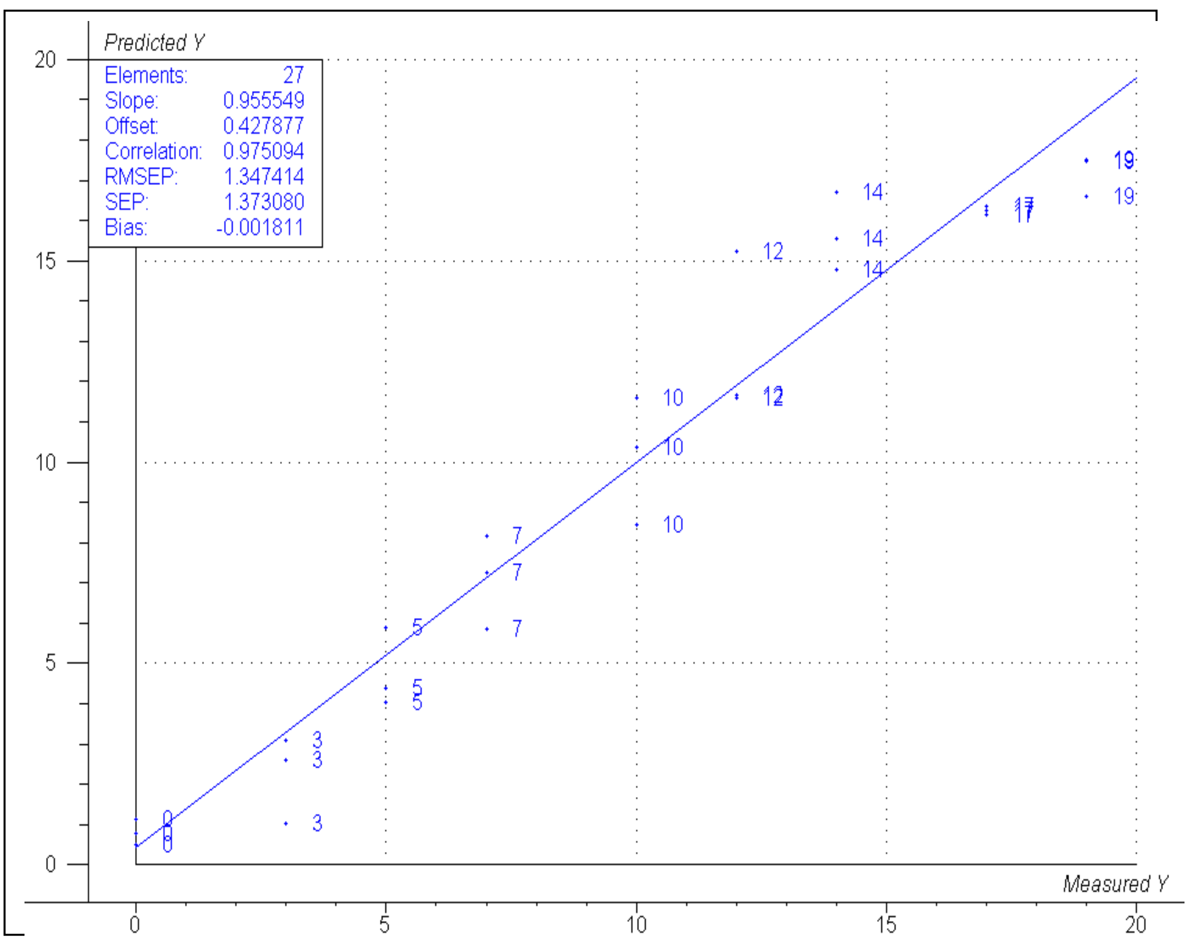
For all trials there was no significant difference between the overall QI score across all times for the fish, but a significant effect for assessor. In all 3 trials, there was no significant (P>0.05) interaction between fish and assessor scores. This indicates that each assessor's average score is different but they are consistent across all fishes. However for each trial, there is a significant difference (P<0.01) between assessors.

8.8.16 Predicted and measured using partial least square regression

Predictability of QI was analysed using partial least square "inverse" regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis, the QI of Saddletail snapper could be used to predict the storage time in ice with an accuracy of ± 1.4 days (Figure 5.8.9, the numbers associated with data points on the graph indicate days of storage of fish in ice)

Thus data from trials 1, 2 and 3 were pool-able thus giving one regression line and 95% confidence intervals to predict storage time with an accuracy of ± 1.4 days. This is based on a total of 27 assessments, scheduled in 3 trials with 5 different fish at each session.

Figure 5.8.9. Standard error of performance of Saddletail snapper QI scores.



5.8.17 Conclusion

A QI scheme was successfully developed and validated for Saddletail Snapper (*Lutjanus malabaricus*) and incorporated into the QI manual.

5.9 Scaly Mackerel (*Sardinella lemuru*)

Trials were conducted by Sue Poole, John Mayze, Paul Exley, Stephanie Kirchhoff, Carl Paulo and Steve Nottingham, Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton, Brisbane.

Note that Scaly Mackerel are part of the group referred to as Australian Sardines. Recent opinion is that the *S .lemuru* from West Australia is a different species to that found in South Australian waters (*Sardinops sagax*).

See http://www.fishnames.com.au/fishnames/fishnames.php?pid=541 (accessed Wednesday, October 21, 2009)

5.9.1 Fish

All fish samples were identically sourced and stored.

- fish were night-harvested by Fremantle Sardine Company (Fremantle, WA) and immediately placed in an ice-slurried brine solution
- fish were packed into styrofoam boxes with cold-packs and air freighted to Brisbane, arriving the following morning
- whole (gut in) fish were stored as they lay in free draining melting ice (0^o–1^oC) within 6 individual lidded drip bins over drip trays. Storage bins were kept in a temperature controlled cold room (2-3°C)
- temperature of fish during storage was recorded to monitor required holding temperature
- fish were checked daily and re-iced as needed

5.9.2 Assessment sheet development trial

The sheet development trial was carried out to observe and catalogue typical changes in attributes over storage time. From these observations, specific descriptors were agreed to as describing the particular attributes at any point of storage.

- 10 randomly selected individual fish were used for each assessment
- each fish was presented on white ceramic plates at 22^oC under fluorescent lighting in individual sensory evaluation booths
- fishes were assessed separately in random order by assessors

5.9.3 Pilot trial

The pilot trial was undertaken to train assessors in the meaning of each descriptor used to assess each attribute. The trial allowed for universal understanding of each descriptor as well as confirmation of its appropriateness.

- assessors undertook group discussions on a single fish before progressing to individual assessment
- 5 randomly selected individual fish were assessed between pairs of assessors
- each fish was presented, as they lay within storage drip trays, to assessors on white ceramic plates
- assessment was performed under standardised evaluation conditions at 22°C under fluorescent lighting within partitioned sensory booths
- fish were assessed in a random order
- assessment of eye attributes was performed on the top eye only as presented to assessors
- rigor was pre-assessed by trial co-ordinator
- assessors entered results directly into a computerised system (CompuSense 5, Ontario, Canada)

8.9.4 Assessment trials (Trials 1, 2 and 3)

Three separate trials were carried out to provide the quality index assessment data to build the model. Assessment of fish samples was performed exactly as in the preliminary trial with the exception of no group discussions and attribute clarifications prior to individual fish assessments.

- 7-13 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the preliminary trial on the specific parameters by which the Scaly Mackerel was to be assessed
- assessors made individual judgements independently and their performance was analysed statistically

5.9.5 Statistical data analysis

Statistical analysis was undertaken using various methods and analysing for the effect of different variables. Averages at each time period were calculated based on the panelists average of five fish and the fish average over the assessors. This allows comparison of the variability between fish and between assessors.

5.9.6 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartlett's test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.9.7 Assessor variation and fish variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also shows if there was any interaction between panellists and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and fish, then the plotted graphs can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly, any interaction between fish and panel member.

5.9.8 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from Excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so x was QI and y was days. Since QI is the sum of n parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter t comes from the AOV regression.

5.9.9 Assessment sheet

The assessment sheet was developed along very similar lines to those of the EU QIM system, in order to be complementary. Initial parameters for assessment were selected from previous experience on spoilage patterns of ice-stored Australian sardines (unpublished data). The parameters were observed during storage with appropriate descriptors discussed and defined at all stages of the sheet development trial.

Early assessment sheets included grey/silver, blue and green as a colour descriptor for skin appearance. However, the addition of colour descriptors could potentially limit the quality index (QI) sheet to an individual species or species locality. To make the QI sheet flexible enough to accommodate for possible inter-species variations, the colour descriptors were removed and replaced with the more generic descriptors: "bright" and "dull". Skin integrity was also initially monitored, though it became apparent that this attribute did not evolve through storage time and was subsequently dropped from assessment.

The attribute of "zippering", skin integrity loss on the underbelly from the anal vent towards the gills, is a commonly acknowledged quality measure used by industry. However, with the species of sardine used in this scheme development, the zippering attribute caused a good deal of confusion. Throughout the sheet development much debate arose between assessors on what constituted the onset of zippering. Some perceived it to be the physical peeling of skin from flesh to expose bone (as observed in previous storage trials with sardine from South Australia; unpublished data) whilst others rated it as the browning of the belly. It was decided that zippering should be assessed as the physical peeling of the skin with discoloration assessed as a new attribute.

Progression through the sheet development trial revealed a gradual darkening of the belly, from silver through to pink then brown. This gradual discolouration was perceived to be dependant on storage time, was more easily assessed than zippering and as such was included as an assessable parameter for further trials.

When assessing eye attribute several methodologies were trialled for their suitability – all attributes assessed on the best eye, only assess the eye which rates the best for each attribute, or average of both eyes. For uniformity between assessments it was decided that only the eye presented to the assessor be assessed – the top eye as the fish rested from catch. Contrary terms of "concave" or "puffy" are also included as descriptors of eye form. Both terms are relevant but are an either /or choice – it was observed that eyes either sank into respective sockets or bulged and burst.

Gill colour ranged from bright red to brown red depending on the method of brining. It was also observed that bright red gills darkened through storage whilst brown red gills faded. Scoring descriptors were modified to include both descriptors throughout the storage time. Along with colour, gill odour and mucus were also initially included as an assessed parameter. However, these parameters were deleted after data analysis revealed constant absence of gill mucus and concerns were raised on the dissipation of gill odour intensity with each opening of the gill cover for assessment, sardines having very small gills. The overall smell of the sardine was assessed instead.

Describing these parameters this way when fish are expected to be perceived as 'perfect' (highest quality) allows flexibility of the scoring system to cope with variations in post-harvest handling techniques.

Table 5.9.1 provides the final QI scheme used during the trials and lists the quality attributes for physical, visual and odour parameters. Note that a hard copy sheet of this QI scheme was not used during assessments. Instead, assessors were presented these descriptors through CompuSense and rated scores computationally.

Table 5.9.1. Quality Index scheme for Scaly Mackerel

Quality Parameter		Description	Score
Belly	**Colouring**	Consistent silver	0
		Yellow / slightly brown / pink patches	1
		Dark brown patches	2
	Condition	Firm	0
		Soft	1
		Burst	2
Skin	**Appearance (*Average of both sides*)**	More than 2/3 bright, shiny	0
		1/3 to 2/3 dull	1
		More than 2/3 dull	2
	Slime	Absent	0
		Present	1
	Smell	Fresh oily / Oceany	0
		Fishy, stale / rancid oil	1
		Rotten	2
Rigor		In	0
		Post	1
Vent	**Condition**	Normal / Tight	0
		Open / Stained	1
Eyes *(Top eye)*	**Pupils**	Clear / Shiny black	0
		Cloudy	1
	Shape	Flat	0
		Slightly sunken / Puffy	1
		Sunken / Burst	2
	Iris	No blood / Silver	0
		Gold	1
		Bloody tinge / Bloody	2
Gills	**Colour**	Bright red or brown if brined	0
		Slightly dark or slightly faded if brined	1
		Very dark or very faded if brined	2
Quality Index			**0-18**

5.9.9 Pilot trial

Assessors were trained in applying the QI attribute scores to Scaly Mackerel in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with Scaly Mackerel throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category and hence the aptness and clarity of the descriptions for each quality attribute was confirmed. Photo records obtained at different storage times during the score sheet development trial were found of invaluable use for assisting assessments.

Assessment methodology was refined a little throughout the pilot trial to improve the quality of data obtained.

- rigor mortis was assessed by the trial co-ordinators before each assessment trial to avoid rigor state being affected by assessor handling of the individual fish. This was only relevant the first 2 days of storage
- capping individual fish assessment to 2 assessors per lot of 5 fish limited artificial inflation of QI scores for any particular attribute through miss-handling during assessment.
- assessment within partitioned sensory booths restricted outside influences on the assessment process, particularly interaction (consciously or subconsciously) between assessors.

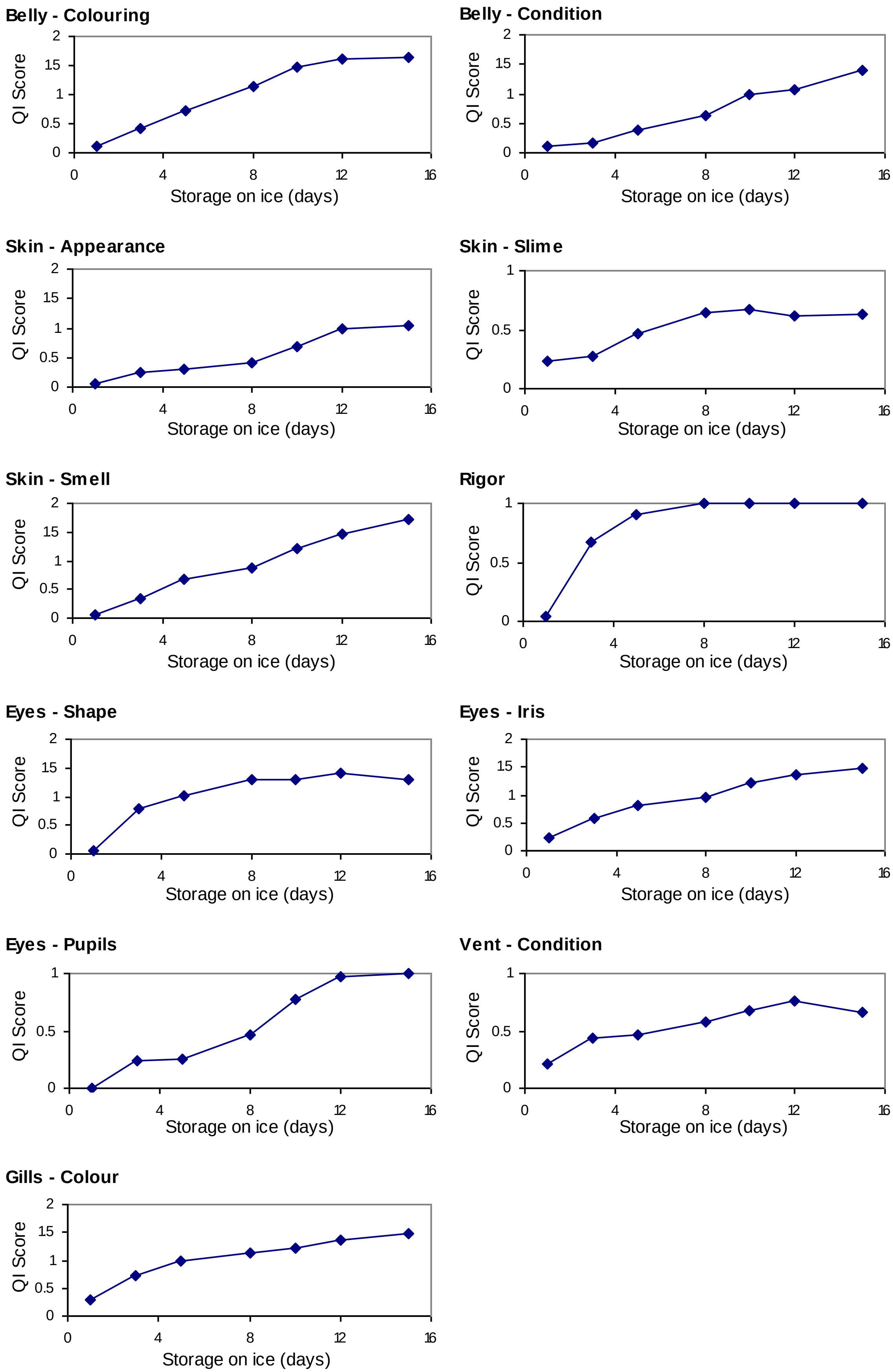
Direct entry of QI scores into Compusense by assessors allowed for precise capturing of all relevant data, which was of particular concern during the sheet development trial where assessors continually missed assessing some attributes.

Before each preliminary assessment all assessors were trained in applying the QI parameter scores to Scaly Mackerel through group sessions. The scoring scheme was explained to each assessor and the descriptions associated with each score observed throughout the full storage period. Discussions occurred until each assessor was confident in understanding the descriptors within each attribute. As such, the aptness and clarity of the descriptors for each quality attribute was further confirmed and refined during the preliminary trial.

Scores were given for each quality attribute according to descriptions, ranging from 0 to a possible maximum of 3, where 0 implies "perfect" and of the highest quality. At each storage time the parameter scores for each assessor and each fish were totalled. The totals were then averaged to provide the final QI score at that particular storage time. The end of storage life was adjudged to be the point when fish were rejected by all assessors as being well beyond acceptable for purchase.

The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials. The appropriateness of each attribute assessed during the trials, and associated descriptors, can be graphically represented by the increasing scores for each parameter over storage time by Increase in score for each parameter over storage time as depicted in Figure 5.9.1. Of the 12 parameters selected all but rigor demonstrated direct relevance with time, indicated by steadily increasing in score over time. Rigor, commonly used as an indicator of freshness, is a unique parameter in that it resolves to completion early in storage with no further change occurring. However, it is worth including because of the universal acknowledgement of 'in-rigor' fish being of ultimate freshness.

Figure 5.9.1. Individual attribute changes of Scaly Mackerel during storage in ice



5.9.10 Assessment trials

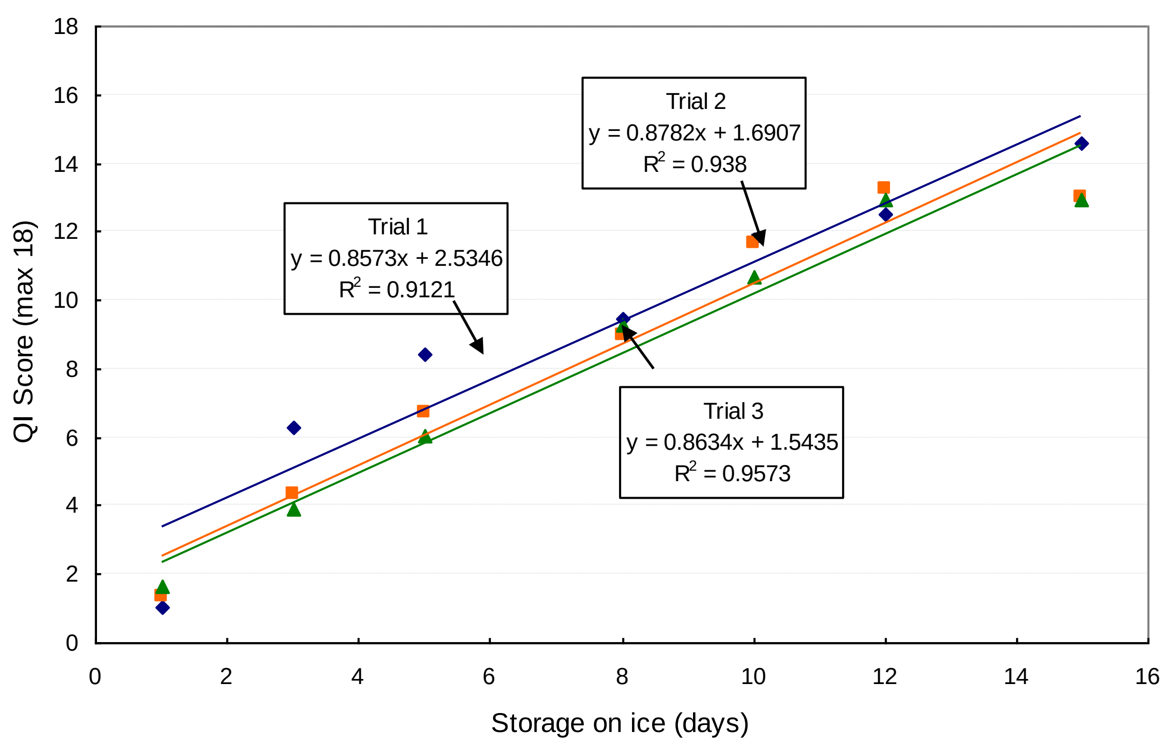
In each of the 3 trials, up to 30 individual fish were assessed during each sampling day, with a maximum of 2 assessors rating 5 fish. The QI was calculated for storage time and graphed against storage days to highlight any relationships. To account for biological variations between samples the final QI score was based on an average of all fishes assessed during each session.

On completion of the assessment trials, a review of the QI Scheme and associated results lead to the deletion of zippering from the QI Scheme and all data excluded from further analysis. Though a linear progression of QI scores was obtained we observed that the conventional sense of zippering, where skin peels away to reveal a zipper like bone structure, was not consistently evident. This progression of QI scores could be evidence of an assessors need to rate zippering as assessment time progressed or confusion between zippering and exposure of bone from a degraded or burst belly.

5.9.11 Combining of data from different trials

Graphically comparing the QI scores within each trial and between trials (Figure 5.9.2) it was clear that the regression lines attained are similar in slope. Analysis gave the assessor average for each fish and provided the mean with a standard deviation across the 5 fishes assessed (data not shown for graph clarity). The variation between fishes across the 3 trials was comparable and no unusual pattern was exhibited, highlighting similar spoilage patterns for Scaly Mackerel stored in ice across the three trials.

Figure 5.9.2 Quality Index for all three trials of Scaly Mackerel



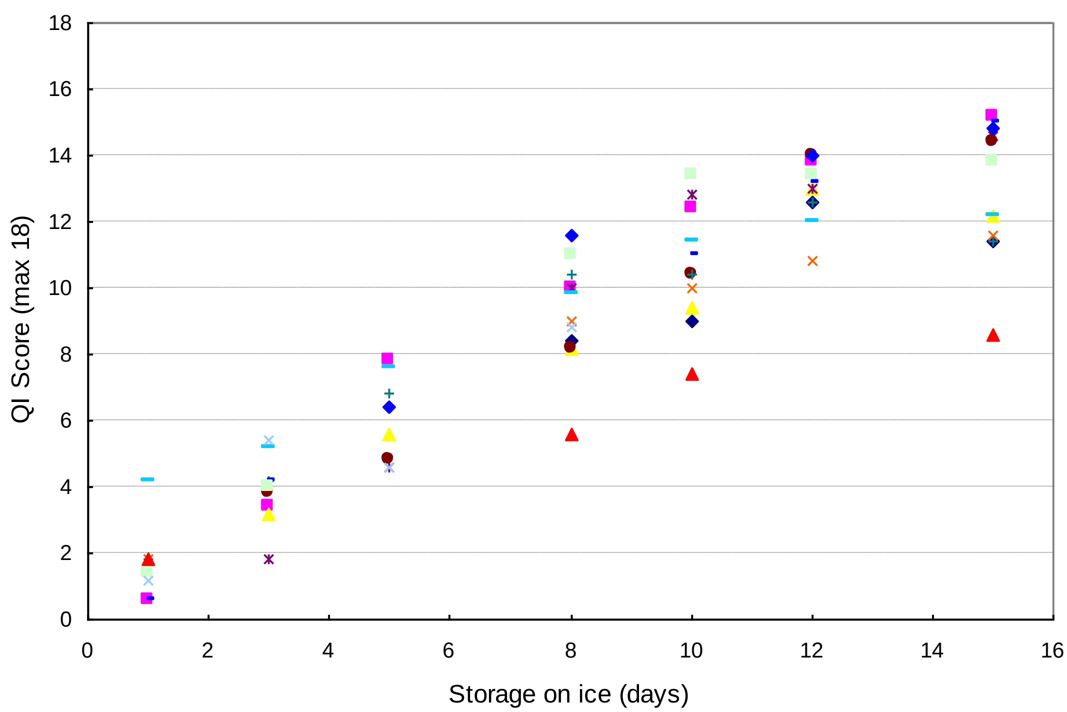
Regression analysis comparing slopes and intercepts from the separate trials showed that the data is poolable across all 3 trials. The pooled data for Scaly Mackerel shows a high correlation between the QI score and the number of days a fish is stored in ice, with an R^2 of 0.95. A graph combining all data could be prepared and compared to the theoretical trend line using a chosen QI for end of storage life at around 15 days

QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored in ice, with fish at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axis origin (0, 0) which was not observed in any of the three trials. Similarly, in no trial did the QI reach the maximum possible score despite the fact that fish were stored past their rejection point (maximum 13-14 of possible 18 demerits). This could be due to assessor's reluctance to use the extreme points within a parameter category. This is a frequently observed phenomenon and should not detract from the usefulness of the data obtained. It is noted that similar occurrences are reported in many QIM schemes (Sveinsdottir *et al*, 2002: reached 17 from a maximum of 24; Sveinsdottir *et al*, 2003: 19 from max 22; Andrade *et al*, 1997: sardine: 24 from max 30; horse mackerel: 18 from max 29; Atlantic mackerel: 26 from max 29).

5.9.11 Assessor variation and consistency

To determine variability between assessors, an average for each assessor's score across the 5 Scaly Mackerel assessed at a particular time was calculated (an example is depicted in Figure 5.9.3). Only those panel members present for at least 50% of the assessments were used.

Figure 5.9.3. QI scores given by individual assessors during storage of fish in ice
(data taken from trial 3)

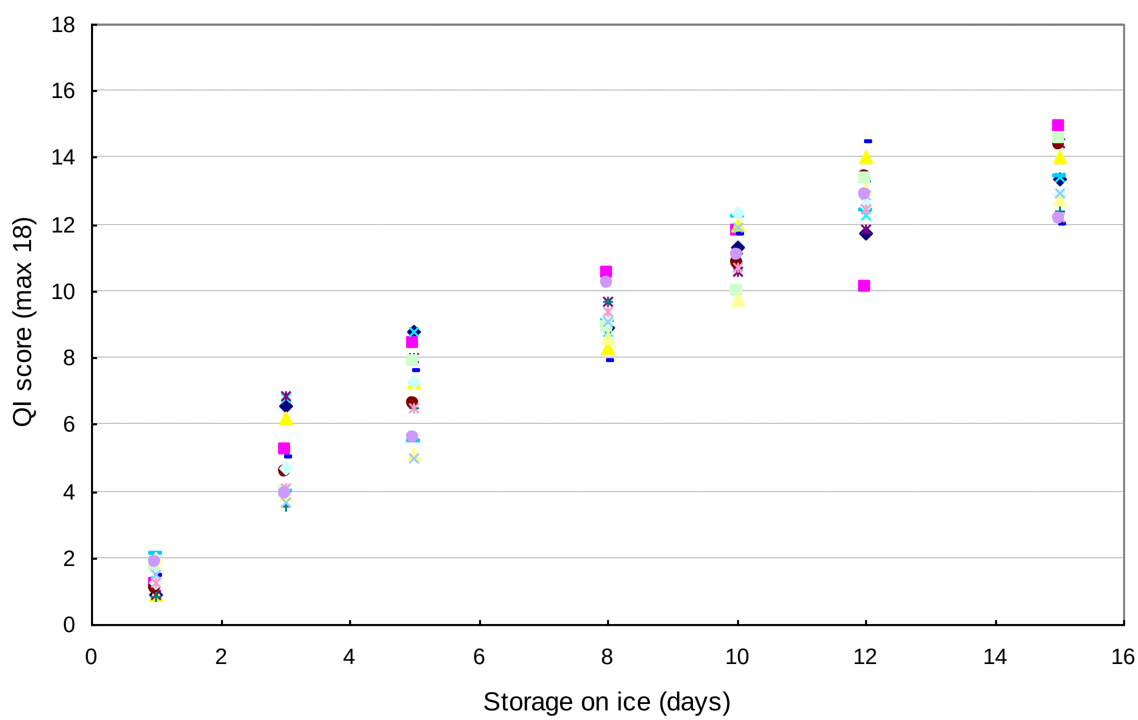


During the 3 trials a total of 15 assessors participated. However, not all participants were present during all sessions or for all trials. Therefore, for statistical relevance only data from assessors who participated in more than half the sessions of any particular trial was included in the analysis. This provided a data pool of 12 assessors for trials 1 and 2 and 13 assessors for trial 3. The variation in the QI obtained by different assessors across all trials was similar for each trial. Each assessor appeared to be relatively consistent in grading over the whole storage period with fluctuations between scores becoming less prominent from trial 1 through to 3 (data not shown). It is possible that assessors became progressively more familiar with the spoilage pattern of Scaly Mackerel and more experienced/trained in the QI scheme.

5.9.12. Variability between individual fish

Around 525 fish have been assessed to establish the QI index of Scaly Mackerel. For each session, new batches of fish were assessed and codes were randomly assigned to fishes. Figure 5.9.4 presents the variability of fish used in the study. QI scores are very close at the first assessment sessions when the fish are very fresh, then the variability between QI on any one day increases and this remains true for the rest of the trial period. However, considering the total number of fish involved the variability in QI scores attained for different fish is surprisingly little. This illustrates that a model for predicting storage life from QI score is robust and can be used with confidence.

Figure 5.9.4. QI achieved for individual fish over storage time in ice



5.9.13 Analysis of variance comparing variation between fish and assessors

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the 3 trials. For the exercise, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly any interaction between fish and panel member. Each panellist assessed five fish within the same sessions. Only 2 panellists assessed the same fish. Fish are different from one session to another.

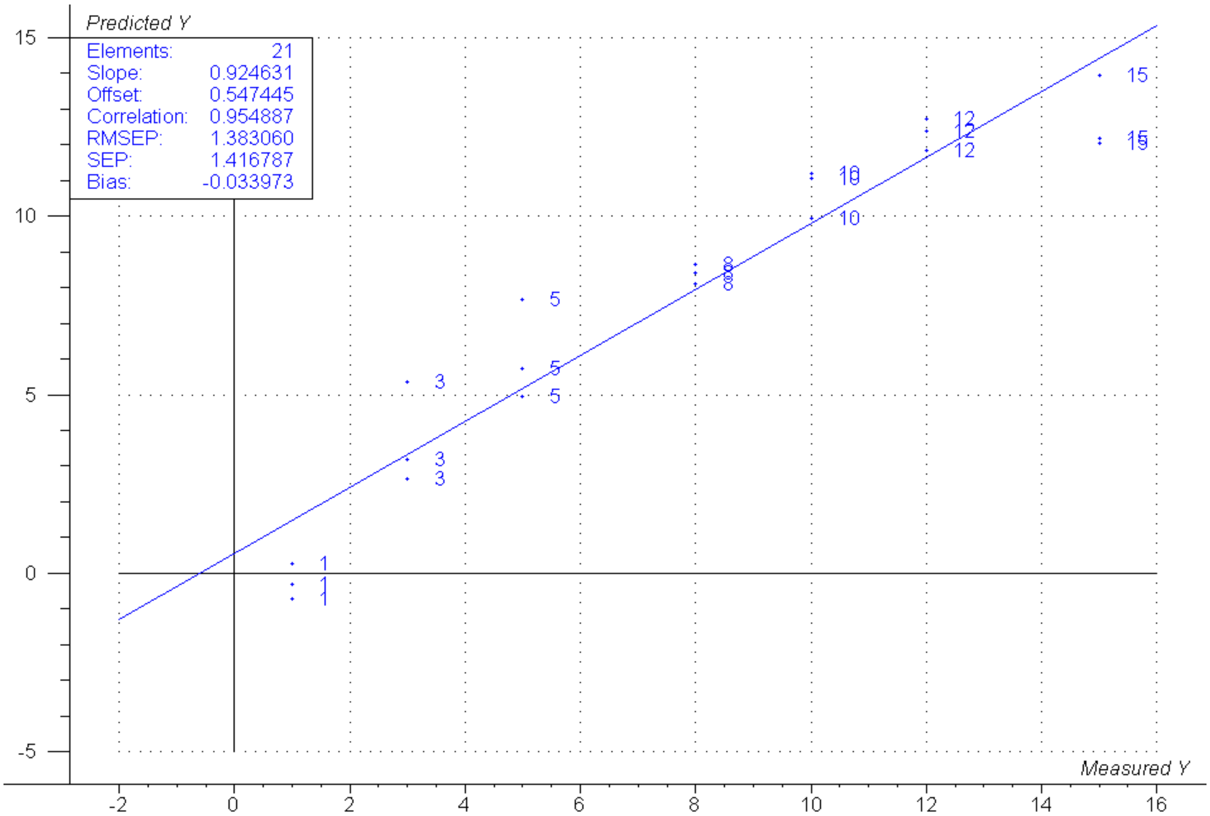
This analysis provides an insight to checking panel performance and consistency. For all trials there was no significant difference between the overall QI score across all times for the fish, but a significant effect for panellist. For all 3 trials, there was no significant ($P>0.05$) interaction between fish and assessor scores. This means that each assessor's average score is different but they are consistent across all fishes. Nevertheless, for each trial a significant difference ($P<0.01$) exists between assessors.

5.9.14 Predicted and measured using partial least square regression

Predictability of QI was analysed using partial least square "inverse" regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis, the QI of Scaly Mackerel could be used to predict the storage time in ice with an accuracy of $\pm$ 1.4 days (Figure 5.9.5, the numbers associated with data points on the graph indicate days of storage of fish in ice).

Thus data from trials 1, 2 and 3 were pool-able thus giving one regression line and 95% confidence intervals to predict storage time with an accuracy of $\pm$ 1.4 days. This is based on a total of 21 sessions within 3 separate trials and assessors rating 5 different fish at each session.

Figure 5.9.5 Standard error of performance of the Scaly Mackerel QI scores.



5.9.15 Conclusion

A QI scheme for Scaly Mackerel (*Sardinella lemuru*) has been developed and validated and is part of the QI Manual.

5.10 Sea Mullet (*Mugil cephalus*)

5.10.1 Preliminary trial fish

- fish were harvested from estuarine waters in Moreton Bay, Qld.
- whole (gut in) fish were stored in ice slurry (0^o – 1^oC)
- fish used for assessment were caught <12hr prior to assessment
- couriered from Moreton Bay to IFT, Hamilton, packed in ice in Styrofoam boxes.
- then stored in melting ice in insulated lidded bins (250L Xactics)
- temperature was monitored throughout storage trial

5.10.2 Pilot and assessment trial fish

- harvested by beach netting from estuarine waters off Kempsey area (NSW)
- fish were from the last catch of the night (early morning)
- whole (gut in) fish, were stored in bins in an ice slurry (0^o – 1^oC)
- transported to Creel Seafoods (Kippa-ring, Brisbane) the day of catch
- packed in to Styrofoam boxes in ice and transported to IFT
- stored in melting ice in insulated lidded bins (250L Xactics)
- temperature during storage was monitored

5.10.3 Samples

- 5 fish randomly selected for each assessment time
- each batch of fish were coded with a random 3 digit number for identification
- each fish was assessed individually under standardised evaluation conditions on a stainless steel table at 22^oC under white fluorescent light

5.10.4 Assessors

- 6-8 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the pilot trial on the specific parameters by which mullet was to be assessed
- assessors made individual judgements independently and their performance was analysed

5.10.5 Statistical data analysis

Averages at each time period were calculated based on the panellists average of the five fish and the fish average over the assessors. This allows comparison of the variability between fish and between assessors. Graphs were made of each of these so outliers and trends could be observed.

5.10.6 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartletts test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.10.7 Panellist variation and fish variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also showed if there was any interaction between panellists and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and fish, then the plotted graphs can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly, any interaction between fish and panel member.

5.10.8 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so X was QI and Y was days. Since QI is the sum of n parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter 't' comes from the AOV regression.

5.10.9 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system so as to be complementary to that system. Parameters for assessment were selected from observation of spoilage during the preliminary trials. Table 5.10.1 shows the QI scheme and lists the quality attributes for physical and visual parameters, as well as odour. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 3, where 0 implies “perfect”. For any storage time, the scores were summed and all attributes summarized and noted as the Quality Index. The end of storage life was confirmed by taste testing of cooked (microwaved, as is) fillet flesh

5.10.10 Pilot trial

Assessors were trained in applying the quality index parameter scores to mullet in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with mullet throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category. During this trial the aptness and clarity of the descriptions for each quality attribute was confirmed. Temperature of the fish was monitored throughout the storage trial and remained between 0^{o} - 0.5^{o}C.

5.10.11 Assessment trials

Assessment trials were carried out with 3 separate batches of fish from different night’s catches. In all trials, 5 individual fish were assessed on each sampling day. The QI was calculated for storage time and graphed against storage days to illustrate relationship. The QI was based on an average of all fish assessed within a trial to allow for biological variation between fish.

Comparing the data from each trial and the individual graphs (Fig 5.10.1) it was clear that the regression lines were similar. The graphs used the assessor average for each fish and provided the mean with the standard deviation of 5 fish. The variation between fish across trials was comparable and no unusual pattern is exhibited.

A regression analysis comparing slopes and intercepts from the separate trials showed that the data is poolable and therefore data presented is based on 15 fish (3 trials of 5 fish) with a graph combining all data prepared (Fig 5.10.2).

The pooled data for mullet shows a high correlation between QI score and number of days fish were stored in ice, with an R^2 of 0.988 (R^2 for individual trials were 0.954, 0.995 and 0.958 respectively for trials 1, 2 and 3). QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored, with fish at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axes origin (0, 0) which was not attained in these trials (extrapolation of the data regression line cuts the axes at 0, 1 implying that mullet with a minimum QI of 0 correlates to 1 day old). If the line is forced through the origin, the correlation between QI and days stored is lower and the slope changes.

Table 5.10.1 QI scheme for Sea Mullet (*Mugil cephalus*)

Quality Parameter		Description	Score
Skin	Colour/appearance	Bright silver / steely blue & iridescent	0
		Loss of iridescence	1
		Dull and/or matt	2
	Scales	Intact and firm	0
		Easy to lift	1
		Loose or easy to pull out	2
	Slime (if present)	Clear	0
		Slightly cloudy	1
		Yellowy brown	2
	Odour	Fresh sea	0
		Neutral	1
		Stale or oily	2
		Off, rotten or rancid	3
	Belly	Firm	0
		Soft	1
		Very soft	2
	Anus	Normal	0
		Raised	1
		raised and/or leaking	2
Eyes	Form	Convex	0
		Flat	1
		Sunken	2
	Pupils	Shiny jet black	0
		Dull black, slightly translucent, patchy	1
		Cloudy, grey or bloodied	2
Gills	Gill Plate	Clear / translucent	0
		Bronzing	1
		Bloody or yellowy bronze	2
	Colour/appearance	Red / dark red	0
		Faded or some discolouration	1
	Mucous	Clear	0
		Blood red	1
		Bloody brown	2
	Odour	Fresh sea	0
		Stale/oily	1
		Sour, chemical, rancid	2
Quality Index			0-24

Figure 5.10.1. Quality index scores for all three trials of mullet stored in ice.

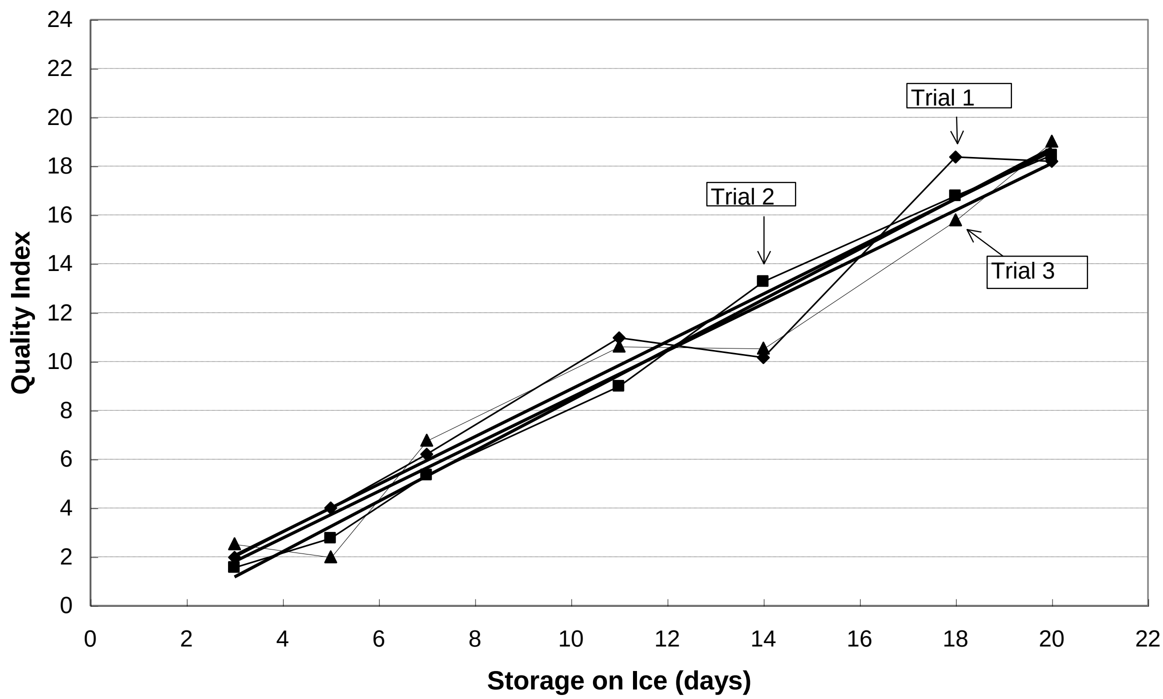
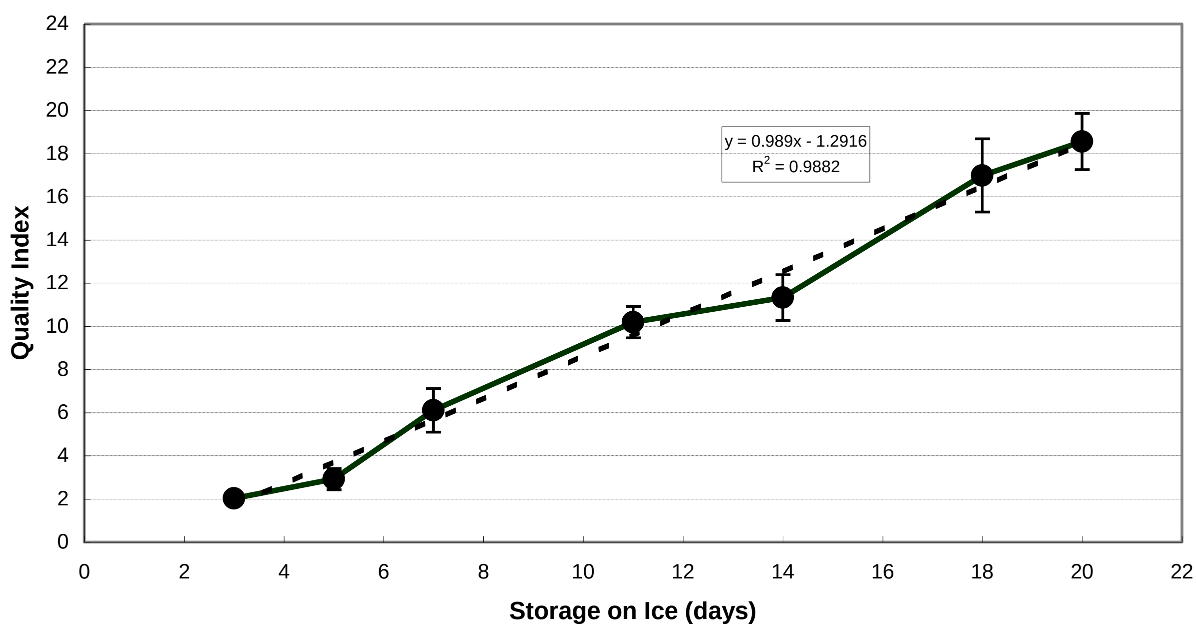


Figure 5.10.2. Quality Index for pooled data (Trials 1- 3) showing scores averaged across fish and assessors with bars indicating standard deviation.

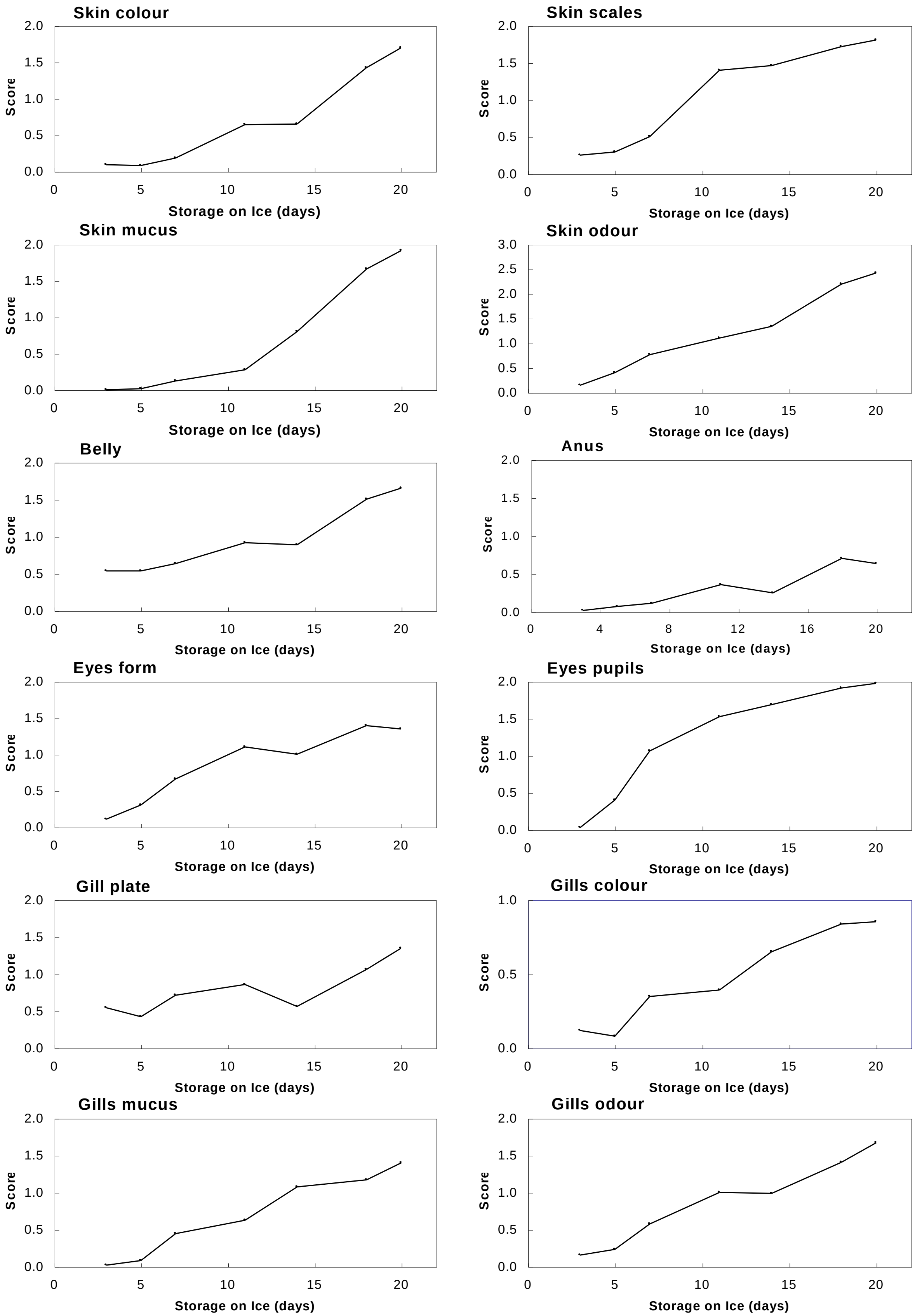


The data for all trials show a similar rate of deterioration of the mullet with time stored in ice, however at the end of storage life, as determined by taste testing, was suppressed a little and did not quite ever reach maximum demerit points. This was despite the fish being stored to rejection point and a little beyond.

It is suspected that this occurs due to assessors being individually reluctant to use the extreme points of a particular parameter category. This is a frequently observed phenomenon (Steve Nottingham, 2004, pers.comm.) and should not detract from the usefulness of the data obtained. Interestingly, similar occurrences are reported in many QIM schemes sighted (see Sveinsdottir *et al*, 2002: reached 17 of maximum possible of 24; Sveinsdottir *et al*, 2003: 19 of max 22; Andrade *et al*, 1997: sardine: 24 from max 30; horse mackerel: 18 from max 29; Atlantic mackerel: 26 from max 29) and was also observed in the QI assessments of gold band snapper and farmed black tiger prawns (see other reports of this work).

The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials. Increase in score for each parameter over storage time is depicted in Figure 5.10.3. Of the 12 parameters selected all demonstrated value, indicated by steadily increasing in score with storage time, except the anus parameter which only changed minimally in any trial. This parameter was originally chosen as having been mentioned by industry operators as one they use on a routine basis. The other parameter that was of only mediocre value was gill plate, where this parameter measured the extent of blood visible in the gill plate area. Mullet stored over time will show increasing blood accumulation and leakage out to the gill plate area, however this parameter can also be affected by handling practices at capture. Hence the variability in score for this parameter.

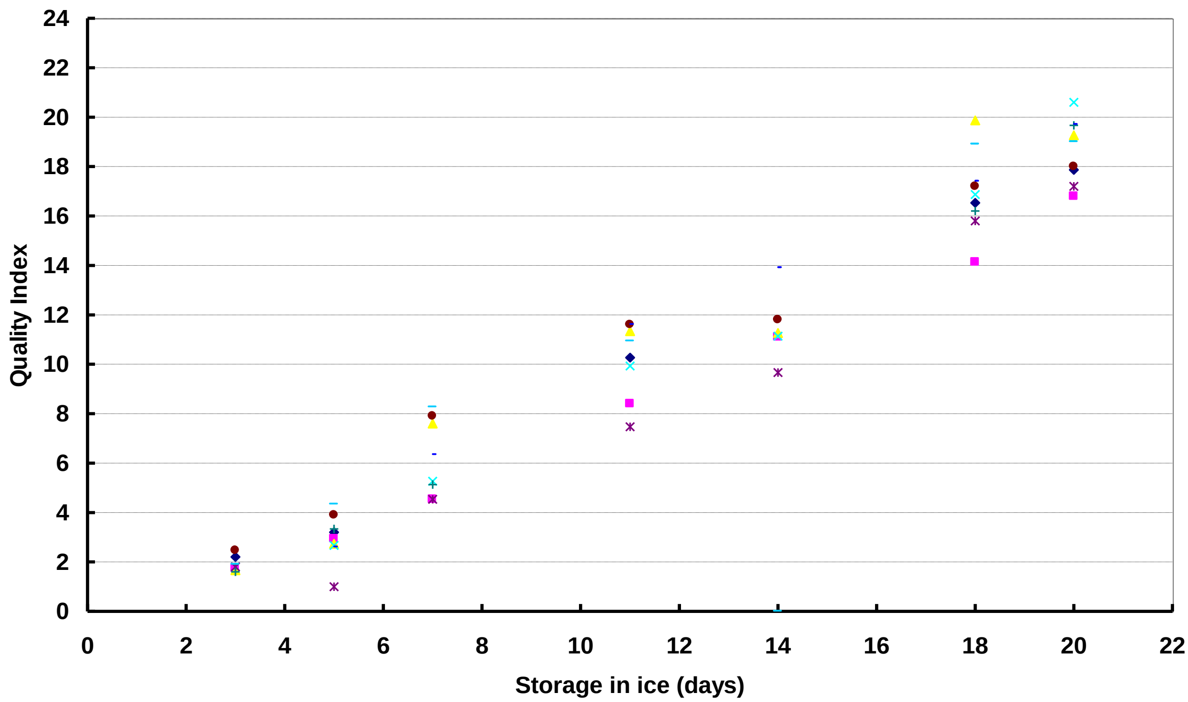
Figure 5.10.3. Scores of individual quality attributes over storage time.



Observations during trials noted that gill colour, which is one of the standard measures used by industry to judge the quality of mullet, surprisingly did not change very much. Freshly caught fish had gills that were dark red with a glossy appearance due to clear fresh mucous present. As the fish were stored, gill colour changed faded only a little to show faint tinges of pale brown and slime (mucous) did not increase. The lack of distinction between gill colour of fish at different storage periods excluded the relevance of including photo examples as staged reference comparisons.

Analysis of assessor performance looked at the average score given by each assessor for all the mullet assessed at a particular time. It showed that while there was variation in the QI scores from different assessors for each trial (Fig 5.10.4), each assessor was consistent over the days assessments occurred. The variation between assessors when scoring mullet was noticeably less when the fish were very fresh (at the beginning of storage life).

Figure 5.10.4. Quality Index scores given by individual assessors on any one day during storage of fish in ice (taken from Trial 2).

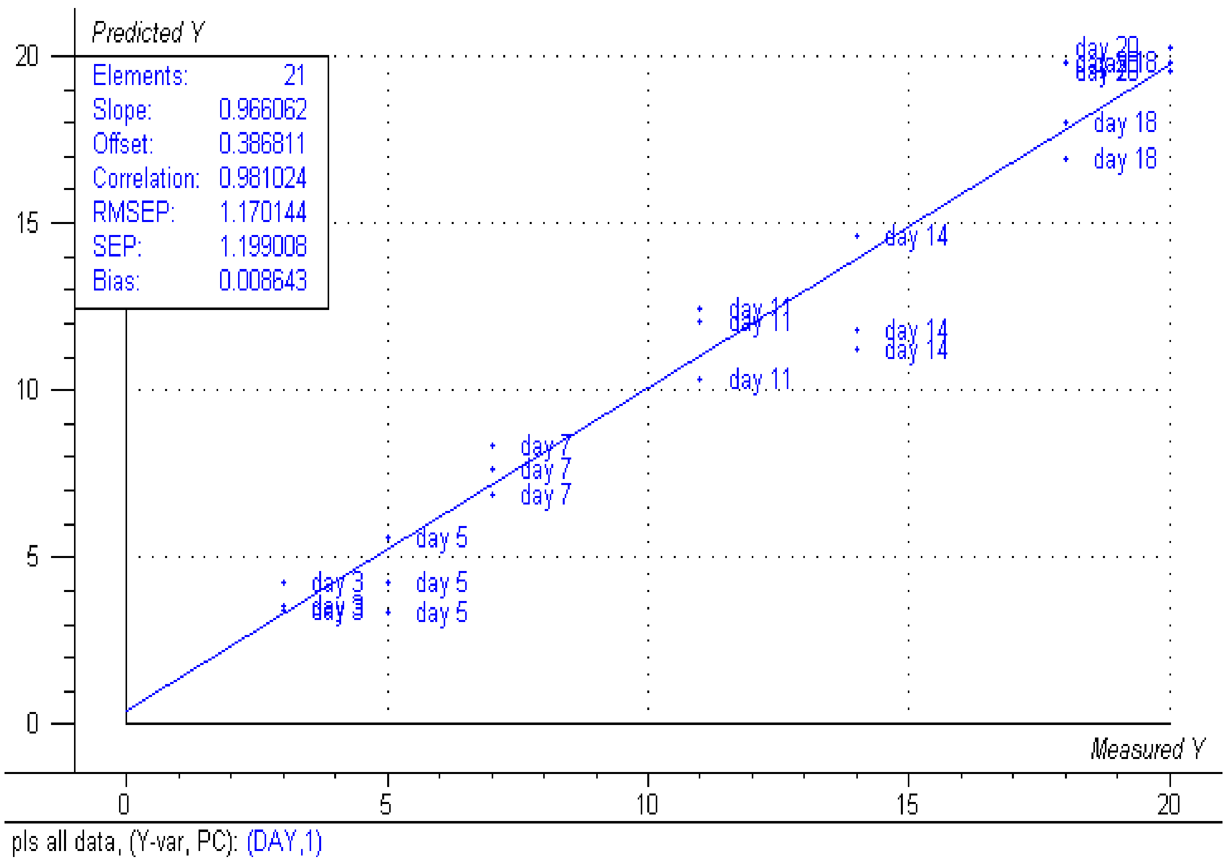


An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the 3 trials. For the exercise, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly any interaction between fish and panel member.

For all trials there were significant differences between the overall QI score across all times given by each panel member and there was also significant ($P<0.05$) fish QI score differences. However in both trials there was no significant ($P>0.05$) interaction between fish and panel member scores indicating that each panel member is using a different part of the scale but is consistent across fish.

Predictability of QI was analysed using partial least square regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 quality parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis the QI of mullet can be used to predict the storage time of the fish in ice with an accuracy of ± 1.2 days (Fig 5.10.5).

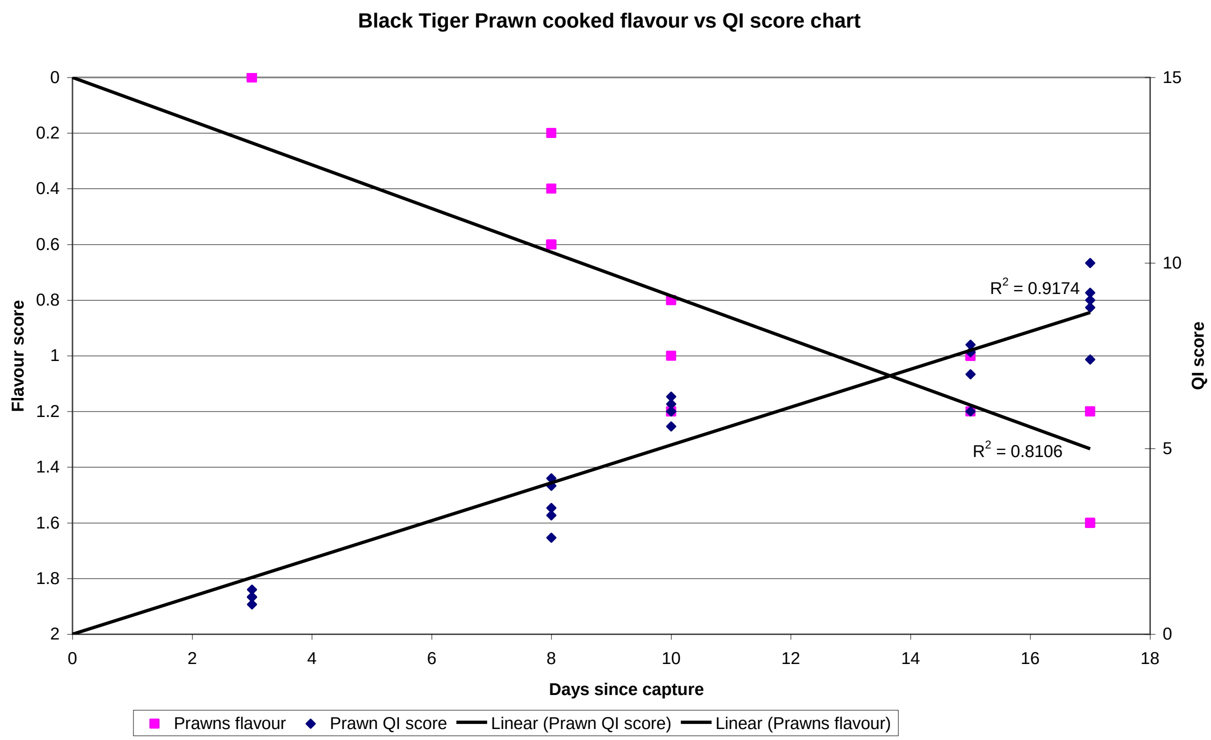
Figure 5.10.5. Standard error of performance of the mullet QI scores



5.10.12 Assessment of cooked flesh

The cooked flesh was assessed for flavour on the Torry scoresheet and the result (Figure 5.10.6) was a negative linear relation between the score for flavour and the number of Icedays stored.

Figure 5.10.6 Comparison graphs of cooked flavour and QI scores versus Icedays for cooked samples of Sea Mullet (*Mugil cephalus)*



5.10.13 Conclusion

A QI scheme has been developed and validated for Sea Mullet (*Mugil cephalus*) and is published in the QI Manual. It has an accuracy of ± 1.2 days.

5.11 Silver Warehou (*Seriolella punctata*)

This trial was done by Dr Felicia Kow and students at the Australian Maritime College (AMC), Beauty Point, Tasmania.

Sensory assessment included visual, odour and texture parameters for all possible features specific to the species product form. Experienced seafood assessors, 6 to 11, were used at each time to ensure that assessment data from a total of 6 assessors were available for analysis throughout the trial. A total of five separate fish were assessed at each sample time and samples were taken 8 times at 2 to 3 days intervals, throughout the storage period.

5.11.1 Pilot investigations

Fish with a known harvest-handling-storage history have been obtained and stored in melting ice. Ice Time was calculated using the Ice Time Calculation Method (Olley, J 1978). At regular intervals (2-3 days) the fish were assessed for their sensory characteristics and relevant descriptors were listed for each stage throughout storage. Electronic images were capture at each corresponding stage.

5.11.2 First trial

Second phase investigations followed the same procedure as described above. Fish samples have been obtained at point of harvest, assessed where possible and transported as soon as possible to the seafood labs at Beauty Point, Tasmania. Transport containers included temperature data loggers to capture storage history. In fact these data loggers were place immediately after the fish have been landed to monitor the core temperature of fish throughout the entire storage period. Full assessment of 5 fish was carried out 8 times throughout subsequent iced storage of the product as mentioned above. It is to be noted that the assessments involved all assessors to reach consensus on what score a particular parameter achieves and at which intensity and to agree/confirm that the descriptors selected for the index were relevant and correct.

During these trials, the definitive points of visual change were noted pertinent for photographic records.

Also during this phase, the end of storage life with respect to consumer acceptability was estimated by 3 assessors from tasting cooked product.

5.11.3 Second trial

A minimum of 40 fish samples of the same species as that in the first trial was obtained following exactly the same procedure as described in the first trial.

5.11.4 Results

Tables 5.11.1 and 5.11.2 give the temperature and sensory records of Silver Warehou from the first and second trials respectively and indicate good control of temperature.

Table 5.11.1 Average temperature and mean sensory score records of Silver Warehou for the first trial

Date	Temp ^{0}C / 24Hr	Equivalent days in ice (ice time)	Actual Sampling Day	Equivalent Sampling Days in ice	Sensory scores
23-Aug	0.6	1.1		1.1	
24	-0.6	0.9		2	
25	-0.2	1		3	
26	-0.1	1		4	
27	-0.3	0.9	5	4.9	4.2
28	0.3	1.1		6	
29	0.5	1.1	7	7.1	9.5
30	0.7	1.2		8.3	
31	0.8	1.2	9	9.5	7.6
1-Sep	0.6	1.1		10.6	
2	0.7	1.2		11.8	
3	0.5	1.1	12	12.9	10.7
4	-0.3	0.9		13.8	
5	-0.3	0.9	14	14.7	10.9
6	-0.2	1		15.7	
7	-0.1	1	16	16.7	15.4
8	-0.2	1		17.7	
9	-0.2	1		18.7	
10	-0.1	1	19	19.7	17.9
11	-0.2	1		20.7	
12	-0.2	1	21	21.7	20.5
	Total			**21.7**	

Table 5.11.2. Average temperature and mean sensory score records of Silver Warehou for the second trial

Date	Temp ^{0}C / 24Hr	Equivalent days in ice (ice time)	Actual Sampling Day	Equivalent Sampling Days in ice	Sensory scores
24-Sept	0.6	1.1		1.1	
25	-0.6	0.9		2	
26	-0.2	1		3	
27	-0.1	1		4	
28	-1.1	0.8	5	4.8	5
29	-0.7	0.9		5.7	
30	-0.6	0.9		6.6	
1-Oct	-0.6	0.9	8	7.5	9.3
2	-0.4	0.9		8.4	
3	-0.4	0.9	10	9.3	9.5
4	-0.4	0.9		10.2	
5	-0.2	1	12	11.2	13.8
6	-0.3	0.9		12.1	
7	-0.2	1		13.1	
8	-0.2	1	15	14.1	15.6
9	-0.2	1		15.1	
10	-0.2	1	17	16.1	17.5
11	-0.2	1		17.1	
12	-0.2	1	19	18.1	20.2
13	-0.2	1		19.1	
14	-0.2	1		20.1	
15	-0.1	1	22	21.1	22.8
	Total			**21.1**	

The QI scheme developed is given in Table 5.11.3

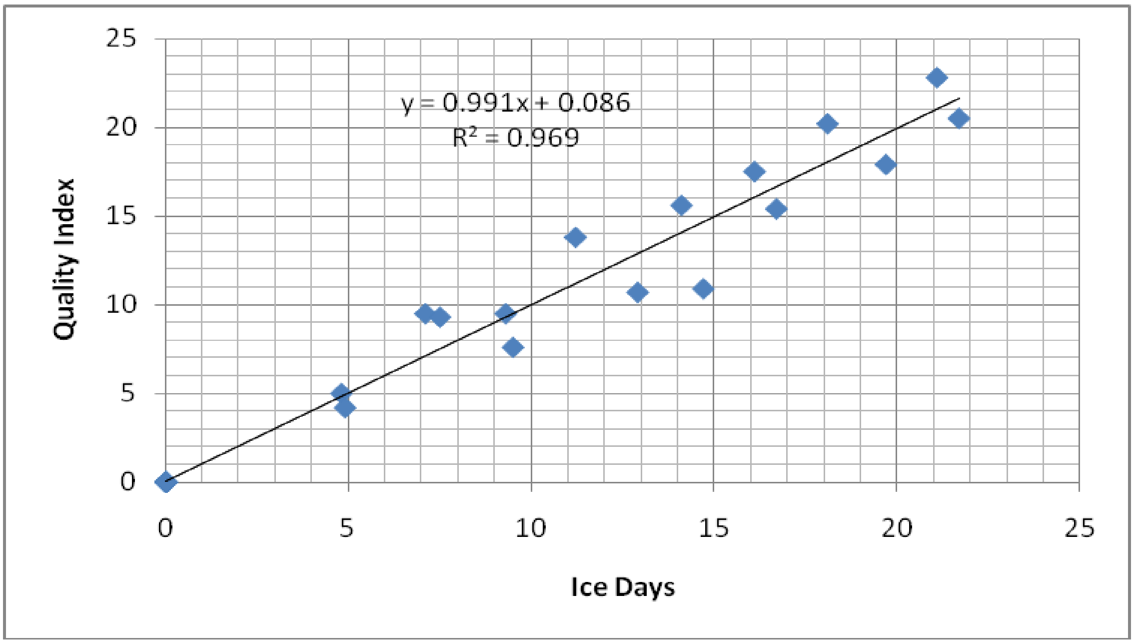
Table 5.11.3 Quality Index Scheme for Silver Warehou (*Seriolella punctata*)

Quality Parameters		**Description**	**Score**
Skin	**Colour/ appearance**	Silver-white on belly	0
		Pale yellowish	1
		Dark yellow near belly	2
	Odour	Fresh sea-weedy	0
		Neutral	1
		Sour	2
		Rotten	3
	Texture	In rigor (no finger mark)	0
		Finger marks disappear rapidly	1
		Finger leaves mark over 3 seconds	2
Eyes	**Pupils**	Clear and black, metal shiny	0
		Dark grey	1
		Matt, grey	2
	Form	Convex	0
		Flat	1
		Sunken	2
Flesh	**Colour**	White	0
		Light yellow/Creamy	1
		Yellowish	2
Gills	**Colour**	Bright, characteristic red	0
		Slightly discoloured, dark red	1
		Discoloured, dark brown	2
	Mucus	Transparent	0
		Milky, clotted	1
		Yellow, clotted	2
	Odour	Fresh, seaweed	0
		Neutral	1
		Sour	2
		Rotten	3
Abdomen	**Blood in abdomen**	Blood red/not present	0
		Blood more brown, yellowish	1
	Odour	Fresh Sea-weedy	0
		Neutral	1
		Sour	2
		Rotten	3
Quality Index			**0-25**

* Texture assessed at the interception of anus and lateral line.

The corresponding linear relationship chart (Fig. 5.11.1) shows that y = 0.991x + 0.086 and R^2 = 0.969.

Figure 5.11.1 Relation between QI score for Silver Warehou and storage period



The fish were judged to be at the end of their usable life after 16 days. The end and the estimation of remaining shelf life is presented in Table 5.11.4.

Table 5.11.4
Estimated remaining shelf life for Silver Warehou when the end used day is 16 Ice Days
Quality Index = 0.991 x days in ice + 0.086 (R^2 = 0.969)

Quality Index	Storage time in ice (days)	Remaining Shelf life (days)
1	1	15
2	2	14
3	3	13
4	4	12
5	5	11
6	6	10
7	7	9
8	8	8
9	9	7
10	10	6
11	11	5
12	12	4
13	13	3
14	14	2
15	15	1
16	16	0

5.11.5 Conclusion

A QI scheme has been developed and validated for Silver Warehou (*Seriolella punctata*) examined in the head on, gills on, gutted form (HOGOG). The temperature control was good and the fish was estimated to have a shelf-life of about 15 days. This is longer than would normally be expected but it is an example of what can be done if strict attention is paid to temperature.

5. 12 Snapper (*Pagrus auratus*)

Trial conducted by Jayanthi Weerasinghe (formerly of CSIRO when project arranged) on the premises of the Victoria University of Technology (VUT), Werribee.

5.12.1 Fish and assessment

A trial batch of 40 whole, ungutted fish (fork length 24 to 27 cm and estimated average weight 239 g) from the Sydney fish market were road-freighted the ~500km to VUT. On two subsequent days, a batch of 40 fish from a single days fishing, possibly from the same location, were obtained at 4am from a wholesaler at the Melbourne Fish Market and were stored well iced in insulated containers for transport 50 Km to VUT. All three batches were placed in a chiller (set temperature 0-4^{o}C). Ice was replenished to the top of the container every day and the temperatures of the fish were logged throughout storage at regular intervals.

In each case five samples were withdrawn at random from storage on 2 to 3 occasions per week over a three week period. Each fish was displayed on a white plastic tray sitting on a bed of ice and was assessed in a different order by each member of the sensory panel. This sensory panel consisted of six students and staff in the Department of Food Science and Marketing who had been trained, in familiarization panels on samples of fish preceding the trials, in the use of the score sheets and were in agreement about the meanings of the terms used with specimens of the species of varying history. The terms used and the scores were based on experience with the species and on published schemes for Snapper (Hyldig and Nielsen 1997; Huidobro et al., 2000). The score sheet developed is shown in Table 5.12.1 and is typical of those used in QIM.

Photographs of the whole fish and the head and gill regions on a grey background were taken at each sampling occasion (Sony Cyber-shot 3.2 MEGAPIXELA EX digital DSC-P5).

Taste testing of the cooked flesh was done by the same panelists at the same sampling. Six pieces of fish (~1.5cm^3) were cut from the anterior dorsal portion of one side of a fish and placed in souffle dish (8cm diameter x 4cm deep), which was then individually over-wrapped in cooking film. The samples were heated together for 60 to 90 s on the high setting in a microwave oven (750W, 2450MHz). The panelists were presented with one sample at a time and were instructed to open the plastic wrap and immediately, take 2-3 short sniffs to evaluate the odour. They then assessed the colour and then the flavor without swallowing the sample. Cups for spitting the sample were provided .Water was available to rinse their mouths between samples. The scoring scheme was based on a demerit point system as shown in Table 5.12.2 and panelists were given training on a range of typical cooked fish samples prior to the main trials.

5.12.2 Statistical analysis and results

The number of Icedays were calculated by multiplying the number of days stored by the rate of change (r) at that temperature (t^{o}C) of storage calculated according to the formula $r = (1+0.1t)^2$ (Bremner et al., 1987).

The mean QI scores for each fish at each session and for each individual panelist were calculated and regression lines of QI scores and Icedays were plotted. For Snapper the theoretical line through the origin was also plotted.

Table 5.12.1. QI scheme for whole Snapper (*Pagrus auratus*) comprising the description for each parameter and the given scores in succession from 0 to 3.

Quality Parameters		Description	Score
Appearance	Skin	Bright red to pinkish with bluish spots	0
		Becoming pale pinkish with pale bluish spots	1
		The colour is changed to dull	2
	Belly	Firm	0
		Soft	1
		Burst	2
	Odour	Fresh sea odour	0
		Neutral	1
		Slightly secondary odour (dish cloth, sour)	2
		Strong secondary odour (rotten)	3
	Scales	Shiny and firmly attached	0
		Slightly dull & less firm	1
		Dull & loosening	2
Eyes	Pupils	Clear and black	0
		Dark grey	1
		Matt, grey	2
	Shape	Convex	0
		Flat, slightly sunken	1
		Sunken	2
Gills	Colour/ appearance	Bright, characteristic red	0
		Slightly discolored, brown/red	1
		Discolored, dark brown/green	2
	Mucus	Transparent	0
		Milky, clotted	1
		Brown, clotted	2
	Odour	Fresh, seaweed	0
		Metal	1
		Sour, mouldy	2
		Rotten	3
Texture	Elasticity	Finger mark disappears immediately	0
		Finger leaves mark over 3 seconds	1
Quality Index			0-21

Table 5.12.2. Score sheet used for taste panel evaluation of cooked Snapper (*Pagrus auratus*) and cooked Tiger Flathead (*Neoplatycephalus richardsoni*).

Quality parameter	Characteristics	Score
Odor	Sweet, marine, sea weedy	0
	Slightly acidic/Sour	1
	Ammoniac / spoiled & putrid	2
	Painty, cardboard, rancid	3
Color	Whitish to pinkish	0
	Pale pinkish	1
	Slightly discolored	2
	Discolored	3
Flavor	Sweet, marine, sea weedy	0
	Neutral	1
	Slightly off flavor	2
	Strong off flavor	3

The first delivery of Snapper was used for further practice as some of the insulated foam boxes had broken and temperature control had not been maintained. The temperature was well controlled for the second and third deliveries and on storage ranged from 1.0 to 1.9°C for batch 2 and 1.0 to 1.6°C for batch 3.

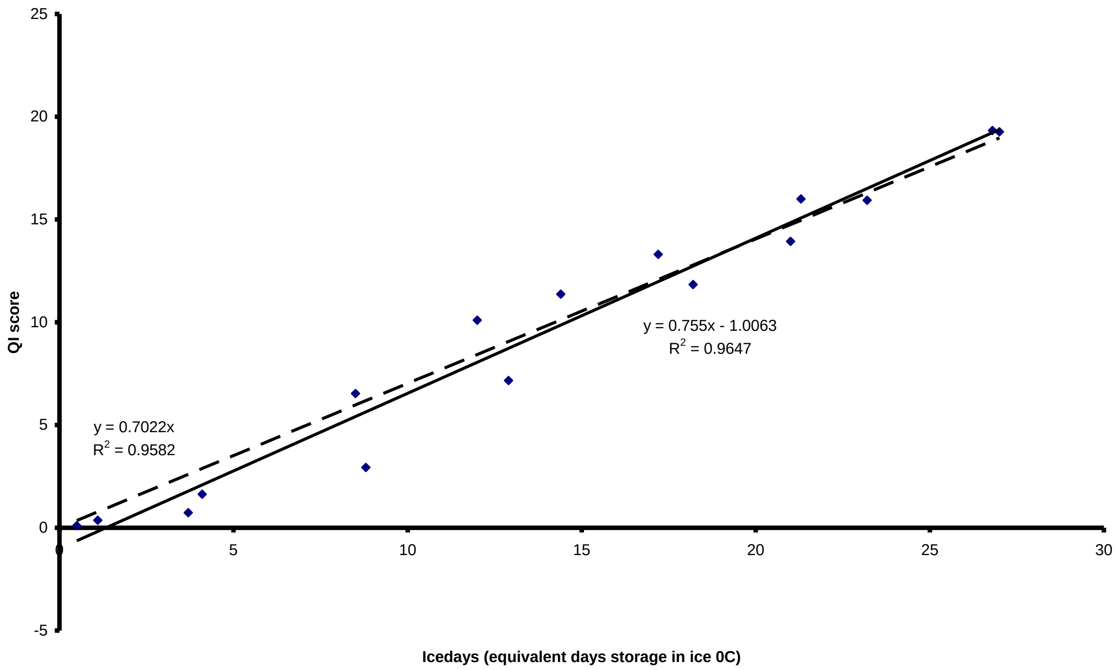
There was considerable agreement between panelists in mean scores given to the five fish at each sampling time for both batch 2 (R^2 =0.980) and batch 3 (R^2 = 0.984) during the trials. The plots of QI score with Icedays had similar slopes (0.763 for batch 2 and 0.761 for batch 3) and covered a similar range but had different intercepts; -1.99 for batch 2 and -0.218 for batch 3.

A combined plot for the two batches resulted in the regression:-

QI score = 0.755 x (no. of Icedays) – 1.01 R^2 = 0.965

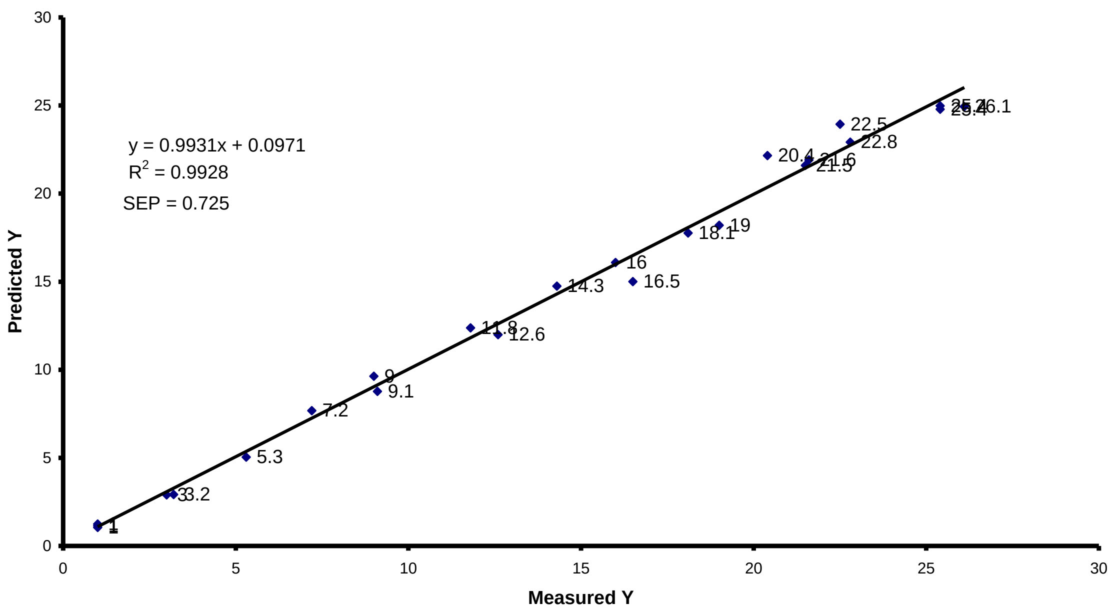
This is shown (Figure 5.12.1) along with a plot forced through the origin. Predictability of the QI score was analysed using partial least square regression (PLS) with full validation (Sveinsdóttir et al., 2002).

Figure 5.12 1. Comparison of regression lines of pooled (batches 2 & 3) QI scores with Icedays for Snapper with (a) line (- -) forced through origin and (b) not forced through origin.



The results of the PLS regression gave an SEP of 1.84 and the corresponding t-value (14 df) was 2.145 with the resulting product being a 95% confidence interval of 3.9 (Figure 5.12.2). This means that the QI score of a batch of Snapper can be used to predict the storage period with an accuracy of ± 1.95 days (effectively 2 days).

Figure 5.12.2. **PLS modeling using full cross validation of quality index data from Snapper stored in ice: Measured with predicted Y values. Average QI for each storage day based on assessment of five Snapper used to predict storage time in days.**



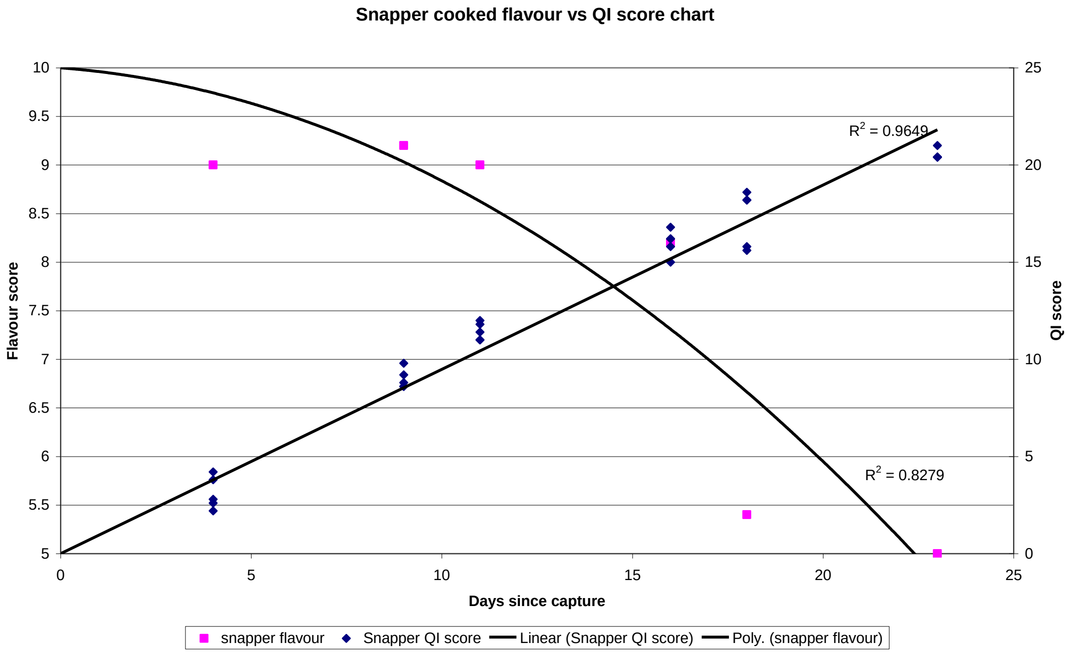
The scores (data not presented) for the samples of cooked flesh indicated that the panel detected no change in odour up to 14 days (QI score 9.6), in colour up to 17 days and in flavor up to 14 days. By about 17 days (QI score 11.8) both batches were reported to have an ammonia-like, spoiled putrid odour, to be slightly discolored and to have passed from a neutral to a slight off flavor.

The scheme for Snapper was very similar to those of Huidobro et al., 2001 but had a higher total score. This was due to the inclusion of the parameters; firmness of belly, attachment of scales and appearance of mucus in gills. It is possible that a revised scheme with fewer attributes could be sufficient.

The small difference in results between the two batches of Snapper is likely to be a consequence of several factors. Firstly, the calculation for Icedays from temperature readings has not been verified specifically for Snapper although it is a very useful general rule and temperatures for individual fish in a batch are notoriously not uniform. A larger panel with more extensive training and a greater number of replicate batches may have resulted in greater homogeneity. Note that the panel was more experienced in the whole technique when it came to Flathead. It would have been preferable to have completed further trials but personnel and funds were not available.

The taste panel indicated that there was negligible change detectable in the cooked flesh of the stored Snapper for at least 13 days. This stability is presumably one reason that the species is popular as, in addition to its initial desirable flesh characteristics, it provides about a fortnight in the distribution chain from point of catch to consumption in which these do not markedly deteriorate. Boyd and Wilson (1977), using a more discriminatory score system based on the ten point Torry Scoring Scheme for cooked fish (Shewan et al., 1953), reported that the rate of change in general appearance for Snapper was very similar to the rate of change in score for odour and flavor of the cooked flesh of the stored fish. This bears out the validity of using the characteristics of general appearance that are embodied in QI scales. A comparison of the QI scores and taste scores indicates that the panel taste scores were curvilinear (Figure 5.12.3) a similar result to that of Goldband Snapper (Fig.5.4.10).

Figure 5.12.3 The QI scores and taste panel scores for cooked snapper plotted versus Icedays



5.12.3 Conclusions

A QI scheme for Snapper (*Pagrus auratus*) has been developed and validated. The accuracy for this scheme is ± 2 days, but it is likely that results of any further trials would de crease this margin.

5.13 Tiger Flathead (*Neoplatycephalus richardsoni*)

Trial conducted by Jayanthi Weerasinghe (formerly of CSIRO when project arranged) on the premises of the Victoria University of Technology (VUT), Werribee.

5.13.1 Fish and assessment

Three batches each of forty ungutted fish (fork length 35 to 47 cm and estimated average weight 494 g) were similarly obtained from the same wholesaler as the Snapper (see 5.12) and were transported chilled in ice to VUT. They had known history, each batch having been caught within the previous 24h from the same location. The details of the panel its training, the presentation of samples and evaluation of cooked samples are the same as those for Snapper (above 5.12). The QI scheme developed with and used by the panellists (Table 5.13.1) was based on preliminary trials and descriptions of storage changes for Flathead (McMeekin et al., 1982).

5.13.2 Analysis and results

Temperature was well controlled in all three batches ranging from 1.0 ^oC to 1.4^oC in the first, 1.0 ^oC to 1.3^oC in the second, to 1.0 ^oC to 1.4^oC in the third and the temperature records were used to calculate Icedays.

The panelists were in good agreement for all three batches with R^2 values of 0.999, 0.991 and 0.996 for batches 1, 2 and 3 respectively. The slopes, goodness of fit, intercepts and range of data for the three batches were in agreement and the data was therefore pooled and, along with a line forced through the origin, are plotted (Figure 5.13.1) to display the relationship:-

QI score = 0.782 x (no. of Icedays) – 0.653 $R^2 = 0.994$

indicating a very strong correlation up to 25 days storage.

The PLS regression resulted in an SEP of 0.725 and with a corresponding t-value (22 df) of 2.074 the resulting product gave a 95% confidence interval of 1.5 (Figure 5.13.2). This means the QI score of a batch of Flathead could be used to predict the storage period with an accuracy of ± 0.75 day (effectively 1 day).

For the cooked fish (data not presented), the taste panel first detected changes in odour of the samples after 6 days (QI score 4.0) for batch 1, but only after 10 days (QI score 7.2) for batches 2 and 3. Conversely changes in colour were first noted after 10 days for batches 2 and 3 and 13 days for batch 1. For flavor the first change was noted after 6 days for batch 1 and 2 but at 10 days for batch 3.

The scores for the cooked fish resulted in a curvilinear relationship with QI when plotted versus Icedays (Figure 5.13.2)

Table 5.13.1. QI scheme for whole Tiger Flathead comprising descriptions for each parameter and the given score in succession from 0 to 3.

Quality Parameters		Description	Score
Appearance	Dark side	Brownish with orange red spots	0
		Brightness becoming pale	1
		The colour is changed to dull	2
	White side	Fresh no discoloration	0
		Some discoloration	1
		Soft, dull and discoloration	2
	Odour	Fresh sea odour,	0
		Neutral	1
		Slightly secondary odour (dish cloth, sour)	2
		Strong secondary odour (rotten)	3
	Mucus on top & texture of belly	Slimy and firm	0
		More slimy & less firm/soft	1
		Very slimy, dull & very soft	2
Eyes	Pupils	Black and eye socket convex	0
		Dark grey and slightly sunken/shrunken	1
		Matt, grey swollen/shrunken	2
Gills	Colour/ appearance	Bright, characteristic red	0
		Slightly discolored, brown/red	1
		Discolored, dark brown/green	2
	Mucus	Transparent	0
		Milky, clotted	1
		Brown, clotted	2
	Odour	Fresh, seaweed	0
		Metal	1
		Sour, mouldy	2
		Rotten	3
Texture	Elasticity	Finger mark disappears immediately	0
		Finger leaves mark over 3 seconds	1
Quality Index			0-21

Figure 5.13.1. Comparison of regression lines of pooled (batches 1, 2 & 3) QI scores with Icedays for Tiger Flathead with (a) line (- -) forced through origin and (b) not forced through origin.

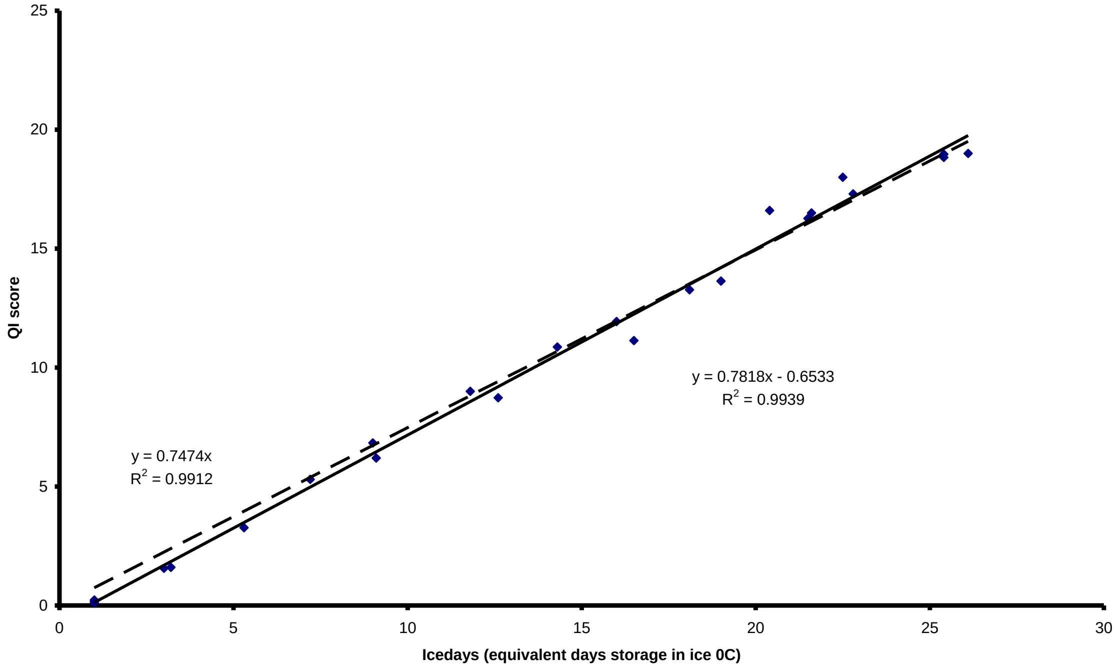
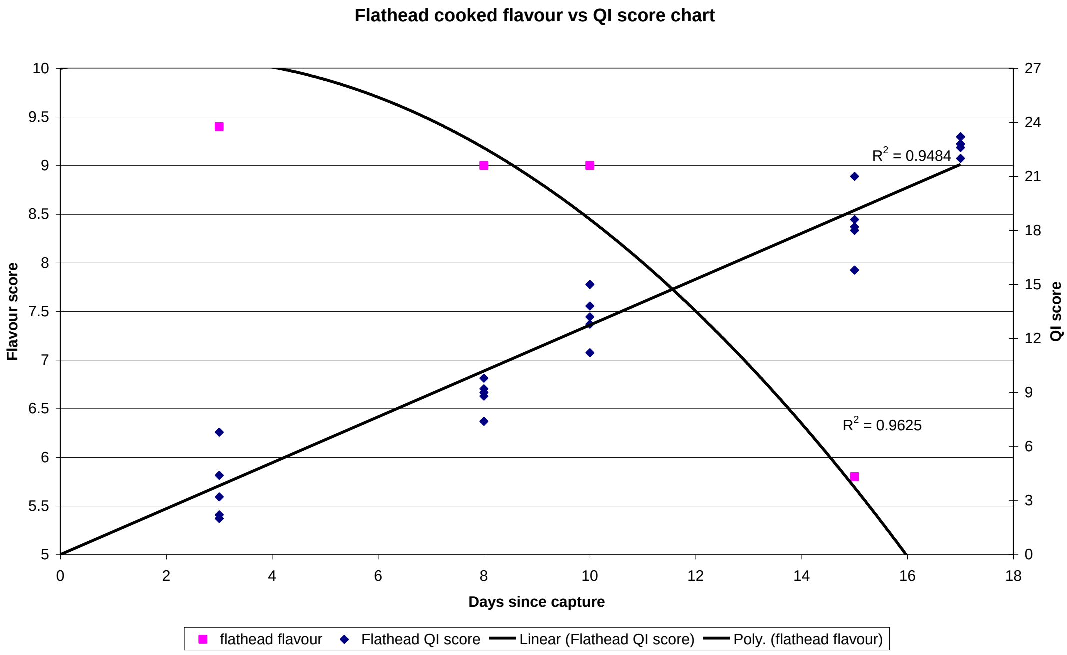


Figure 5.13.2 Plot of cooked flavor score and QI for Tiger Flathead versus Icedays



5.13. 3 Discussion and Conclusion

There was excellent replicability of QI scores between the three batches of Tiger Flathead but less agreement in changes in odour and flavor. The resulting QI scheme has been published in the QI Manual.

5.14 Yellowtail Kingfish (*Seriolella lalandi*)

Trials were conducted by Sue Poole, John Mayze, John Nagle, Paul Exley, Stephanie Kirchhoff and Steve Nottingham, Innovative Food Technologies (IFT), DEEDI (formerly QDPI&F), Hamilton, Brisbane and Ron Wong a visiting Senior Research Scientist from New Zealand Institute for Crop & Food Research Limited.

5.14.1 Preliminary trial fish

The preliminary trial was carried out with fish obtained as soon after harvest as possible (<24h) and then stored in flaked ice to observe typical changes in attributes over time. From these observations, specific descriptors were determined and agreed as describing the particular attributes at any point of storage.

- fish were harvested from a seacage farm in South Australia, where the seacages were held in clean open seawater
- fish used for assessment were harvested according to usual commercial operation
- fish were chilled, packed and air-freighted to Brisbane arriving the next day
- whole (gut in) fish were stored in free draining melting ice (0°–1°C) in insulated lidded bins (250L Xactics) which were stored in a temperature controlled environment (22°C room). Temperature of the fish during storage was recorded to monitor required holding temperature. Fish were re-iced as needed.

5.14.2 Pilot trial and assessment trial fish

The pilot trial was undertaken to train the assessors in the meaning of each descriptor used for the different attributes of the fish and to confirm agreement that descriptors were appropriate and universally understood.

- all fish used in trials were harvested from the same seacage farm in South Australia and were harvested as for commercial operation
- fish were packed out for sale on the Sydney Fish Market and air freighted to Brisbane arriving <24h from harvest
- whole (gut in) fish were stored in free draining melting ice (0°–1°C) in insulated lidded bins (250L Xactics) which were stored in a temperature controlled environment (22°C room). Temperature of the fish during storage was recorded to monitor required holding temperature. Fish were checked daily and re-iced as needed
- pilot trial was carried out on a single lot of fish.
- Assessment trials were carried out with 3 separate batches of fish from different harvests

Three separate trials were carried out to provide the quality index assessment data to build the model. Photographic records were obtained each day of assessment.

- 5 randomly selected individual fish were used for each assessment
- each fish was assessed separately under standardised evaluation conditions on a stainless steel table at 22°C under fluorescent lighting
- fish were assessed in a random order

5.14.3 Assessors

- 8 -10 assessors were used for each assessment
- assessors were selected for their expertise and experience in sensory assessment of fish and seafood
- additionally, all assessors were trained in the pilot trial on the specific parameters by which kingfish was to be assessed
- assessors made individual judgements independently and their performance was analysed statistically

5.14.4 Statistical data analysis

Statistical analysis was undertaken using various methods and analysing for the effect of different variables. Averages at each time period were calculated based on the panellists' average of the five fish and the fish average over the assessors. This allows comparison of the variability between fish and between assessors

5.14.5 Combining of data from the separate trials

For each trial the average QI for each assessment day was calculated and the regression line was plotted on the one graph. This allowed easy visual comparison of the trials and whether linear regression was appropriate.

The four characteristics of any linear equation fitted to some data are: goodness of fit; slope of regression line; elevation of regression line (the intercept); range of scores achieved. If the individual regression lines agree well on each of these characteristics we are justified in stating that the relation between the variables was the same in each trial and could then pool the data from all trials and obtain an overall regression equation. Exact tests of significance are available for testing between the first 3 characteristics while inspection of the data will suffice for the fourth.

Comparison of the residual mean sums of squares for more than 2 lines uses Bartlett's test for homogeneity of variances and for 2 lines the ratio of the residual variances is sufficient. To test for the slopes and intercepts Genstat linear regression was used. This gave regression models with and without the groups and tests for inclusion of the different trials and any interaction present.

5.14.6 Assessor variation and fish variability

Each panellist's average for each trial on each day was plotted to show variation between scores across the storage time. It also shows if there was any interaction between panellists and time. Assuming fish were randomly chosen for each assessment and the panel composition was consistent, also that no interaction occurs between panellist and fish, then the plotted graphs can also show variation between individual fish at a particular storage time.

An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the trials. For the process, time was used as a blocking factor and panel member and fish were considered as two factors. This gives an overall measure of any panel member differences and fish differences and more importantly, any interaction between fish and panel member.

5.14.7 Predicted and measured using partial least square regression

This was based on analyses similar to those for Atlantic salmon (Sveinsdottir *et al*, 2002, 2003) and Unscrambler software was used to perform the calculations. It is used to evaluate the predictability of the QI and give 95% confidence intervals based on standard error of prediction (SEP). Data was imported into Unscrambler from Excel. PLS1 option was chosen with full validation and no weighting but using the inverse model so *x* was QI and *y* was days. Since QI is the sum of *n* parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated by SEP times t (residual df). The parameter *t* comes from the AOV regression.

5.14.8 Assessment sheet development

The assessment sheet was developed along very similar lines to those of the EU QIM system so as to be complementary to that system. Parameters for assessment were selected from those gained from experience of previously stored kingfish. The parameters were observed during storage with appropriate descriptors discussed and defined at all stages of the preliminary storage trial. Scores were given for each quality attribute according to descriptions, ranging from 0 to a maximum of 3, where 0 implies “perfect”. At each storage time, the attribute ratings were summed and noted as the QI score of that assessor for each fish. All the parameter scores were totalled for each assessor and for each fish. The totals were then averaged to provide the final QI score at that storage time. The end of storage life was adjudged to be the point when fish were rejected by all assessors as being well beyond acceptable for purchase.

It was noted that Yellowtail Kingfish were rejected and considered “rotten” on physical parameters (visual and odour quality attributes) before the cooked flesh from the same fish was rejected by off-flavour. This phenomenon occurred repeatedly and was judged to be the case by all assessors. The maximum scores attained at rejection point of fish were Trial 1: 19.4, Trial 2: 17.8, and Trial 3: 20.1. It is proposed to arise from an inherent behaviour of assessors to not select extreme values on a scale and occurs at both anchored ends of scoring scales. It has been observed to hold true in other storage life trials undertaken by the researchers (Poole *et al*, 1991 and unpublished data) and by authors developing QI schemes for European species.

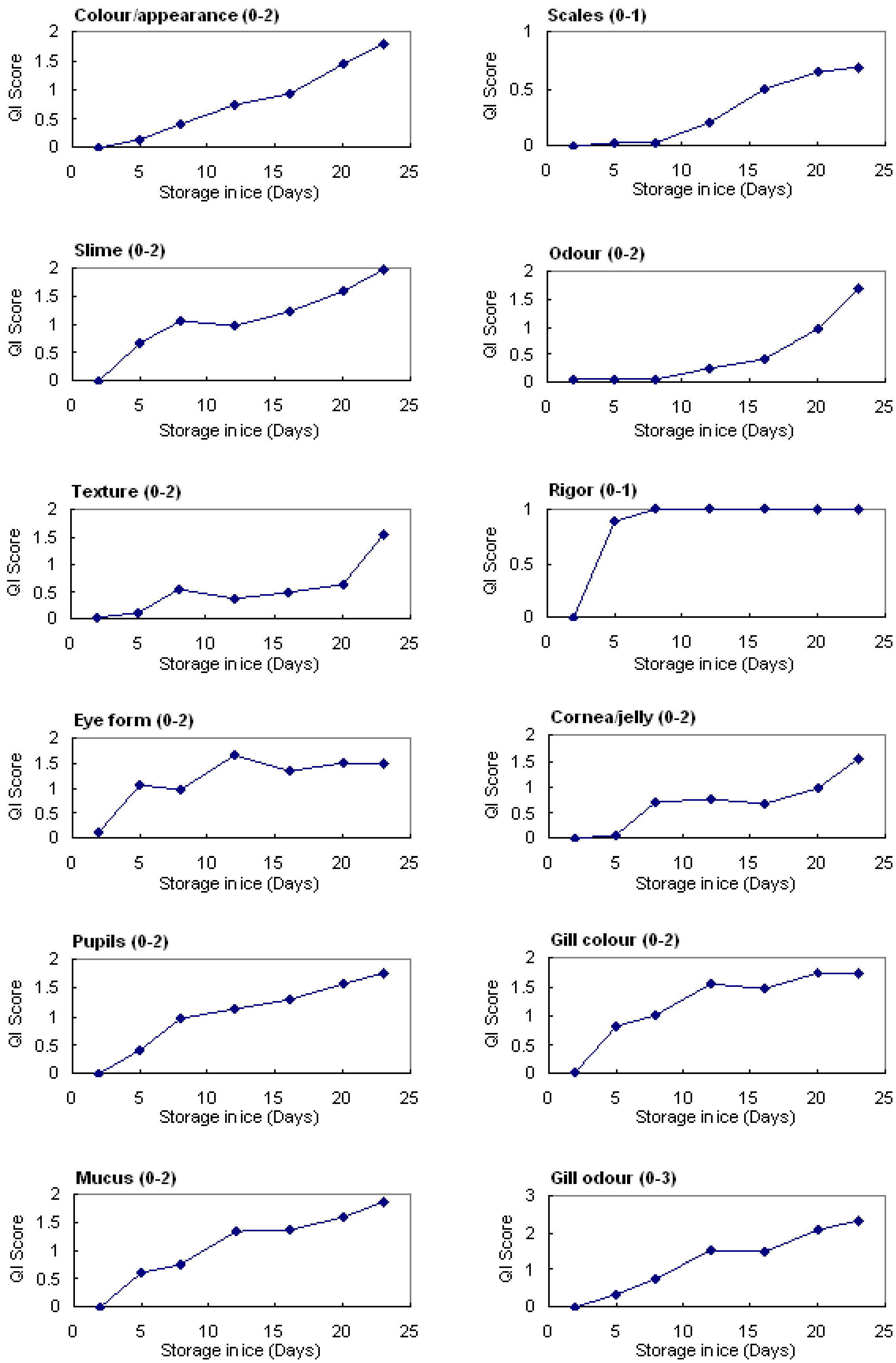
Table 5.14.1 provides the final QI scheme and lists the quality attributes for physical and visual parameters, including odour.

The parameters chosen for assessing the fish were demonstrated to be effective in the pilot trials. Increase in score for each parameter over storage time is depicted in Figure 5.14.1. Of the 12 parameters selected all but rigor demonstrated direct relevance with time, indicated by steadily increasing in score over time. Rigor, commonly used as an indicator of freshness, is a unique parameter in that it resolves to completion early in storage with no further change occurring.

Table 5.14.1. Quality Index Scheme for Yellowtail Kingfish.

	Quality Parameter	Description	Score
Skin	**Colour/ appearance**	Bright &/or iridescent. Strong blue or blue-green upper with yellow band on midline, white-silver below. Lower fins bright yellow. Lateral line indistinct viewed from ventral.	0
		Loss of brightness &/or iridescence. Prominent scale pattern. Olive band on midline. Viewed from dorsal - Pink tone on 2nd operculum & base of pectral and ventral fins. Lateral line less distinct.	1
		Dull &/or matt. Bronze tinge. Lateral line bronze. Pink tone on 2nd operculum & base of pectral and ventral fins. Green tinge on body.	2
	Scales	Attached	0
		Loose / missing	1
	Slime (if present)	Clear / absent	0
		Slightly cloudy / brown	1
		Milky or opaque	2
	Odour	Fresh sea / neutral	0
		Not so fresh or cabbage or sour	1
		Off or rotten	2
	Texture of flesh	Firm, bounce when pressed	0
		Slightly soft, slow bounce back	1
		Soft, finger mark remains over 3 seconds	2
	Rigor	Pre	0
		Post	1
Eyes	**Form**	Convex	0
		Flat	1
		Concave	2
	Cornea/jelly	Clear	0
		Cloudy	1
		Fully opaque	2
	Pupils/Iris	Pupil. Black. Iris. Yellow.	0
		Pupil. Dull black. Iris. Yellow-black.	1
		Pupil. Cloudy / grey. Iris. Pale bronze / grey	2
Gills	**Colour/ appearance**	Red/Dark red	0
		Brown-red &/or some discolouration	1
		Brown &/or discoloured	2
	Mucus	Milky/cloudy	0
		Cloudy brown	1
		Brown	2
	Odour	Fresh seawater/seaweed.	0
		Not so fresh, stale	1
		Sour, vegetable, meaty, chemical, oily, rancid	2
		Rotten	3
Quality Index			**0-23**

Figure 5.14.1 Scores for individual attributes over time (data taken from Trial 1)



5.14.9 Pilot trial

Assessors were trained in applying the QI attribute scores to Yellowtail Kingfish in group sessions over storage time. The scheme was explained to the assessors and the descriptions associated with each score observed with kingfish throughout the full storage period. Discussion occurred until each assessor was confident in understanding the descriptors within each category and hence the aptness and clarity of the descriptions for each quality attribute was confirmed. Photo records obtained at different storage times during the score sheet development trial were found of invaluable use for assisting assessments.

5.14.10 Assessment trials

In each of the 3 trials, 5 individual fish were assessed on each sampling day. The QI was calculated for storage time and graphed against storage days to illustrate relationship. The final QI score for a sampling time was based on an average of all fish assessed in each trial to allow for biological variation between fish.

5.14.11 Combining of data from different trials.

Data from each trial were examined as the plot of the data with standard deviation between fish assessed on any one day, along with the regression line and equation (Figs 5.14.2; 5.14.3; 5.14.4). The correlation coefficients in each trial are good, indicating a tight correlation between days stored in ice and QI score attained.

QI schemes are developed on the assumption that there is a straight line relationship between QI and days stored in ice (Hyldig and Nielsen, 1997), with fish at the point of capture having a theoretical QI of 0. The regression line would therefore pass through the axes origin (0, 0) which was only attained in one of the three trials for yellowtail kingfish.

A graph of QI scores from the three trials (Figure 5.14.5) shows that data from trials 1 and 2 present similar regression lines. The regression line of trial 3 has a greater slope and crosses the regression lines of the two other trials. A regression analysis comparing slopes explains that there is a significant effect from assessment day and specific trial therefore there is a significant interaction between day and trial. This suggests an inconsistency across trials perhaps arising from assessor behaviour differences or occurrence of different immediate-post-harvest handling treatment. It is known that fish in all trials were held and handled throughout the storage phase under exactly the same controlled conditions. A difference in fish treatment at harvest appears the likely reason as fish in trial 3 spoiled more rapidly compared to the two previous trials. The data of the three trials are not pool-able and as confirmation of the validity of data in trial 3 was unable to be undertaken, the data was not considered further within the analyses.

In developing a scheme as standard reference for future use, the more robust the scheme the greater the applicability within industry or research and robustness comes from more data sets being included. Data from trials 1 and 2 are pool-able and a QI scheme could be achieved using just this data. However, to improve predictability from the scheme we looked at data achieved from the pilot trial for possible inclusion.

Figures 5.14.2-4 present the regression lines for each trial.

Figure 5.14.2 Quality index scores with storage time for Trial 1.

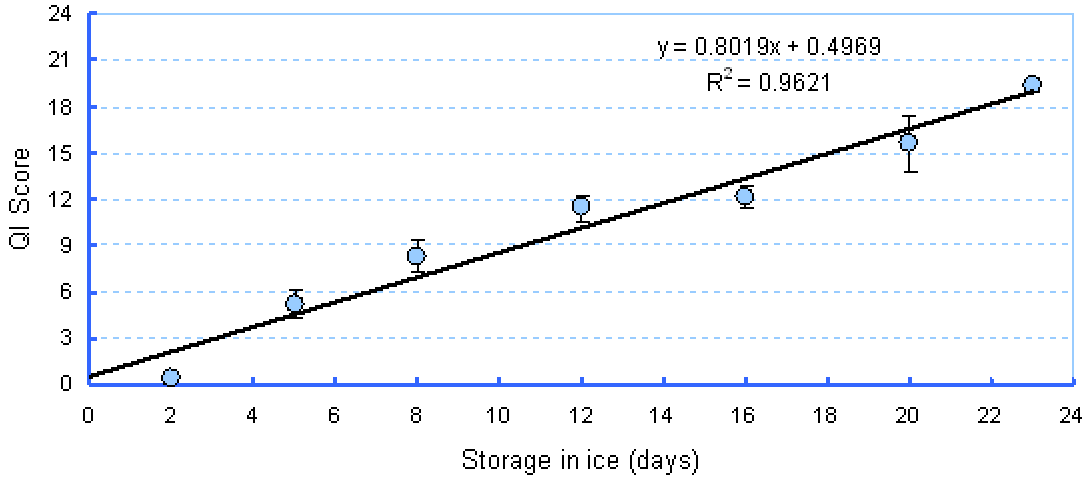
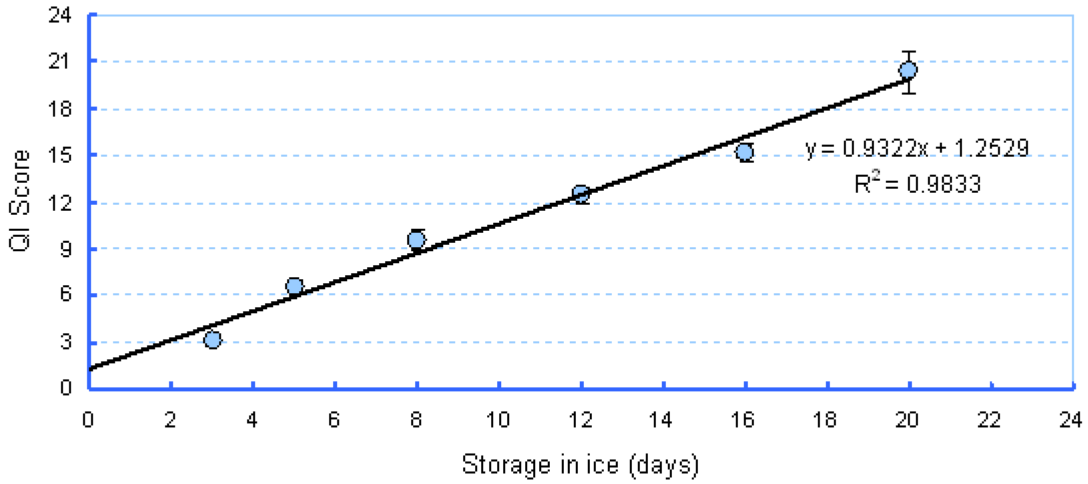


Figure 5.14.3 Quality index scores with storage time for Trial 2.



5.14.4. Quality index scores with storage time for Trial 3.

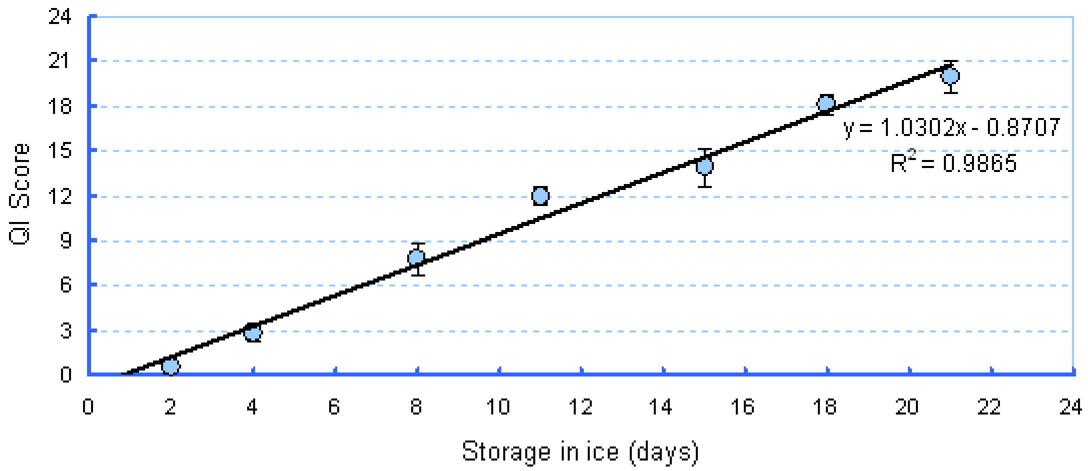


Figure 5.14.5. Quality index scores for trials 1, 2 and 3.

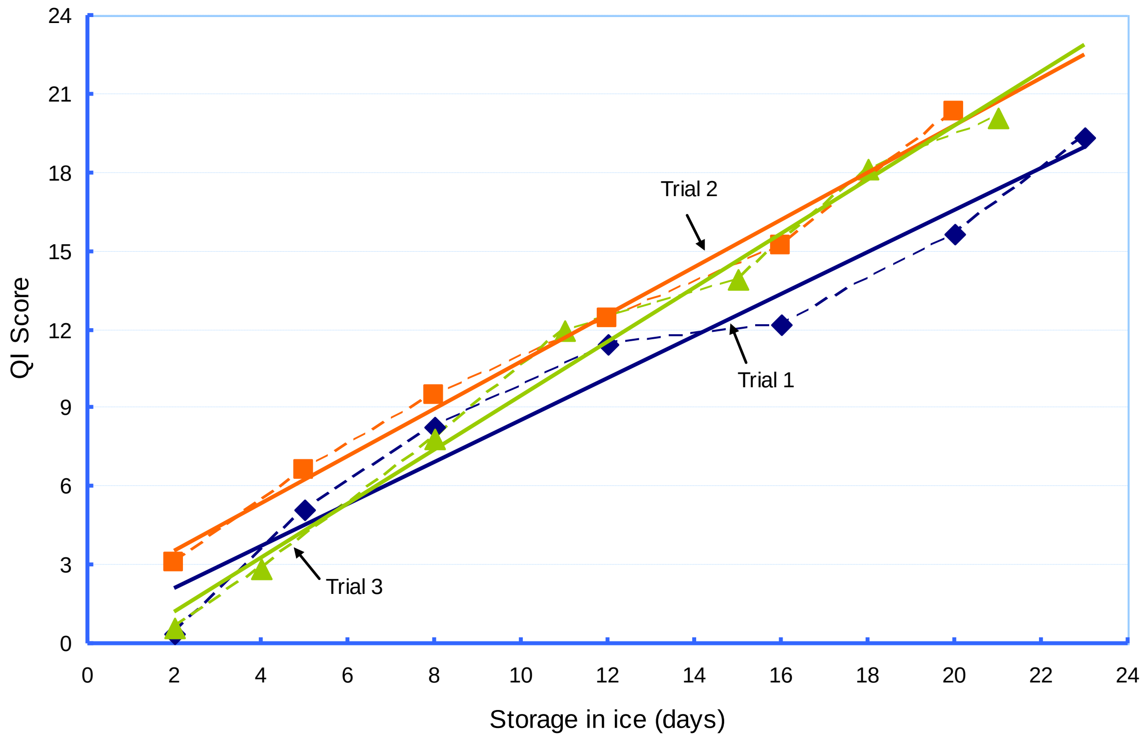
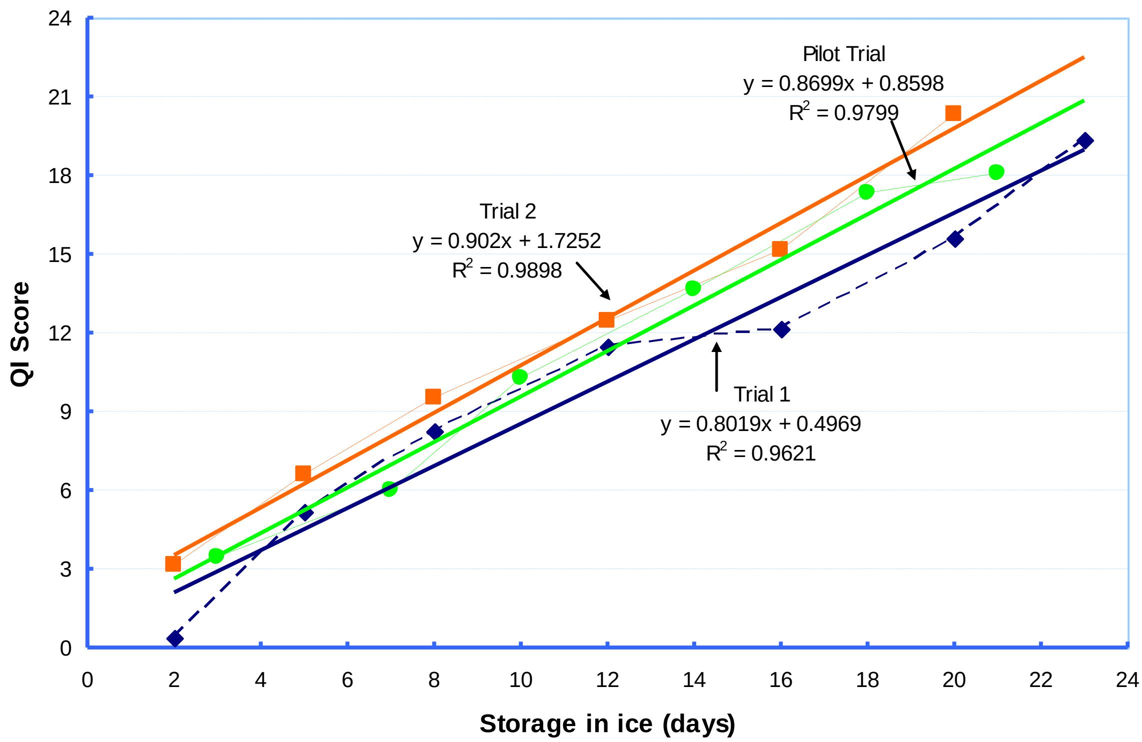


Figure 5.14.6. Quality index scores for trials 1, 2 and pilot trial.



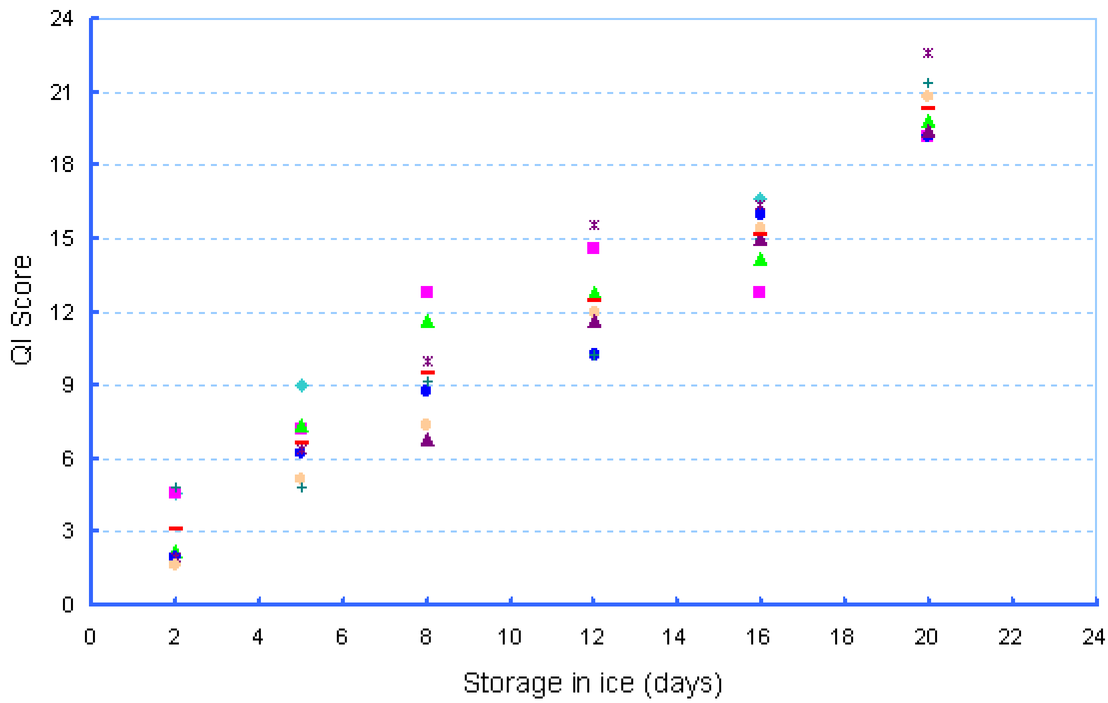
Figures 15.14.5 – 6 show the combined regression line data. The data of these three trials still present a trial effect but there is no more interaction between day and trial. The trial

effect could be explained by trial 1 having one more session compared to the two other trials and pilot trial sessions were scheduled one or two days later compared to trials 1 and 2. Regression analysis indicates that the data from trials 1, 2 and the pilot are pool-able. Therefore a graph combining all data can be prepared and compared to the theoretical trend line using a chosen QI for end of shelf-life at around 22 days.

5.14.12 Assessor variation and consistency

Depiction of variation between assessors (Figure 5.14.7) present the average for each panel member across all five kingfish assessed at a particular time. Only those panel members present for at least 50% of all assessments were included.

Figure 5.14.7. QI scores given by individual assessors during storage of fish in ice (data taken from trial 2)

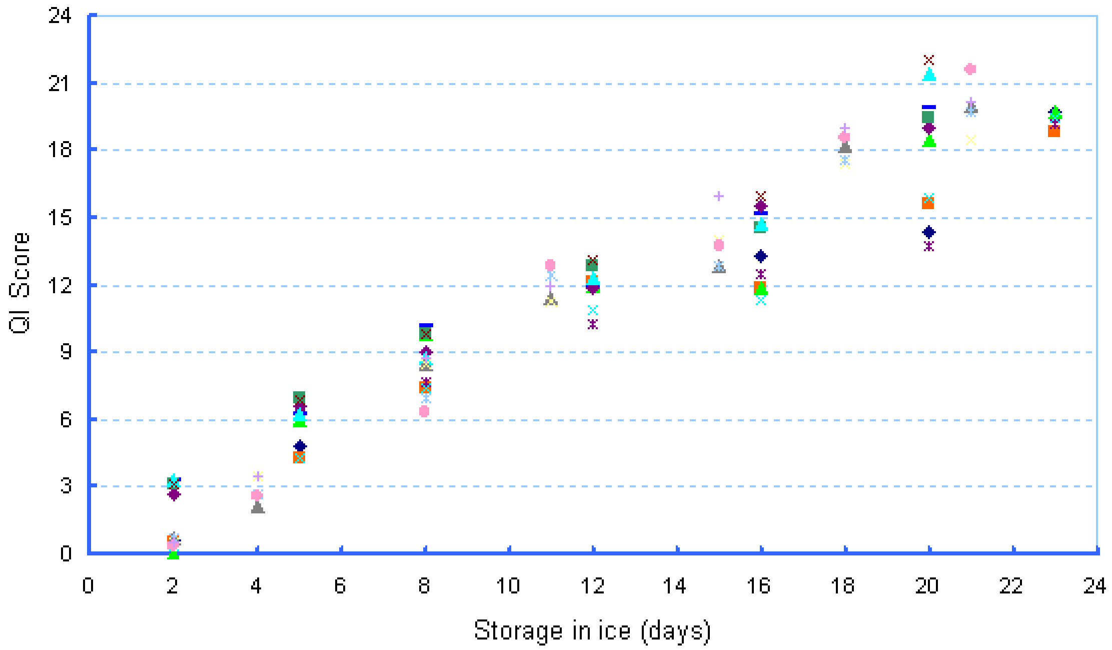


The variation in the QI obtained by individual assessors across all trials was much the same. In the preliminary trial, greatest variation between assessors occurred at the end of the storage period, despite assessors being very familiar with the attribute descriptions by this time. This was also the case in trial 1, with a large variation at day 23 however there was a similar variation at day 5 within this trial. In trial 2, the largest variation occurred around day 8 and close assessment at the end of storage.

5.14.13 Variability between individual fish

Data depicted in Figure 5.14.8 uses all assessments for each fish at each sampling time within all 3 trials. A separate set of five fish were used on each assessment day. From graphs of data for each trial it was seen that the variation across trials is comparable although trial 1 fish contributed to the large variations between fish on day 20. The preliminary study data presented equivalent QI scores for the last two assessment of the trial (days 18 and 21).

Figure 5.14.8 Variation in QI for all fish assessed in all trials.



5.14.14 Analysis of variance comparing variation between fish and assessors

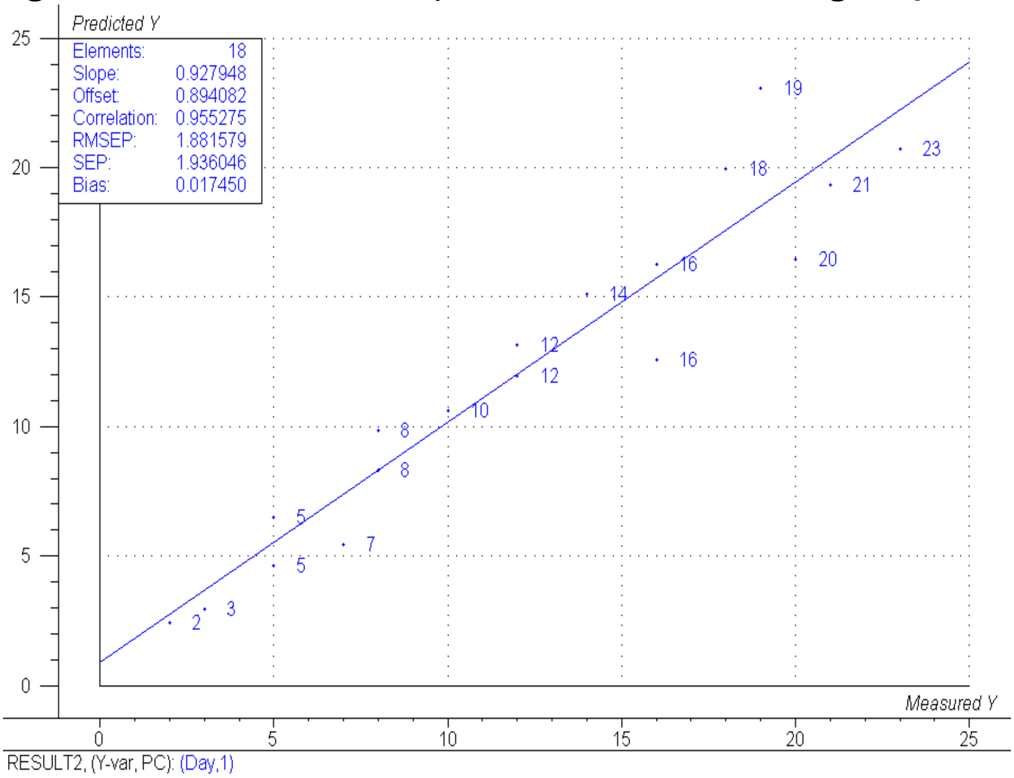
An overall 2-way analysis of variance in randomised blocks was used to analyse the individual data from the three trials. For this exercise, time was used as a blocking factor with assessor and fish considered as two factors. This gives an overall measure of any assessor differences and fish differences and more importantly, any interaction between fish and assessor.

For all trials there were significant differences between the overall QI score across all times given by each panel member which is to be expected as the fish deteriorate with increasing iced storage time. There was also significant ($P<0.05$) difference in fish QI scores in trial 1. However, in all three trials there was no significant ($P>0.05$) interaction between fish and assessor scores. This means that each assessor’s average score on any one day is different but that individual assessors are consistent across individual fish.

5.14.15 Predicted and measured using partial least square regression

Predictability of QI was analysed using partial least square "inverse" regression model (PLS) with full validation and this also gave a SEP (standard error of prediction) value which is used to evaluate the predictability of the QI. Since QI is the sum of 12 parameter values, the measurement error may be assumed to be normally distributed and a 95% confidence interval is estimated. For this combined analysis, the QI of Yellowtail Kingfish could be used to predict the storage time in ice with an accuracy of ± 2 days (Figure 5.14.9, the numbers associated with data points on the graph indicate days of storage of fish in ice)

Figure 5.14.9 Standard error of performance of Yellowtail Kingfish QI scores.



Data from trials 1, 2 and the preliminary trial were pool-able thus giving one regression line and 95% confidence intervals to predict storage time in ice with an accuracy of ± 2 days. This is based on data from 15 individual fish at any one day of storage.

5.14.10 Conclusion

A QI scheme for Yellowtail Kingfish (*Seriola lalandi*) has been developed and validated and published in the QI Manual.

6.0 General Discussion

QI schemes for a total of 14 valuable Australian commercial species have now been developed and published in a QI Manual (Boulter, M. et al, 2009) (see attached disc for a pdf copy of the manual). These represent a valuable resource, the first of its kind for Australian species. It provides a guide that will prove invaluable in training personnel and in acquainting all members of the supply chain with the means of monitoring and improving their performance.

6.1 Notes on timing and progress

The development, reporting and publication of the first version of the QI Manual dealing with QI schemes for 6 species (objectives 1 –3 of this project) took just over 3 years from the signing of the project agreement. The development of QI schemes for a further 8 species added another 18 months from signing of the supplementary agreement to publication of the version 2 QI Manual including all 14 species (objectives 4 and 5 of this project). There was a 20 month hiatus between the completion of objective 3 and the initiation of objective 4 - the signing of the agreement for the further 8 species.

The set up phase and sourcing of the raw material proved more difficult than originally planned but was not unanticipated. Finding the right raw material of known history is not easy. This was further exacerbated by variations in availability of the catch due to seasonal issues, for example Spanish Mackerel was in the plans and preliminary work started on it. However, it had to be abandoned as catches proved to be few.

The application of the QI schemes to cooked material, such as prawns, has never been attempted before since the scheme is predicated on the kinetics of known types of change both microbial, enzymic and bulk properties. However, cooked prawns are known to change during storage and the experimenters in this project have managed to identify those attributes that change progressively which can be incorporated into the format of the QI scheme. This required elimination of some attributes that would commonly be considered indicators of ‘quality’ such as the hepatopancreas and the degree of melanosis. The researchers found that these seemed to be more related to the pre-cooking, handling and time-temperature history rather than to post-cooking history. This may open an avenue to produce QI schemes for other types of cooked crustaceans such as crabs or lobsters.

7.0 Benefits

The main benefits regarding the use of the scheme are available throughout the whole chain from point of capture to retail sale or restaurant use.

Since it is a number, the QI score is easily entered on records and on labels, transmitted by paper, voice, over the phone, by SMS, by computer or any electronic means or wireless connection. Only one entry per time is required as there is no loss in transcription. It does not require description or translation and so is internationally recognizable.

These schemes allow the user to examine catches and batches of any of the species to evaluate the QI. From the graph they can then determine the number of equivalent days in ice since the sample has been captured and then, from known shelf-life under given temperatures, can calculate the remaining shelf-life. Should the QI prove higher than anticipated then either the date of capture is incorrect, or, more likely, the temperature has not been well controlled. Either way, steps can be taken to repair the problems in the future. This may include changing supplier, implementing better traceability, use of better insulated containers, improved refrigeration, more expeditious handling and transport, or a combination of any of the above.

The QI also allows the user to make decisions about different batches as to which product stream the batch should go into, about mixing of batches of similar QI (equals equivalent shelf-life elapsed), whether it needs rapid chilling and decisions on storage.

For manufactured seafood products that undergo several further processing stages into final product form intake records of QI can be related to characteristics of different batches of product to improve quality control and predictability of product turnout.

The QI scores can be used as indicators of practice between different skippers, crews, boats and as a means of comparing different catch and handling practices, different seasons or different aquaculture stocks, culture practices and feeds. There may also be a use in determining the optimum onset of seasonal closures.

Since the schemes are mainly just available and hence are not yet widely adopted these benefits remain potential. However they are major benefits as they provide certainty about material, better control of material, greater confidence in the product and hence brand protection.

Training in the method is quick and it is easily understood at all levels however, the critical role of temperature is not always fully appreciated. And this needs further emphasis in any training.

The use of QI scoring can be used at any point in the chain to place pressure back up the chain to provide better product (that is, if it is desired – an assumption inherent here), further, any improvements from this point benefit any further stages in the chain. The use of the QI can generally be said to begin for capture fisheries at the point of offloading or delivery to the first receiver be it a Co-operative, a market, a trader, a processor or at a shop. The assessment at this stage can be used to put pressure back on the boat and crew to improve their methods if necessary. Any improvement at the early stages of the chain opens up more possibilities for the later parts of the chain. If it is assumed that better returns flow from better product then increased returns should benefit the whole chain. This is a rather broad approach as each part of the chain generally considers it does not obtain its fair share. What is certain is that poorer product will not improve anyone's chances of a better return.

The situation for aquaculture is somewhat different as the raw material is completely managed by the farm and the harvest is planned. The value of QI still comes into play at the first receiver e.g., processor even if they are on-farm. After this the chain is similar to that of the capture fish.

One major use of QI ought to be in reinforcing the knowledge (until practices are second nature) that storage of seafoods at 0^{o}C halves the rate of deterioration and doubles the total shelf-life over seafoods stored at 4^{o}C.

The better returns and less waste should eventuate from better control of time and temperature and better control is not expensive *per se*. Thus the benefit to cost ratio is inherently favourable. Better products, with less waste, are more acceptable to consumers.

As outlined earlier, the Coff's Harbour fishermen's cooperative have started branding fish with no QI demerits as 'Coff's Premium' to distinguish it from other product in the marketplace.

8.0 Further Development

8.1 Dissemination of QI scheme tool to industry

It is felt that input is now required through some mechanism, potentially the Oceanwatch Seanet extension officers, to disseminate the scheme to relevant persons in industry to facilitate the adoption of the tool by the Australian Seafood Industry.

8.2 Development of future QI schemes

During the life of this project the Australian Seafood CRC has been initiated. As one of its targets it has set an objective to ensure that in total 50 QI schemes are developed for Australian species. A proposal to the Research Advisory Committee of the Seafood CRC is currently being constructed to achieve this.

This plan needs to take into effect the hard won experience gained in this project and that needs to take in the following aspects.

A great deal of flexibility needs to be built in to accommodate seasonal and general availability. This means development of schemes may need to be held over to a following year. The consequence being that a stable panel of judges is required. Despite the best planning and sourcing, aberrant batches of fish occur and funds to do repeat trials are essential. Greater care in coordinating all details of approach by the separate laboratories involved is necessary. This is achievable by initial and follow up meetings. Similar equipment and techniques for photos and ancillary measurements is also required. Funding must be allocated to cover these matters.

9.0 Planned Outcomes

The main output from this project is the updated QI manual with QI schemes for 14 important commercial species of Australian seafoods. Thus the main outcome to date is that the industry can now be provided with, and trained in these QI schemes. Since these schemes cover a broad range of species types and characteristics, harvested by different methods from different areas and depths, it demonstrates that the approach is widely applicable and that it can be used by industry and scientists with confidence. It can also be used as a template for the development of QI schemes for other commercially important species.

The QI scheme provides a numerical index that, plotted on a straight line shows the rate of change with storage in ice at $0^{o}C$. Any batch of fish can be evaluated and the resulting score equated to equivalent days in ice. From this, any business can readily calculate the elapsed shelf-life and the remaining shelf-life, by appropriate criteria, under a range of storage temperatures. This allows for decision making about grading, setting product standards - such as only purchasing at a QI below 5 for premium products - for remote buying sight unseen and for separation into different product streams. It also has a role in trouble shooting along the distribution chain to ensure good temperature control, and in comparison of boats, skippers, suppliers, transporters and seasonal variations. Companies who adopt the practice can gain these and other benefits as it provides certainty and control.

The list of planned outcomes, described below, can now become reality as the advantages of the technique become progressively known and adopted.

- As a tool for setting clear guidelines, instructions and product specifications (if required) to buyers and suppliers;
- To open up greater potential for remote buying, electronic trading and auctioning;
- To improve buyer confidence in the product and improve marketing efficiencies in the supply chain; as a means of developing better price-quality information;
- For conflict resolution as it provides unbiased quality scores readily understood by all parties;
- As a way of providing a very good indication of remaining shelf-life;
- As a means of defining acceptable shelf-life for different contexts and uses;
- As a tool for evaluating performance of individual suppliers and catchers;
- As a check on transport conditions and procedures and in trouble-shooting;
- To reduce wastage of spoilt produce;
- As a tool for ‘educating’ retailers and supermarkets; and
- As a formal technique in training and educational courses and workshops at all levels.

As the QI manual has only recently been produced and has yet to be rolled out to industry uptake of the technique is currently low. However, Sydney Fish Market has used the technique to set freshness standards in product specifications for raw materials to be used in the range of Market Pride products. The outcome for the consumer is the benefit that it makes it possible to buy branded reliable product that is uniformly at the same standard.

The Coff’s Harbour fishermen’s cooperative, who have been given some training in freshness assessment and the Quality Index method through this project, have started branding fish with no QI demerits as ‘Coff’s Premium’ to distinguish it from other product in the marketplace.

10. 0 Conclusions

The primary outcome from this project is that Australian seafood industry can now be trained in the use of the QI schemes using the QI manual which now contains 14 commercially important species found around Australia. The original project outcomes, listed in section 9 above, can now start to come to fruition as the technique becomes understood and adopted.

There is a need to now consider through what vehicle the dissemination of this information should best take place. Some discussions with the Australian Seafood CRC are already taking place to explore appropriate mechanisms.

10.1 Progress against Objectives

10.1.1 Objective 1. To develop appropriate quality index (QI) schemes for the initial 6 nominated species.

These were completed but not all the initially nominated species could be tackled as some became unavailable. Schemes for Spanish Mackerel were underway but the fishery in QLD became non-productive and it was not continued. Seasonal difficulties also plagued availability even from prawn farmers. Ultimately QI schemes for Snapper, Tiger Flathead, Black Tiger Prawns, Goldband Snapper, Atlantic Salmon and Sea Mullet were completed. An original research provider (CSIRO Food Science Australia) dropped out and alternative arrangements had to be made and this was achieved.

10.1.2 Objective 2. To validate the initial 6 QI schemes and investigate their application in appropriate commercial supply chains.

Developed QI Schemes were demonstrated to industry personnel through the means of the Seafood Services Australia Network meetings and SSA and FRDC news publications to find appropriate supply chains that could use the schemes available at the time (6).

The schemes were demonstrated in Perth in November 2004 and at Catalano Seafoods in January 2005 where a training session was conducted. This identified defects in their cold transport and holding chain and in traceability of the product.

A training session was held at Coff's Harbour Fish Cooperative 6th May 2005. Whilst they seemed reluctant to adopt the scheme for routine use, they now assess fish and those with no QI demerits are tagged as 'Coff's Premium' to distinguish it from other product in the marketplace. This is analogous to the Swedes who from about 1994 were using it to pick only the best herring for the traditional pickle by fermentation for several months in barrels to make their gourmet line, and to the Dutch in Ijmuiden who were using it to select the best for their 'Silver Sealed' packaged fillets.

In September 2005 a demonstration workshop was held at the International IAFI Conference in Sydney September 2005 and an industry workshop on 23 March 2006.

An internal course for staff of Simplot and Regal Seafoods was held at Simplot 16 May 2007. The following comments demonstrate the benefits that course participants felt they had gained from the course and their views on the course.

- *‘I believe I gained a greater insight into the individual characteristics of the species assessed in the different aged fish, which is adaptable to other species as a means of screening overall quality’.*
- *‘The QI manual provides a detailed well structured and user friendly approach to measuring the changes of fish over the shelf life’.*
- *‘The course was of benefit to all who attended although at varying degrees; with some of the practical exposure being more relevant to people less familiar with fish species and the chemistry side of things being more relevant to those with a food/ chemistry background’.*
- *‘I honestly had doubts prior to the QI course, as I thought that, growing up in the fish industry, why should and how can someone tell me if a fish is fresh?... But your course goes beyond just that. It is about enlightening for those who know fish, and those who don’t’.*
- *‘It was a very worthwhile course for me, as sometimes people would ask me “How can you tell if the fish is fresh?” and my normal reply was “It just is - look at it!” Even though in my head I would know what and how I wanted to describe, your course makes it easy for someone with no/minimal exposure to fish to be guided in the right direction’.*
- *‘I feel this is exactly what our industry needs; an easy-to-use guide that practically anyone can pick up and assess to reasonable accuracy the quality and freshness of fish’.*

10.1.3 Objective 3. QI Manual produced on 6 validated QI schemes.

This was produced. However, because a decision was made to develop a further 8 species (objective 4) and the roll out of this version 1 QI manual was kept very limited.

10.1.4 Objective 4. Develop QI schemes for 8 additional species - King Prawns, Scaly Mackerel, Silver Warehou, Pink Ling, Barramundi, Yellowtail Kingfish, Saddletail Snapper and Redthroat Emperor

These eight schemes have been developed.

10.1.5 Objective 5. Updated QI manual with 14 species produced

All 14 QI schemes have been incorporated into the version 2 QI manual, which has been completed.

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APPENDIX 1 - List of all the intellectual property and/or valuable information arising from the research

QI Schemes for the following species;

Atlantic Salmon (Salmo salar)
Black Tiger Prawns (Penaeus monodon)
Goldband Snapper (Pristopomoides multidens)
Sea Mullet (Mugil cephalus)
Snapper (Pagrus auratus)
Tiger Flathead (Neoplatycephalus richardsoni)
Barramundi (*Lates calcarifer*)
King Prawns (*Melicertus plebejus*)
Pink Ling (*Genypterus blacodes*)
Redthroat Emperor (*Lethrinus miriatus*)
Saddletail Snapper (*Lutjanus malabaricus*)
Scaly Mackerel (*Sardinella limuru*)
Silver Warehou (*Seriolella punctata*)
and Yellowtail Kingfish (*Seriola lalandi*)

APPENDIX 2 - Staff List

Sydney Fish Market: Mark Boulter, Lucas Woolford, Erik Poole, Brigid Trelor, Roberta Muir

DEEDI: Sue Poole, John Mayze, John Nagle, Carl Paulo, Stephen Nottingham, Stephanie Kirchhoff, Paul Exley plus (Ron Wong on sabbatical from Crop and Food NZ)

AMC: Dr Felicia Kow and the help of many students

Curtin University: Dr Hannah Williams, Philip Anthonisen

VUT: Ms Jayanthi Weerasinghe and the help of other staff

Allan Bremner and Associates: Allan Bremner

Seafood Services Australia: Jayne Gallagher

SQMA: Don Nicholls

APPENDIX 3 - The CD of the QI Manual is attached