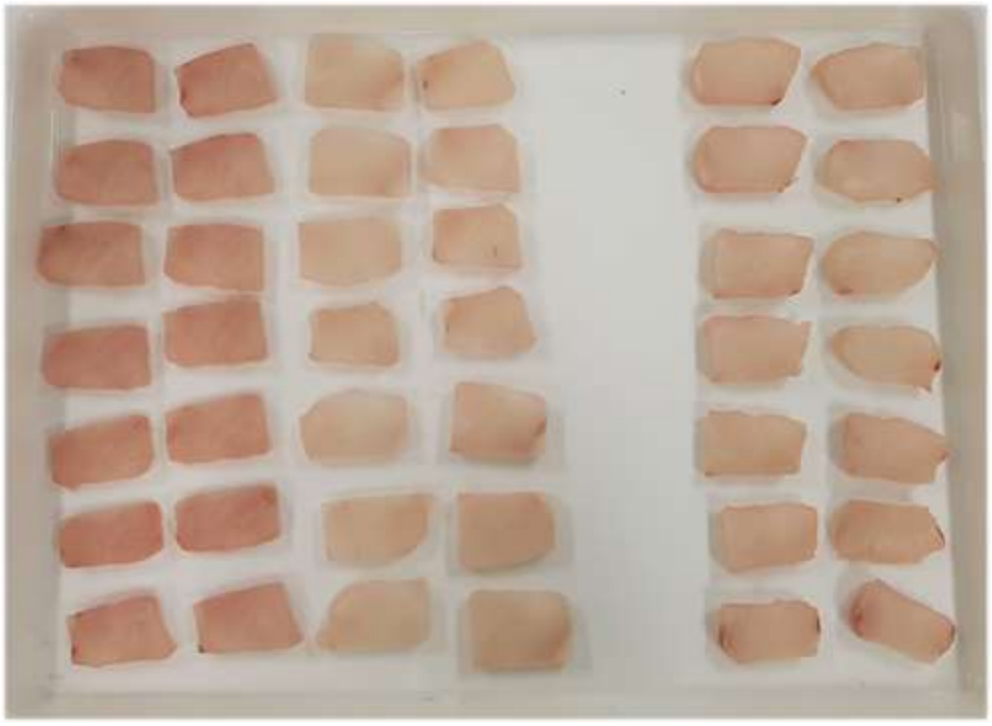
Sensory testing of seafood - fresh versus frozen - and development of frozen seafood recipes

Sensory testing – sub-component



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Executive Summary

There is a strong negative perception of frozen fish amongst consumers, with many considering that frozen product is of inferior quality compared to ‘fresh’ (chilled) fish. The resistance to purchase frozen fish continues, despite modern freezing technology and practices resulting in frozen product that remains as premium quality for longer than chilled fish.

The research described in this report was driven by the Fisheries Research and Development Corporation in an endeavour to establish whether there was a discernible difference between fresh and frozen product of the same species. Two evaluation methods were used: a Chefs Table focus group method and an experienced seafood panel assessment by difference testing. Both methods were used to evaluate sashimi and cooked formats of the fish samples.

Results from both methodologies indicated that there was no discernible difference between frozen and fresh fish samples. This finding held true for lean fish species up to a six month frozen storage period. The feedback from head chefs, two of whom adamantly adhered to a policy of only using fresh fish in their kitchens, was highly elucidating. All four chefs involved in the Chefs Table focus group were amazed at the difficulty they had in trying to differentiate between fresh and frozen samples. In discussions following the assessment session, all commented on heightened awareness of frozen product meeting high level quality parameters and the potential benefits use of frozen fish could provide within their businesses. The perception of frozen fish being indiscernible from fresh fish was confirmed by the seafood panellists using difference testing methodology. The opportunities and benefits of reduced reliance on fresh fish supply were raised and discussed in terms of flexibility and stability for menu design, reduction of wastage and better supply logistics.

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1 Background

Freshness has been noted as the most important factor for consumers in relation to quality of fish (Brunso, 2003) and in almost every study undertaken universally. This is clearly evidenced by the continuing demand for fresh fish at purchase points and matched by a strong resistance to frozen fish product. While there is widespread and well-documented recognition of freezing as an effective way of preservation of fish quality (Duflos *et al*, 2002; Fagan *et al*, 2003, Saez *et al*, 2015) there is however, a strong negative perception of the frozen product format established in the minds of consumers with respect to eating quality (Peavey *et al*, 1994). Hence, consumer demand remains directed towards fresh fish product.

The term 'fresh' is used ubiquitously and yet has no formal or regulatory definition but is interpreted differently according to individual opinion and experience. Consumers often have strong opinions but they usually find it difficult to explain in detail why they prefer one product to another (Sveinsdottir et al, 2009). For example, in one study fresh fish was perceived as healthier than frozen product but the perception was not based on any substantiation (Vanhonacker *et al,* 2013). The over-riding consumer perception is that 'fresh' implies close to capture, however the retail sector tends to use the term 'fresh' to mean 'not previously frozen'.

Negative perceptions associated with frozen fish include: poorer quality; poor texture from greater moisture loss causing excessive gaping in fillet and a mushy eating quality; flesh colour differences through loss of translucency (Salvadori and Mascheroni, 2002; Hansen et al, 2009; Kaale *et al,* 2011). These noted attributes for frozen fish product were likely established historically at a time when freezing technology was less sophisticated and scientific knowledge of the effects of the freezing process was less understood. Current advances in freezing technology permit production of high quality frozen product. Increased scientific understanding recognises that the rate of freezing is critical to physical changes during the process and the flesh temperature needs to reduce rapidly through the physical states from liquid to solid state (Chevalier *et al*, 2001; Zhu *et al*, 2003; Kaale and Eikevik, 2014). This is correlated to rate of ice crystal formation within the fish flesh, both intra-cellular and extra-cellular, where slow freezing rates allow large and jagged ice crystal formation which damage the integrity of the fish muscle cells, resulting in flesh textural changes and greater water loss from the muscle flesh. Contrastingly, very rapid freezing causes small ice crystal formation with concomitant lack of muscle cell damage occurring.

The current research was commissioned by the FRDC as a sub-component of a wider project in this field, FRDC 2017-179: Sensory testing of seafood - fresh versus frozen - and development of frozen seafood recipes, to provide sound information on whether differences between chilled ('fresh') and frozen fish flesh of the same fish species could be determined by sensory evaluation.

2 Materials and Methods

2.1 Fish samples and handling

Fish species for the Chefs Table and the difference testing trials were selected and sourced as per Table 1. All fish were received within five days from harvest or catch and, with the exception of Goldband, were supplied as chilled whole fish. Goldband were filleted, skinned and vacuum-packed immediately after catch by the fisher, half were blast frozen at -40ºC and the remainder held chilled, before freighting to the DAF research facility. On arrival at the research facility whole fish were immediately filleted, skinned and each fillet vacuum packed. Mackerel were an exception with fillets vacuum packed with the skin still attached. Fillets were then held chilled or frozen as follows: for the Chefs Table a total of three to five fish were sourced per species. Fillets from half of the fish across each species were last frozen and held at -30°C and fillets from the remaining fish were stored chilled at 2°C. For assessment of frozen-stored samples, a further three fish of each species were sourced at the three and seven month time points and assessed as chilled samples.

Table 1. Fish sourced for the experimental trials.

Trial	Common name	Scientific name	Source
Chefs Table	Barramundi (*farmed*)	*Lates calcarifer*	Daintree Saltwater Barramundi (*Wonga Beach, QLD*)
	Goldband snapper (*wild*)	*Pristipomoides multidens*	TomKat Line Fish (*Kurrimine Beach, QLD*)
	Spanish mackerel (*wild*)	*Scomberomorus commerson*	Daren Formosa (*Kurrimine Beach, QLD*)
	Cobia (*farmed*)	*Rachycentron canadum*	Rocky Point Aquaculture (*Woongoolba, QLD*)
	Queensland grouper (*farmed*)	*Epinephelus lanceolatus*	Rocky Point Aquaculture (*Woongoolba, QLD*)
Difference Test	Barramundi (*farmed*)	*Lates calcarifer*	Daintree Saltwater Barramundi (*Wonga Beach, QLD*)
	Barramundi (*wild*)	*Lates calcarifer*	Len Rex (*Kanimbla, QLD*)
	Spotted mackerel (*wild*)	*Scomberomorus munroi*	Coffs Harbour Fishermen's Co-op (*Coffs Harbour, NSW*)
	Goldband snapper (*wild*)	*Pristipomoides multidens*	TomKat Line Fish (*Kurrimine Beach, QLD*)

2.2 Sample preparation

All samples were prepared on the day of the respective trials. Fillets from the left side of the fish were utilised for sashimi assessment and fillets from the right side for cooked assessment. Thawing involved submersing fillets in ambient potable water while still vacuum packed. Both chilled and thawed fillets were then prepared for either sashimi or cooked assessment as follows.

Preparation of sashimi samples differed between the two experimental trials. For the Chefs Table trial, the core temperatures of both chilled and thawed fillets were firstly equalised by sitting fillets at room temperature for 20 minutes. A participating chef, trained in sashimi cutting, then prepared sashimi samples by thinly slicing each fillet. This approach was different to the difference test trial which assessed evenly sized medallion pieces. Only the middle loin section of each fillet was utilised, with the top dorsal and bottom belly sections discarded along with all red muscle. Mackerel was an exception

with the whole fillet (both top and bottom loins) being utilised. A small portion was sliced off from the shoulder end of each working loin to create a straight edge to cut medallions from. A minimum of 14 medallions were prepared from each loin with each medallion measuring 6mm thick.

For cooked assessments a single standardised cook method was adopted across both trials. Medallion pieces measuring 15mm thick were prepared as per above. Cooking was conducted one species at a time as per the trial design. All fresh samples and all frozen samples were cooked in parallel on separate Silex grills pre-heated to 220°C (Image 1). Prior to each cook a light wiping of rice bran oil was applied to each grill. Medallions were cooked on the cut surface, flipping after 1 min 40 seconds or as soon as the middle portion turned from opaque to white. After flipping a thermocouple probe (Comark C26) was inserted into the visually thickest medallion and medallions cooked to 70°C. Cooked medallions were immediately plated into foil cups with aluminium foil lids and quickly served.

Image 1. Fish medallions cooked on Silex grill.

2.3 Trial design

2.3.1 Chefs Table

Four head chefs from high end seafood restaurants were included in a focus group led by an experienced group moderator, Philippa Lyons. During the focus group, discussions and tasting sessions were guided by the moderator with the aim of discovering the thoughts and opinions of the participants with regards to the organoleptic properties (appearance, aroma, flavour and texture) of the fresh and frozen fish samples and to guide stage two of this project (difference testing).

The session was structured in three parts:

1. Assessment and discussion of sashimi samples
2. Assessment and discussion of cooked samples
3. Summary of session outcomes and stage two planning

Parts one and two consisted of participants assessing blind coded samples of both fresh and frozen fish (of each individual species) side by side. This exercise prompted discussion regarding the differences between the two samples and the significance of these differences.

Part three involved both moderator led and participant led discussions. The moderator summarised the overall outcomes of the session, highlighting the key areas for future project development, whilst encouraging participants to provide their own thoughts as to how the session will influence their operational decisions in the future.

The qualitative information obtained during this session indicated the importance of conducting consumer trials in stage two.

2.3.2 Difference test

A triangle test methodology was implemented for the trials conducted on individual fish species at three time points (Table 2).

Table 2. Difference test trial matrix

Trial	Time point	Species assessed
T0	0 months	Barramundi (*farmed*)
		Barramundi (wild)
		Spotted mackerel (*wild*)
		Goldband snapper (*wild*)
T1	3 months	Barramundi (*farmed*)
		Spotted mackerel (*wild*)
		Goldband snapper (*wild*)
T2	7 months	Barramundi (*farmed*)
		Goldband snapper (*wild*)

The difference test method chosen for assessment was a triangle test method. The International Organisation for Standardisation (ISO) describes the aim of a triangle test as determining whether or not a perceptible sensory difference or similarity exists between samples (ISO 4120:2004). This method is a forced choice procedure and is applicable whether the difference exists in a single sensory attribute or several attributes.

Frequent fish consumers (n=24) took part in each trial, recruited from the Health and Food Sciences Precinct, Coopers Plains. Samples were assessed as both sashimi and cooked product. Samples were prepared and placed in individual, blind coded plastic pots and covered foil tart tins respectively. The trial took place at the DAF sensory facility, Coopers Plains, under controlled conditions. Red lighting was used to mask naturally occurring colour differences between samples.

Three samples of each triad were presented simultaneously, following a structured design, on a line to be sampled always from left to right. Within the triad assessors are able to make repeat evaluations of each sample as desired. Assessors were instructed to evaluate the samples in the order provided. They were informed that of the triad, two samples were identical and one different. Each assessor was then asked to indicate which of the three samples was different from the other two. Assessors were not given the option of reporting no difference, as this is a forced choice methodology. However, they were asked to outline their reasons for this answer, if they took a guess they would indicate this here. Assessors were provided with water and crackers in order to cleanse their palates in between samples.

2.4 Statistics

To analyse the data obtained from the triangle tests, statistical tables were used (as can be found in ISO 4120:2004). If the number of correct responses is greater than or equal to the number given in the correct statistical table (which corresponds to the number of assessors), it can be concluded that a perceptible difference exists between the samples.

The *p*-value was calculated using Xlstat sensory software, at an α-risk of 1% (probability $p \leq 0.01$).

3 Results

3.1 Chefs Table

Direct comparison of fresh and frozen samples, presented side by side, subjects samples to the most rigorous evaluation conditions. Additionally, chefs were asked to indicate whether or not they preferred the fresh or frozen sample (Image 2). Following are the outputs from the Chefs Table focus group:

Image 2. Chefs table focus group.

3.1.1 Farmed Barramundi

Little distinction could be made between fresh and frozen sashimi samples. Both samples were described as having a clean and fresh taste with a firm bite. The frozen sample had a slightly duller appearance in comparison to the fresh sample. Four of the seven panellists had no preference for either sample, three preferred the fresh sample.

Panellists could not discern a difference between the fresh and frozen samples when cooked. Both samples were described as having a soft and juicy texture with a tooth stick attribute. Four of the seven panellists preferred the fresh sample, one panellist preferred the frozen sample and two panellists showed no preference.

3.1.2 Grouper

The fresh and frozen sashimi samples differed primarily in appearance. The frozen sample was described as translucent with good colour and a clean appearance whereas the fresh sample had a yellow/brown hue and was slightly dull in appearance. However, texture and flavour of the two samples were indiscernible. Four panellists preferred the fresh sample, three panellists had no preference.

When cooked, panellists exhibited mixed opinions regarding the samples and were unable to identify the fresh and/or frozen samples. Both samples were described as being sweet in flavour but no agreement could be reached with regards to the texture; moist and dry attributes were used to describe both samples. Three panellists preferred the fresh sample, two the frozen sample and two had no preference.

3.1.3 Spanish mackerel

Panellists identified a difference in appearance between the fresh and frozen sashimi samples; noting that the frozen sample was duller and the fresh sample had a brighter appearance. The texture of both samples was acceptable, as was the flavour. Despite the difference in appearance, three panellists preferred the frozen sample and two the fresh sample. Two panellists showed no preference.

When cooked, panellists identified a difference between the texture of samples. The frozen sample was described as dry, firm and slightly chewy in comparison to a soft, moist and succulent fresh sample. This difference strongly influenced preference, five of the seven panellists preferred the fresh sample, and two had no preference.

3.1.4 Cobia

There was little discernible difference between the fresh and frozen sashimi samples. Panellists described both samples as clean and fresh with a sweet flavour and crisp, firm texture. Five panellists showed a preference for the fresh sample and one for the frozen. One panellist had no preference.

Panellists identified a clear distinction between the texture of the cooked samples. The frozen sample was described as moist, firm and soft whereas the fresh sample was firm and dry. Despite this however, five panellists showed a preference for the fresh sample and one for the frozen. One panellist had no preference.

3.1.5 Goldband snapper

Panellists were mixed in their opinions of the fresh and frozen sashimi samples. Flavour was the most definitive characteristic; the frozen sample was described by some as clean and rich whereas others believed it to be slightly chemical. The fresh sample was described as fresh, sweet and earthy but with an iron aftertaste. Of the seven panellists, two preferred the frozen sample, three the fresh and two showed no preference.

Similarly, when cooked, panellists were not in agreement. Some believed the frozen sample to have a better flavour and firmer texture however others believed the frozen sample to be dry and bland. The fresh sample was described as dry by some and moist by others. One panellist was extremely confident that the fresh sample was indeed that which had been frozen. These comments were reflected in preference; three panellists preferred the frozen sample and two the fresh, two showed no preference.

In this study the response and discussion from the head chefs was the most surprising. Two of the four chefs were adamant on their strict policy of only serving ‘fresh’ (chilled) fish in their restaurants, with additional comments indicating this was an inflexible stance taken on the basis of eating quality. The other two chefs held similar positions although admitted that they would consider frozen fish product on the proviso that they were familiar with the specific fisher, purchased directly from the fisher and then, only after a long-standing relationship and trust had been developed. All four were astonished that they *struggled* (their word) to determine a difference between chilled and frozen product. They were slightly more confident in identifying between samples with the sashimi format, wholly based on minor visual appearance where frozen flesh had lost a hint of the natural flesh translucency. However, there was no noted differences in texture or flavour for sashimi product and the chefs agreed that without the visual trigger, they would not differentiate between the samples. For the cooked samples of the same species, the chefs admitted they were almost guessing when forced to make a choice. The recognition of indiscernible difference between chilled and frozen samples, engendered further discussion from the chefs, that in real-world scenarios the same species of fish would not ever be presented side by side in a dining experience. Hence, the use of well-frozen product would have no deleterious effect on restaurant nor chef reputation with respect to serving premium quality product. The additional factor of sashimi characteristically being eaten with wasabi and soy sauce condiments was also raised.

3.2 Difference test

Positive identification of the 'odd' sample for both sashimi and cooked triangle tests are depicted in Table 3 and Table 4 respectively. As per ISO method 4120:2004, results presented show the number of correct responses (i.e. those that correctly identified the different sample) out of 24 panellists. Results highlighted in red show the number of panellists able to differentiate between fresh and frozen samples to a statistical significance level.

Table 3. Sashimi triangle test results

	0 months	3 months	7 months
Farmed Barramundi	10	11	12
Wild Barramundi	13*	-	-
Goldband snapper	12	10	9
Spotted mackerel	7	11	-

*Significant at α=0.05

Table 4. Cooked triangle test results

	0 months	3 months	7 months
Farmed Barramundi	12	11	6
Wild Barramundi	16*	-	-
Goldband snapper	8	4	13*
Spotted mackerel	8	14*	-

*Significant at α=0.05

Sensory panellists performing the difference tasting, frequently commented post-session that differentiation between the samples was extremely difficult. With red lighting (

Image 3) panellists were forced to focus and differentiate on texture and flavour only. Several panellists who were frequent sashimi eaters, found the lack of a visual parameter during assessment very difficult which underpins the importance of the recognised premise that first decisions on 'quality' are dictated visually.

Image 3. Panellists evaluating samples under red lighting.

4 Discussion

The sensory findings from this work clearly indicate that fish handled well and frozen rapidly, soon after harvest and processing, cannot be differentiated by eating quality from chilled ('fresh') fish. This is a similar finding to that of work by Cappeln and others who concluded that when "frozen immediately after catch and processing, stored at low, non-fluctuating temperatures, and thawed in the best way according to its rigor-state, the quality can be as good or better than fresh fish stored for several days at 0°C" (Cappeln *et al*, 1999). Other studies included stored frozen fish and when compared with 'fresh' found that "frozen fish stored for up to three months cannot be differentiated from fresh fish regarding colour, taste, and texture parameters" (Nielsen and Jessen, 2007).

Although freezing is known to be one of the most effective methods for preservation for highly perishable foods, a recent survey illustrated that 32 percent of people in Britain consider frozen food to be inferior to 'fresh' (The Grocer, 2015). Of those respondents, more than half said they considered the concern with frozen fish was the quality of it. However in balance to this widely-held opinion, there is an array of information available in the public domain that advances the premise that quality of frozen fish is just as good as 'fresh'. Many commercial websites address the fresh versus frozen fish 'debate' in some detail: Global Seafoods Distributors, Western Australia; Birdseye, UK; Alaska Seafood Marketing Institute, as examples. The good reasons to buy frozen fish are identified as taste, convenience and price. There is emphasis on: "Since the fish is frozen at its peak of freshness, all of its flavour and nutrition, as well as its texture, is locked in". Aliza Green (author of The Fishmonger's Apprentice: The Expert's Guide to Selecting, Preparing, and Cooking a World of Seafood, Taught by the Masters), states "frozen fish is not inferior, nutritionally speaking". Nutrient retention in frozen fish is supported by research science. For example, in a study of five fish species, Sahari and co-researchers found that B vitamin group were fully retained and slight losses in vitamin A, C, D and K occurred during long-term frozen storage, however the losses were not significant. Vitamin E was reduced during frozen storage for some species but there was no loss for other species (Sahari *et al*, 2014).

The freezing process itself can cause disruptive changes to fish quality directly related to fish muscle structure and loss of water from flesh. However, this is most likely to occur under a slow freezing process and, with current developments in technology for rapid freezing to very low temperatures, deteriorative quality changes are minimised. Hence, to retain premium quality, it is of critical importance to freeze fish fast, under appropriate packaging conditions and hold at constant low temperature.

5 Key Considerations

The most surprising finding from this study was that expert palates of head chefs from high-end restaurants with a focus on seafood, could not readily identify which sample was frozen and which was chilled. There was a change of headspace from the chefs who realised the opportunities presented by the high acceptability of frozen product.

The finding was further exemplified by experienced seafood panellists, under demanding testing conditions of being forced to make a choice, also finding there was no discernible difference in eating quality between frozen and chilled samples. The difficulty to differentiate between chilled and frozen samples continued even after many months of frozen storage. It is important to qualify that these findings pertain to tasting samples from fish that were well-handled and frozen quickly to low temperature soon after harvest.

One of the first opportunities raised by the chefs was the potential logistics benefit. The ability to use frozen fish product eased the daily supply demands and this benefit would apply to all sectors of the supply chain: traders - both wholesale and retail sectors, as well as hospitality and catering sectors and the consuming public. There was specific discussion around how frozen product use would allow

adaptability within supply chains which potential could reduce product costs, especially with respect to transport logistics.

Chefs particularly were aware of the opportunity in menu design suggesting that frozen fish would permit both stability and flexibility of menu structure. Wastage reduction and cost saving were also raised related to cooking fish directly from frozen state for appropriate dishes and hence avoiding the guesswork factor for thawing the correct quantity of seafood for the meal service each day. Additionally, discussion recognised the very short time chilled fish retains premium quality with all agreeing this factor was a large contributor to wastage and revenue loss. Other practicalities were also raised: the use of frozen product would need cold storage space logistics to be reconsidered, including potential additional cost; the thawing process would need to be established for each species and would demand specific kitchen space (never at a premium); staff would need training and food safety considerations implemented.

One of the important factors raised was around communication to dining clientele. Diners often ask if the fish on the menu is 'fresh' and are not impressed if told it is frozen. However, the chefs were confident of their reputations and that they could inform clientele they were only providing the best quality fish. Chefs considered that a provenance story behind the product would be important here.

6 Extension and Adoption

This study found that, when handled and prepared well, frozen fish can be indistinguishable from fresh. With a common perception that frozen is inferior to fresh, this finding challenges many consumer's pre-conceived ideas of what drives quality. The challenges faced include how to effectively convey this message across to consumers and enable them to feel confident in purchasing, handling and preparing frozen product. Some in-roads have been made in trying to meet these challenges through:

- Project findings presented to industry at Seafood Directions 2019.
- Project work to be featured in a two-part series focussed on the science behind food, to be aired on ABC's Catalyst program early 2020.
- Publication of the "Fish Fresh+Frozen" cookbook by FRDC highlighting recipes that utilise frozen fish.
- Featured articles in "FISH" (FRDC) circulated to the Fishing Industry and "Appetiser" (BidFood), a nationally circulated magazine focussed on the food and hospitality industry.

Additional to these, further extension and awareness can be generated through:

- Educating chefs at the start of their learning curve through inclusion of frozen fish product within seafood handling course sections in chef training schools and registered training organisations like TAFE. As recognised leaders in the food consumption arena, chefs are ideal public figures to help raise new awareness in consumers.
- On-going publication of feature articles in chef and hospitality focussed magazines as well as on websites like Australian Food News.
- On-boarding online influencers to promote education and consumption of frozen fish.
- Incorporating a component around handling and cooking of frozen fish within the Sydney Fish Market's seafood school. As a top tourist destination with high traffic, SFM's seafood school offers a unique opportunity to directly interact with the general public and help build consumer confidence around utilising frozen fish.
- In-store promotional campaigns to empower and educate regular shoppers.

7 Further Research

Suggestions on additional research work and possible next phases to further build on project findings include:

- Investigate the effect of different freezing and holding temperatures on product quality and impact on consumer's ability to discern between fresh and frozen treatments.
- Identify ideal frozen storage periods across individual species and methods to extend keepability past 12 months to close the supply gap between seasons.
- Expand current work comparing fresh and frozen "fillets" to include comparisons across fresh and frozen "whole fish", particularly for small fish species that are typically retailed whole.
- Develop most suitable cooking practices tailored specifically for frozen product.
- Further work on additional fish species to expand current understanding of consumer preferences between fresh and frozen product.

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