AUSTRALIAN SOUTHERN BLUEFIN TUNA
INDUSTRY ASSOCIATION LTD (ASBTIA)

CCSBT-EC/1910/27

NB: This paper has been submitted by the Australian Government on behalf of the Australian Southern Bluefin Tuna Industry Association. The content, analysis, conclusions and recommendations contained in the paper are not necessarily endorsed by the Australian Government.

A further Review of Tuna Growth performance in Ranching and Farming Operations, and of the CCSBT expert advice.

Brian Jeffriess
ASBTIA

Executive Summary

Issues

Since 2008, various CCSBT Committees have reviewed papers from Japan that hypothesise there is unaccounted catch mortality in the Australian southern bluefin tuna (SBT) ranching process. While these note that Australia is declaring the correct number of SBT caught for farming, and the correct weight and number of fish harvested, they hypothesise that the method of taking the ***actual*** weight and length into the pontoons (sample of ~3,000 fish @ ≥ 10kg) is potentially under-stating the weight into the pontoons.

The most recent developments are:

a. Japan's estimate of the Australian excess catch has moved as follows:

2012-2016 av	32%
2013	56%
2017	5%
2018	4%

At the ESC, Japan was not able to explain the major change but noted it could be an Australian Government error in the sampling. Australia rejected this. ***<u>This question needs to be urgently addressed before the calculation for 2019 is done.</u>***

b. The normal scientific and/or compliance process when hypotheses such as Japan's are raised is for the data used to be available for scrutiny. Despite repeated formal requests by the Australian Government and others, Japan has declined to supply the data for the last 10 years – ***<u>and the CCSBT expert (see below) was therefore unable to recommend it be available for scrutiny.</u>***

c. CCSBT appointed a farm expert (Dr Ana Gordoa) to review all the data and suggest a way forward. There is no report from Dr Gordoa but the expert did make a slide presentation (without References) to the 2019 ESC. As in b. above, the ***first step*** would normally be for the data used in Japan's hypothesis to be available – but Japan appears to have declined to provide it.

d. In the absence of Japan supplying the data used to support its hypothesis, Dr Gordoa raised a number of other possible options. These are addressed later.

Recommendation

For the Compliance Committee to assess the points raised by the author of this Paper, so that further work by experts can be considered.

COMMENTS ON OPTIONS RAISED BY DR GORDOA

EXECUTIVE SUMMARY **3**

BACKGROUND **6**

GROWTH PERFORMANCE ....

MEDITERRANEAN ATLANTIC BLUEFIN TUNA (ABT) 7
JAPAN PACIFIC BLUEFIN TUNA (PBT) 8
MEXICAN PACIFIC BLUEFIN TUNA (MPBT) AND OTHER TUNA 9
AUSTRALIAN SOUTHERN BLUEFIN TUNA (SBT) 9

GROWTH PERFORMANCE IN WILD TUNA **10**

APPLYING WILD TUNA STOCK MODELS DERIVED FROM CATCH AND RELEASE CONVENTIONAL TAGS **10**

ASSUMPTIONS TO INFORM ANALYSIS OF *UNACCOUNTED CATCH MORTALITY OF AUSTRALIAN RANCHED SOUTHERN BLEUFIN TUNA* **11**

BACKGROUND TO THE RAW DATA USED IN THEIR CALCULATIONS 11
APPLICATION OF 141 TAGGED WILD FISH CAUGHT AND TRANSFERRED INTO FARMS 12
IMPACT OF ENVIRONMENTAL CONDITIONS ON GROWTH PERFORMANCE 13
BIAS IN AVERAGE WEIGHT SAMPLE TO DETERMINE VOLUME OF CATCH 14
THE ECONOMIC AND FEED CONVERSION RATIO (FCR) IMPLICATIONS BENCHMARKED INTERNATIONALLY 14

POINTS RAISED BY JAPAN PREVIOUSLY **16**

DISCUSSION POINTS FOR PARTICIPANTS OF THE CCSBT COMPLIANCE COMMITTEE **16**

REFERENCES **17**

COMMENTS ON OPTIONS RAISED BY DR GORDOA

In the slide presentation, Dr Gordoa raised the options (see 2019 ESC Report):

(1) Of using stereo video to assess what length cohorts were in the pontoons.
(2) Using tagging to assess fish growth.

The author of this Paper noted with Dr Gordoa at the meeting that:

(1) Tagging fish at sea or in pontoons showed very variable results, both in the short term at sea, and in the growout period in the pontoons. Japan's expert in this area (Dr Peter Miyake) had noted that the bigger tuna out-competed the smaller fish.
(2) There appeared to be major issues on whether the final stereo video sample in the Mediterranean is representative of the size cohorts in the transfer. Basic analysis of data for tonnage in and out, indicates there are significant doubts over the system used. We agreed to liaise further with Dr Gordoa on the data.

To assess the evidence on these issues, we note that another expert on the issue (Professor Terry O'Neill, DSI Consulting, "Review of the Data and Commentary on the 2011 Stereo Video Trial, August 2011) had already reached very different conclusions from Dr Gordoa:

(1) The current sample of 100≥ 10kg is the only ***direct*** method to estimate the tonnage because it is actual length and weight. Using an algorithm only ***infers*** a tonnage.
(2) Given that stereo video excludes a substantial number of fish from the sample for various reasons which are often size-selective, the number of eligible fish is not the best measuring stick of alternative systems.

Background

There are 3 types of Bluefin tuna growout systems:

1. Ranching of larger fish (input weight 8 – 200kg)

This process was developed in Australia in 1991 through a joint project between the Japanese Government and the Australian Southern Bluefin Tuna Industry Association (ASBTIA). The technology was transferred to the Mediterranean and Mexico in the early 2000s.
Wild Bluefin are captured live by purse seine, transferred underwater into specially designed tow pontoons, and towed to ranching areas. In general, the tuna are maintained for 5-8 months except in specialist multi-year grow-out areas including Croatia and Mexico.
The average size of wild capture fish has been approximately 15-20kg in Australia, 15-40kg in Mexico and 8-200kg in the Mediterranean. We also understand that there are some similar operations in Japan, growing out captured PBT of around 15kg.

2. Ranching in Japan (input weight 400g – 1kg)

The traditional method used in Japan of capturing small Bluefin with an average weight of 500g and then on-growing for a period of 3-4 years depending on geographical location.

3. Farming (hatchery raised)

Hatchery raised PBT have been commercially available in Japan since 2010 and now comprises over one-third of total seed stock into all farms in Japan. This is farming in the true sense as stock is raised from the egg rather than the ranching approach in (1) and (2) above. It normally takes about 3 months for a hatchery fingerling to reach 500g.

The ranching growout strategy varies considerably between regions. In Australia, the fish feed immediately at a high level – up to ~10% of body weight/day at peak feeding times (Ellis 2013). In other regions, the literature suggests a delay before higher feeding levels begin, and then not to the same level as Australia. This is because of the length of tow, the multiyear holding of the fish in other countries, and high feed cost in some ranching operations.

Growth performance in tuna ranching and farming

Mediterranean Atlantic Bluefin Tuna (ABT)

The following table depicts growth performance in Atlantic bluefin tuna (*Thunnus thynnus)*

Table 1. Summary of growth performance studies of Mediterranean Atlantic bluefin tuna (*Thunnus thynnus)*

Reference	**Conclusion**
Kataviæ et al. (2001)	In a trial conducted in the Adriatic Sea trial over 17 months (June 1999-December 2000) the results showed a much faster growth in length and weight in farms than in the wild. For example, in the 85-120cm category (10-25kg) the monthly growth was 2.16cm and 2.42kg. This was despite an initial tagging mortality of 50%, plus 5% during the trial, indicating stress on all tagged fish.
Cort (2003)	Summer growth in wild ABT aged 1-3 years is 5-6 times more intensive than their winter growth.
Ticina et al. (2007)	ABT of 12kg reached a whole weight of 45kg after 18 months. In the same period tunas with an initial weight of 5kg increased their weight up to 25-30kg – normally achieved over 3 years in the wild.
Ticina et al. (2007)	Tuna reared from 4-8 months had higher specific growth rate (SGR) values than those reared for 17-20 months. In the shorter grow-out, the SGR values are mostly related to summer growth.
ICCAT (2009) SCRS report	Cage trials in Croatia (SCRS/2009/190) have confirmed the gain estimates applicable to small fish, with 10kg fish reaching 45kg after 18 months and a further doubling to 90kg after another 12 months.
Deguara et al. (2010)	A 4 months trial in Malta (February to June 2009) on 5-6 year old Atlantic Bluefin Tuna achieved a 43.5% increase in weight and an increase in length from 142.5 cm to 157.9cm. In the wild, such ABT age groups take over one year to gain that length.
ICCAT (2009) SCRS Report	Apparent growth gain in both length and weight of individual fish held in farms is much higher than observed for wild fish over a wide range of sizes.
Tzoumas et al. (2010)	"*the length of fish (ABT) in cultured conditions can grow faster than in the wild and have a big impact on the overall weight gain."*
Galaz (2011)	In cages with just young tunas, growth is more important as the direct competition for food has been removed. Data suggests juveniles under 20kg originating from the Balearic Islands show significant weight increase reaching a SGR of 88.8 % in November (121 days).

Japan Pacific Bluefin Tuna (PBT)

The following table depicts growth performance in Japanese Pacific bluefin tuna (*Thunnus orientalis)*

Table 2. Summary of growth performance studies of Japanese Pacific bluefin tuna (*Thunnus orientalis)*

Reference	**Conclusion**
Ikeda (2003)	PBT at the Wakayama (Kinki University) research station stocked at 150-500g could achieve a weight of 50kg in 3 years. PBT at Okinawa of same input size could achieve 100kg in 4 years. Wild PBT are 30kg at 3 years, and 40kg at 4 years.
Masuma et al. (2008)	Concluded farmed PBT exceeded growth of wild PBT
Goto (2014)	The most recent data we have seen is where two trials with a trial manufactured feed and a baitfish control showed similar length and weight growth for both feeds. The manufactured feed results were: ***Trial One*** Place: Nagasaki Period: 16/6/13 to 16/12/13 Water temp: 16-29^{O}C Feeding: Once/day for 6 days/week Feed rate: 1.5-2.0%BW/day FCR: 3.8 Weight growth: Start 16kg – end 33.5kg Length growth: Start 89cm – end 113cm ***Trial Two*** Place: Kagoshima Period: 7/11/13 to 26/5/14 Water temp: 19-24^{O}C Feeding: Once/day for 6 days/week Feed rate: 1.5-2.5%BW/day FCR: 3.7 Weight growth: Start 9kg – end 18.5kg Length growth: Start 77cm – end 98.5cm

Mexican Pacific Bluefin Tuna (MPBT) and other tuna

The following table depicts growth performance in Mexican bluefin tuna (*Thunnus orientalis)*

Table 3. Summary of growth performance studies of Mexican Pacific bluefin tuna (*Thunnus orientalis)*

Reference	**Conclusion**
Sylvia et al. (2002)	Growth performance of tunas over a 2.5 months period in water temperature 18-22^{0}C **Species** **Start wt (kg)** **Final wt (kg)** PBT 45 70 Bigeye (*Thunnus obesus*) 25-30 45 Yellowfin (*Thunnus albacares*) 20-25 35

Australian Southern Bluefin Tuna (SBT)

The following table depicts growth performance in southern bluefin tuna *Thunnus maccoyii*

Table 4. Summary of growth performance studies of Australian Southern bluefin tuna, *Thunnus maccoyii*

Reference	**Conclusion**
Gordon et al. (2006)	Examples from confidential feed research in 2002 showed the following growth performance **Days in culture** **Start wt (kg)** **length (cm)** **Finish wt (kg)** **length (cm)** 173 16 95 30.13 108 170 14.5 97 28.7 109 174 26 112 45.3 120 The growth achieved was despite high mortality levels as a result of tagging and an 18-day weaning period for manufactured feeds.
Ellis (2013)	Specific Growth Rates in feed trials in 2005 were around 60% better than Atlantic Bluefin of the same size and age, and held for a similar period, as reported in Ticina et al. (2007). This is despite noting a period of suppressed feeding in the SBT trials – apparently due to blood fluke infections (*Cardicola forsteri*).

Australia had an intensive research program on development of alternative feeds (to wet feeds) in the 1990's and first half of the 2000's when the focus shifted to fish health. As a result there was no specific research on growth rates – but data on wet feed controls and on manufactured trials are available.

Growth performance in wild tuna

The Commonwealth Scientific Industrial Research Organisation (CSIRO) has completed various studies in wild SBT fishery growth and dynamics since the 1960s (Polacheck et al. 2004). A significant portion of this research has been based on tag and release data obtained by inserting conventional dart tags at the base of the second dorsal fin locking in the pterigiophores and recovered through fishing mortality. This information has been used to define age growth coefficients despite a rising amount of information suggesting tagging impacts on growth performance of southern bluefin tuna (Glencross et al. 2002; Gunn et al. 2002; Ellis 2013), other tunas (Ticina et al. 2007) and other species of fish (Loftus et al. 1988; Keiffer et al. 1995; Phillip et al. 1997; Crozier and Kennedy 2002; McLeay et al. 2002).

On a positive note, Hearn (1990) noted SBT grew from 3kg to 15kg in 10 months (tagged January/February) in the Great Australian Bight. According to Hearn, a high growth rate was most conspicuous in fish tagged in Jan/Feb and recovered 2-6 months later. This was supported by Glencross et al. (2002) who noted a one-year tag recapture growth performance of 3kg to 16.6kg.

Applying wild tuna stock models derived from catch and release conventional tags

Major assumptions exist when applying growth information derived from catch and release data obtained from wild or free roaming southern Bluefin tuna.

The first assumption is the impact of tagging on obtaining robust information to determine growth. There can be a significant weight loss of 7-12% for tagged fish in the first month after release (Hampton 1986; Hearn 1990). In another study PBT did not feed normally for approximately the first 30 days after release so that data for the first 60 days after tagging was excluded from an analysis of PBT feeding frequency and temperature preferences (Itoh et al. 2003). However, tagged fish have recovered weight loss after a year at liberty and tagged wild fish in farm pens indicated no retardation in length growth after 150 days (Hearn and Polacheck 2003). Quantifying age / growth coefficients is challenging for wild or free roaming fish as defining length at age is a direct relationship of tagging.

Whilst some authors have speculated fish in captivity will rebound or undertake a period of compensatory growth following tagging (Ticina et al. 2007; Ellis 2013), the handling and tagging impact can be very significant. In two related but different studies SBT were observed to have no growth 5 weeks after tagging (Glencross et al. 2002) and mortality in one trial pontoon reached 37% and low food intakes as a direct result. This handling stress potentially had long lasting impacts on fish physiology whilst compromising growth performance (Gunn et al. 2002). The stress through handling and tagging resulting in high mortalities of tagged SBT was reported in another trial (Gordon et al. 2006). In one study Atlantic Bluefin tuna reported negative Specific Growth Rate (SGR) 44-53 days post tagging and no significant increase in condition factor compared with untagged fish (Ticina et al. 2007). These authors went on to state

> *"Consequently growth rates calculated on the basis of tag-recapture data probably underestimates overall growth performance of small BFT farmed in given conditions."*

To manage these tagging influences in growth and nutrition trials Ellis (2013) advises comparisons should be made more accurately between the differences in treatments as opposed to absolute SBT growth performance.

Gunn et al. (2002) summarises further issues including

> "*Models for wild SBT are unlikely to be applicable to farmed fish for two major reasons. Firstly, the stocking and harvesting cycle involved in SBT aquaculture means that growth in the farming environment is generally measured on an intra-annual basis. Data used for standard growth curves, either gathered by direct ageing methods or from tagging experiments are generally collected over inter-annual time scales. This means that the*

magnitude of error acceptable from growth models based on inter-annual data may be too great for useful predictions of short-term growth. Secondly, the growth of wild fish is probably related to intra-annual variation in food availability, and migration costs dependent on different environmental conditions. Farm conditions are very different to those in the wild and may alter growth rates considerably via different consumption rates, possibly restricted activity levels and altered thermal conditions."

Gunn et al. (2002) found that that the von Bertalanffy model did not perform well with the variance in the data being too great to obtain plausible parameter estimates. The relatively short time span of farm growth data restricts the usefulness of the von Bertalanffy in this situation as the variance in the data is too large relative to the growth being modelled. Furthermore, *"the parameter estimates of the* von Bertalanffy *growth function (VBGF) (used) were not plausible and the model predicted growth badly."*

The bioenergetics models indicate the large degree to which tunas utilise energy for movement rather than growth, and why Food Conversion Ratios (FCR) are relatively high in tuna ranching compared with other fish. Gunn et al. (2002) notes:

"Tunas have generally been found to turn over energy at a high rate through continuous swimming for ram ventilation and through the need to cover large distances in order to find food in an uncertain and patchy pelagic environment."

"it is possible that taking away the need for active foraging and the restriction of the cage significantly alters the activity pattern from those (compared with) those in the wild. This will undoubtedly alter the energy budget and growth of the fish."

A bioenergetic model approach is now widely used in Australian tuna ranching operations to optimise growth and performance (Gunn et al. 2002; Ellis 2013).

Assumptions to inform analysis of *Unaccounted catch mortality of Australian ranched southern bluefin tuna*

Background to the raw data used in Japanese calculations

Itoh et al. (2012) outlined the data used in its calculations as follows:

"The Ministry of Agriculture, Forestry and Fisheries of Japan requested importers to submit data on the length and weight at harvest of farmed SBT which is imported to Japan after May 2007. The size data of harvested SBT imported to Japan, reaching a total of 420 thousands individuals from 2007 to 2010, were used for the analysis. After removing several anomalous records, data used were 174,980 individuals in 2007, 94,352 in 2008, 61,843 in 2009 and 89,004 in 2010."

Data for which both length and weight information was available was (N=76,080 in 2007, N=57,233 in 2008, N=58,964 in 2009 and N=49,948 in 2010).

To understand the background to the data, it may be helpful to understand the supply chain for fresh and frozen Australian ranched SBT:

1. The Catch Documentation Scheme (CDS) was not implemented until 2010 so therefore reporting of length was not required in the 2007-2009 period.
2. Japan indicated in its early analyses that the data they were using was "Packing lists information from Japanese buyers." (see CCSBT-EC/0610/35). The packing lists for fresh fish

normally show only a total weight shipment. For frozen fish, a packing list consists of number of fish in weight categories.

3. For fresh shipments, the fish are actually owned by the Australian exporter so that any documentation was owned by the Australian company. What is referred to in documents such as CCSBT-EC/0610/35 as “Japanese buyers” are actually agents of the Australian company, not a buyer. These agents simply take a commission (normally 3.5%) on the sale.
4. Fresh SBT shipments are not randomly selected and are specifically chosen for the Japanese market and larger and higher conditioned fish are selected.
5. In discussions with fresh product agents, all have rejected that any documents they may have held have been supplied to anyone else. In addition, length/weight data could not come from auctioneers who have no reason to know the length of individual fish or record this information.
6. The number of samples used by Japan in 2007 and 2008 is more than the number of fresh ranched SBT shipped to Japan in those years.
7. For frozen SBT, there are two channels:
    a. Japanese freezer/reefer vessels handle the large majority of frozen fish. The fish are slung onto these boats in groups of 5-15 fish.
    b. Some SBT are shipped via freezer container, particularly to smaller buyers who do not have the volume for a freezer boat.
8. The freezer boat process is that the SBT are harvested at the pontoons, gilled and gutted, and then taken to the freezer boat, then slung as above. Because the fish are then graded depending on size, quality and condition, a representative of the Australian company is always on the freezer boat. After finishing the final processing on the freezer boat, the SBT are then frozen.
9. To our knowledge, until 2014, there has never been any indication that fish were measured and they were seldom individually weighed by the frozen buyer.

Japan’s reason for not supplying the raw data is that they may be breaching confidence with those agents in Japan, which handle Australia’s fresh SBT. However, because these Japanese companies are only agents, the data actually belongs to the Australian tuna ranching company.

Therefore, as the owners of the data, the Australian industry is pleased to provide the permission to agents to provide it back to us for cross-checking. This will provide some cross-checking of the accuracy of the data base.

Application of 141 tagged wild fish caught and transferred into farms

These fish were caught within 30 days of tagging with the average period between tag and catch being 15.4 days (Sakai et al., 2009).

Most of the literature on growth performance in intensive tuna production is based on tagged fish. The following estimated mean growth ratios have been produced (Sakai et al., 2009).

Age 2 – 1.818

Age 3 – 1.544

Age 4 – 1.448

The assumption in Itoh et al. (2014) is that tagged fish retain the ***same or greater weight*** from the point of tagging in the wild to entry into the farms.

This appears to be the opposite and in contrast to information presented in this review in respect to growth achieved by bluefin tunas worldwide and the impact of tagging and handling in controlled research experiments focused on growth.

Impact of environmental conditions on growth performance

Itoh et al. (2014) note the following von Bertalanffy growth coefficient K (VBKs) for various wild tuna species

SBT (ages 2-6)	0.219
Pacific BT	0.173
Atlantic BT	0.089
Bigeye	0.180
Yellowfin	0.557
Albacore	0.134

As reported in the Mediterranean, Mexican and Japan growth performance sections of this paper, growth in farms is dimensionally greater than these wild VBK's. Part of the reason is that the above VBK's are not seasonally based (Gunn et al. 2002), and cover a range of age groups with different growth patterns.

Itoh et al. (2014) note that different captive Pacific Bluefin growth rates in different farms in Japan could be related to higher water temperatures and compare the temperatures in Japan with the lower ones in Port Lincoln. However, this is in contrast to very high growth rates achieved in both weight and length in water temperatures averaging 16.9^{0}C (Deguara et al. 2010).

The bioenergetics model of Gunn et al. (2002) found that food consumption is the key indicator of growth – a linear relationship between consumption and growth and predicted higher temperatures should result in more efficient assimilation rates. However, thermoregulation may "buffer" SBT metabolism to temperature effects to a degree that is not found in other ectothermic fish. They found temperature much less important in the case of SBT and that it is relatively unimportant in determining growth.

These researchers concluded that it is plausible there is an optimum temperature range for growth performance in SBT, with a peak occurring around 18^{0}C. This may be related to activity levels due to water temperature or changes in metabolic demands due to water temperature. This is consistent with the findings of Ellis (2013) that SBT feel greater heat stress at water temperatures above 20^{0}C. This is perhaps also consistent with Itoh et al. (2003) who found PBT preferred a temperature range of 14-20^0 C.

In Japan, Masuma et al. (2008) found water temperature important in growth performance
PBT at age zero reach the following weights after 3 years in culture

- 30-50kg in Shizuoka (north of Kinki)
- 50kg in central Japan (Kusimoto)
- 60kg at Kagoshima (south of Kinki)
- 75kg at Amami further south, and
- 100kg at Yaeyama (the southernmost island of Japan) after 4 years.

Possible reasons for the difference in growth could be related to

- Feed delivery and frequency
- Nutritional content of feed

- Development of the thermoregulatory capacity of small juvenile tuna. It is likely the southern warmer waters allow tuna to develop this capacity quicker thereby facilitating increased growth in the early stages
- It is likely small juvenile PBT do not have cold adapted enzymes to assist with digestion thereby holding back their digestive capability in cooler waters
- Site-specific conditions relating to blood fluke infections of *Cardicola orientalis* and *C. opisthorchis*. These trematode parasites cause significant impacts to the cardiovascular system and result in depressed feeding, stress and mortality. For example, the SBT ranching mortalities were 10.5% and 13.5% in 2009 and 2010 respectively, before falling to ~ 1% in 2015 when a solution was found.
- SBT have very short towing periods allowing ranching companies to increase growth rapidly through optimised feeding strategies using *Formu-bait* © (van Barneveld and Ellis, 2007)

From a health point of view SBT are very robust having survived high mortality in the wild (Nowak et al. 2003).

Bias in average weight sample to determine volume of catch

The papers presented to support the "Australian unaccounted catch mortality" hypothesis (e.g.Itoh et al. (2014)) assume there is a feeding hierarchy in the tow pontoon biasing the sample weight downward and/or that the sampler has a technique to target smaller fish.

In commenting on feeding hierarchies, Dr Peter Miyake, a leading Japanese researcher, and a major author on tuna science in Japan, noted:

> "As is well-known, if fish of different sizes are kept in the same cage, small fish cannot compete with big fish and therefore these small fish show very slow or no growth." (Source: Dr Peter Miyake, OPRT Newsletter, December 2013).

There is no other evidence to suggest smaller or larger fish are more aggressive feeders resulting in a sampling bias. Indeed, Galaz (2011) suggests feeding aggression of the bigger tuna is a key factor for tuna growth in fattening cages. Other studies suggest small tunas (100-160 cm) grow less than large tunas (Aguado and García-García 2005; Tzoumas et al. 2010). This result, among other reasons, is a reflection of the population structure within the different tuna cages. In those cages where large tunas are dominant (in terms of biomass), small tunas are almost totally suppressed from feeding and stay near the bottom of the net for nearly the entire feeding process. Only when (after a while) larger specimens significantly reduce their feeding activity, then smaller specimens begin to feed (Galaz 2010).

There are strict rules to follow when catching fish to determine the average weight sample to eliminate catching bias in the Australian SBT ranching industry and these rules are defined in the SBT management plan (see www.afma.gov.au/SBT/Pre-season Brief 2017/18).

In brief, the sampling process involves spreading feed over a large area of the pontoon and a single hook thrown into the middle of the spread feed at the same time. An invitation was extended to member scientists, government officials and industry to visit Port Lincoln in 2014 to observe this process first-hand. The QAR group also saw the weight sample in March 2014.

From a commercial farm husbandry and feed management perspective a range of techniques is used to eliminate feeding hierarchy including surface spreading and sub-surface feed delivery, feed timing and frequency, and satiation feeding. These techniques are not allowed at the weight sample.

The economic and Feed Conversion Ratio (FCR) implications, benchmarked internationally

Australian SBT quota owners have the choice each year to use the quota for harvesting from the wild or catching for growout. Growout, even for a short period, is a major risk because:

(1) There is no forward market for SBT. Therefore, when the SBT are caught for ranching, the operator takes the risk of not knowing the Yen price and exchange rate until the harvest up to 7-8 months later.

(2) The risk of substantial mortalities

(3) The capital assets of the quota owner can be used for either ranching or catching directly for the market.

If Itoh et al. (2014) methodology was correct then no one would be ranching SBT. The reason is that the largest cost is feed and the foundation of ranching profitability is the Feed Conversion Ratio (FCR). Based on Itoh et al. (2014) methodology, the following would apply in 2014.

Table 5. Assessing the economic viability based on an assumption of a 40% estimate of over catch

Item line	**Value**
Industry Average Weight (kg) – In/out whole wt	18.73/38.98
Imputed average weight gain (kg)in farm (whole kg) (Based on a hypothetical 40% estimate of overcatch (i.e. actual in-weight 22.67kg)(1)	12.76
Total industry whole weight increase (tonnes) – 255,486 fish x 10.62	3,311t
Imputed Feed Conversion Ratio (FCR) – whole weight (57,373t/3,311 feed)	17.33
Imputed Feed Conversion Ratio (FCR) – processed weight	20.1
Imputed Feed cost ($) for adding 1kg of processed weight (Bait is $0.88/kg)	17.69
Feed cost is 41% of ex-farm cost so total cost/kg added (2)	43.2
Price ranched product ex-pontoon $/kg (3)	14.53
Price Australian longline SBT $/kg – for comparison	17.25

Notes to the table -

(1) Data on average weights in/out of farm – Source: AFMA (supplied to CCSBT and Japan).
(2) Local sardines – 33,500t (Source: PIRSA); imported (Source: Australian Bureau of Statistics)
(3) Ex-farm price (Source: Australian Bureau of Statistics)

Therefore based on Itoh et al. (2014) calculations it would be cost prohibitive to ranch tuna in Australia.

Another way of assessing the implications is comparisons with the FCR of tagged tunas in SBT and other tuna ranching/farming operations.

Table 6. Food conversion ratio based on growth and baitfish consumed by tagged tuna in research trials

Citation	**Species**	**Food Conversion Ratio (whole wt)**
Goto (2014)	Japanese PBT *Thunnus orientalis*	10.7
Sylvia et al. (2002)	Mexican PBT *Thunnus orientalis*	7.0
Gunn et al. (2002)	Australian SBT(1) *Thunnus maccoyii*	10.0
Gordon et al. (2006)	Australian SBT(1) *Thunnus maccoyii*	8.3

Notes to the table -

(1) These tuna were tagged with conventional dart tags with associated impacts on physiology and growth performance

It is implausible that the FCR of untagged SBT in commercial operations could be about double that of tagged SBT required to meet the hypothesis of a 40% overcatch estimate into farms.

Note: The above analysis for 2014 Australian ranching produces a very similar answer to the analysis for 2013 (see CCSBT-ESC/1409/11). The preliminary analysis of the 2015 data also produces a similar outcome.

The importance of the Condition Index (CI) of a tuna

The fatness of a tuna is the major reason for a higher price. The target of tuna farming is to produce faster growth and a higher level and consistency of fatness than a wild fish.

The widely used method to calculate fatness is the length and whole weight in a simple formula. In Australia the formula most used is:

$$CI = W/(L/100)^3$$

The normal CI of a 2-3 year old wild SBT is 19-20.

Testing the hypothesis of Itoh et al (2014) for 2013 – with the *agreed* average out-weight of 33.3kg ww.

Itoh et al. (2014) hypothesise is that the majority of the fish into farms are 4 year old, with an average weight into farms of 26.9kg (about 110 cm).

Japan's hypothesis produces a CI of around 20 – far below the Australian farmed fish average of 24-26.

The realities of catching SBT for farming in the Great Australian Bight (GAB)

Itoh et al. (2014) hypothesise is that the majority of the SBT caught for farming are four year olds. This is significantly inconsistent with the realities of catching SBT in the GAB for the following reasons:

(1) The number of four olds in the 2-4 year old stock is about 11% of total 2-4 year old fish in the stock.
(2) Fish of four years or older are rare in both the transect and SAPUE aerial surveys.
(3) Even assuming all four year old fish return to the GAB each year, The "ASF unaccounted catch mortality" hypothesis assumes that Port Lincoln industry is able to target four year olds to a high degree. That is totally unrealistic in the GAB.
(4) Such a high degree of targeting is unrealistic in a normal purse seining situation – in farming it would be even more unrealistic. The reason is that filling a single tow pontoon normally requires 5-10 shots over a number of days in different areas. Once the tow pontoon takes the first shot, it can only be towed at average one knot to accept the rest of the shots.

Discussion points for participants of the CCSBT Compliance Committee

We propose participants of the CCSBT Compliance Committee review this information in response to the hypotheses of farm unaccounted catch mortality. The extensive literature shown in the analysis, and the realities of Australian and global tuna farming, do not support the hypotheses of unaccounted catch mortality in farming. However, the

Compliance Committee is encouraged to recommend that:

- That Japan supply the data base used to calculate UAM in Australian farming.
- That Australia and interested members continue information exchanges on the issue at the various meetings and inter-sessionally.

References

Aguado-Giminez, F. and Garcia-Garcia., B (2005). Changes in some morphometric relationships in Atlantic bluefin tuna (*Thunnus thynnus* Linanaeus 1758) as a result of fattening process. Aquaculture, Volume 249, September 2005).

Cort J. (2003). Age and growth of the bluefin tuna (*Thunnus thynnus thynnus*) of the Northeast Atlantic. In: Bridges, C.R., Gordin, H., Garcia, A. (Eds.), Proceedings of the Symposium on Domestication of the Bluefin Tuna, *Thunnus thynnus thynnus*, 3–8 February 2002.

Crozier, W and Kennedy, G. (2002). Impact of tagging with coded wire tags on marine survival of wild Atlantic salmon (*Salmo salar* L.) migrating from the R. Bush. Northern Ireland Fisheries Research. 59 Vol 2, 209-215.

Deguara S., Saviour, S., Caruana, S. and Agius, C. (2010). Results of the first growth trial carried out in Malta with 60kg farmed Atlantic Bluefin Tuna (*Thynnus thynnus* L.). SCRS/2009/134 Collect. Vol. Sci. Pap. ICCAT, 65(3): 782-786 (2010).

Ellis, D. (2013). The measurement of visceral temperature patterns and implications for feeding practices in ranched southern bluefin tuna *Thunnus maccoyii*. Submitted in fulfillment for the degree of Master of Applied Science, June 2013, University of Tasmania.

Galaz, T. (2011). Eleven years – 1995-2005 – of experience on growth of bluefin tuna (*Thunnus thynnus*) in farms. SCRS/2011/160 Collect. Vol. Sci. Pap. ICCAT, 68(1): 163-175.

Glencross, B., Clarke, S. and Buchanan, J. (2002). Temporal Growth Patterns of Farmed Juvenile Southern Bluefin Tuna, *Thunnus maccoyii* (Castelnau) Fed Moist Pellets. Journal of the World Agriculture Society. June 2002.

Gordon, R., Bayly, G. and Foster, C. (2006). Commercialisation trials for a manufactured tuna feed. Aquafin CRC Project 1A.3 January 2006.

Goto, T. (2014). Development of artificial feed for farmed bluefin tuna, *Thunnus orientalis,* Nippon Suisan Kaisha. Presentation to WAS Conference, Adelaide, June 2014.

Gunn, J., Patterson, T. and Rough, K. (2002). Experimental analyses of the effects of ration and feeding frequency on the thermodynamics, energetics, growth and condition of farmed Southern Bluefin Tuna. CSIRO Marine Research. FRDC Project 97/363. May 2002.

Hampton, J. (1986). Effect of tagging on the condition of southern bluefin tuna, *Thunnus maccoyii* (Castlenau). Australian Journal and Freshwater Research 37 in 1986.

Hearn, W. and Polacheck, T. (2003). Estimating long-term growth rate changes of southern Bluefin tuna (*Thunnus maccoyii*) from two periods of tag return data. Fishery Bulletin January 2003.

Hearn, W. (1990). Comments on Optimal Growth of Southern Bluefin Tuna (SBT). CSIRO Division of Fisheries 6 April 1990.

ICCAT. (2009). Report for the Biennial Period 2008-2009, Part II (2009), Vol 2. SCRS

Ikeda, S. (2003). Rearing Market and domestic production of cultured tuna in Japan – cultured tuna in the Japanese market. In: Bridges, C.R., Gordin, H., Garcia, A. (Eds.), Proceedings of the 1st International Symposium on Domestication of the Bluefin Tuna, *Thunnus thynnus thynnus*, 3-8 February 2002. Cartagena, Spain. Cah. Options Mediterr., vol. 60, pp. 83– 84.

Itoh, Y.,Tsuji, S. and Nitta, A. (2003). Migration patterns of young Pacific bluefin tuna (*Thunnus orientalis*) determined with archival tags. Fishery Bulletin, July 2003.

Itoh, T., Akatsuka, Y., Kawashima, T., and Mishima, M (2012). Analyses on age composition, growth and catch amount of southern bluefin tuna used for farming in 2007-2101. Paper CCSBT-ESC/1208/30 to ESC 2012.

Itoh, T., Suzuki, K. and Takeda, S. (2014). Unaccounted catch mortality in Australian SBT farming fishery between 2001 and 2013 estimated from information of TIS and CDS. Paper CCSBT-

OMMP/1406/09 (Rev). July 2014

Kataviæ, I., Tièina, V. and Franièeviæ, V. (2001). A preliminary study of the growth rate of Bluefin tuna from Adriatic when reared in floating cages. SCRS/2001/092

Keiffer, J. D., Kubacki, M. R., Phelan, F. J. S., Phillip D. P. and Tufts, B. L. (1995). Effects of catch and release angling on nesting smallmouth bass. Transactions of the American Fisheries Society. 124, 70-76.

Loftus, A.J., Taylor, W. W., and Keller, M. (1988). An evaluation of lake trout (*Salvelinus namaycush*) hooking mortality in the upper great lakes. Can. J. Fish. Aquat. Sci. 45, 1473-1479.

Masuma, S., Miyashita, S., Yamamoto, H. and Kumai, H. (2008). Status of bluefin tuna farming, broodstock management, breeding and fingerling production in Japan. Review in Fisheries Science. 16:385-390.

McLeay, L. J., Jones, G. K. and Ward, T. M. (2002). National Strategy for the Survival of Released Line-caught Fish: A Review of Research and Fishery Information. Fisheries Research and Development Corporation Project 2001/101. Henley Beach, South Australia. South Australian Research and Development Institute, 121 pp.

Norita T. (2002). Feeding of bluefin tuna : Experiences in Japan and Spain**.** In : Bridges C.R. (ed.), García, A. (ed.), Gordin, H. (ed.). *Domestication of the bluefin tuna Thunnus thynnus thynnus.*

Nowak, B., Rough, K., Ellis, D., Crane, M., Cameron, A. and Clarke, S. (2003). Aquafin CRC – Southern Bluefin Tuna Aquaculture Subprogram: A risk assessment of factors influencing the health of southern bluefin tuna. Fisheries Resaerch and Development Corporation and Aquafin CRC.OPRT. (2013). Organization for the Promotion of Responsible Fishing (OPRT). Newsletter. December 2013.

Phillip, D. P., Toline, C. A., Kubacacki, M. R., Philipp, D. B. F. and Phelan, F. J. S. (1997). The impact of catch-and-release angling on the reproductive success of smallmouth bass and largemouth bass. North American Journal of Fisheries. 17, 557-567.

Polacheck, T. (2012). Assessment of IUU fishing for Southern Bluefin Tuna. Marine Policy, 36, 1150-1165.Polacheck, T., Eveson, J. P. and Laslett, G. M. (2004). Increase in growth rates of southern bluefin tuna (*Thunnus maccoyii*) over four decades: 1960 to 2000. Can. J. Fish. Aquat. Sci. 61, 307-322.

Sakai, O., Itoh, T. and Sakamoto, T. (2009). Estimation of growth in farmed Southern Bluefin Tuna using the CCSBT conventional tagging data. Paper CCSBT-ESC/0909/31 to 2009 CCSBT.

Sylvia, P. Belle, S. and Smart, A. (2002). Current status and future prospective of bluefin tuna (*Thunnus thynnus orientalis*) farming in Mexico and the West Coast of the United States. In : Bridges C.R.(ed.), García A. (ed.), Gordin H. (ed.). *Domestication of the bluefin tuna Thunnus thynnus thynnus.*

Ticina, V., Katavic, I. and Grubisic, L. (2007). Growth indices of small northern bluefin tuna (*Thunnus thynnus*, L) in growth-out rearing cages." Aquaculture (2007)

Tzoumas, A., Ramfos, A., De Metrio, G., Corriero, A., Spinos, E., Vavassis, C. and Katselis, G. (2010). Weight growth of Atlantic Bluefin Tuna (*Thynnus thynnus*, L.1758) as a result of a 6-7 months fattening process in the Central Mediterranean. SCRS/2009/135 Collect. Vol. Sci. Pap. ICCAT, 65(3): 787-800

van Barneveld R. and Ellis, D**.** (2007). Practical nutrition of farmed Southern Bluefin Tuna *Thunnus* maccoyii. Aquafin CRC, Adelaide. Commercial in confidence.