

**EXPERIMENTAL FIELD STUDIES AND PREDICTIVE
MODELLING OF PCB AND PCDD/F LEVELS IN
AUSTRALIAN FARMED SOUTHERN BLUEFIN TUNA
(*Thunnus maccoyii*)**

by

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EXECUTIVE SUMMARY

Farmed Southern Bluefin Tuna (SBT) (*Thunnus maccoyii*) is an important export product for South Australia (SA). It is exported to Japan, China, Korea and the United States for the sushi and sashimi markets. The primary purpose of SBT farming in SA is to fatten wild-caught juvenile fish (2-4 years of age with initial mean weights between 12-20 kg) over a period of approximately five months by feeding a selection of baitfish types. Farmers, farm managers and consumers of SBT all have an interest in managing chemical residues that have the potential to biomagnify in the fatty tissue of the farmed SBT fillets. Of particular interest are chemical residues of polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-*p*-dioxins / dibenzofurans (PCDD/Fs).

This research presents the investigations and experimental validation of a predictive model that can be used to address the levels of residues in the fillets of farmed SBT at harvest from feeding (as the source) when applied to SBT aquaculture. An additional industry-focussed aim of this research was to determine if a Longer Term Holding (LTH) farming period, with a duration of an extra 12 months after a typical farming period of approximately five months, could produce SBT with higher condition index (CI) and lipid content, while keeping levels of PCBs and PCDD/Fs low, compared to the typical farming period.

The justification for this research is that an adequate quantitative model is essential to help industry achieve targeted concentrations in the final fillet product by making scientific-based decisions on baitfish selection (baitfish strategies for the feeding of SBT), and longer term, to confidently demonstrate to local markets and importing countries that Australia is actively managing levels of PCBs and PCDD/Fs in farmed SBT, to ensure a high quality and safe product is delivered to the consumer.

The novelty of this research is underpinned by four integrated stages, and the criteria for an adequate model established. The important criteria included: accurate predictions *versus* observed data demonstrated through the analysis of residual plots, potential physiological interpretation of model coefficients, parsimony – the model should be as simple as possible (but no simpler) and that the model should be easy to use.

Firstly, a logical starting point was the development of a risk framework for residues in SBT. The developed framework was based on conventional principles of microbiological risk assessment highlighted in Codex Alimentarius. The risk framework consists of five governing principles: hazard identification, hazard characterisation, exposure assessment, risk characterisation and model validation. The advantages of the risk framework is that it provides a systematic research approach and permits information to be handled unambiguously, especially important for the niche SBT industry where chemical residue research is carried out for the first time.

Secondly, because of a lack of available scientific data in context of this research, commercial-scale experimental field data for levels of PCBs and PCDD/Fs in typical farmed SBT as affected by feeding and growth were collected over 17 months at seven time intervals from Farm Delta Fishing Pty Ltd in 2005/06 ($n = 50$). Field data from another commercial company, Farm Alpha Fishing Pty Ltd, was collected over the typical farming period specific to this company, spanning 15 weeks at three time intervals in 2006, for validation work ($n = 15$). The data obtained from Farm Delta Fishing Pty Ltd revealed that whole weight of farmed SBT increased from 18.5 kg to 30.3 kg for a typical farming period, and subsequently to 41.0 kg by the end of the LTH farming period. A maximum mean CI of $24.0 \pm 0.5 \text{ kg}\cdot\text{m}^{-3}$ and a maximum mean lipid content of $17.6 \pm 0.5\%$ was achieved at the third time interval of the typical farming period, for the baitfish types and ratios used as feed. There were no significant differences in the CI and lipid between the final harvests of the typical farming and LTH periods, i.e. even after an additional 12 months of farming. PCB and PCDD/F concentrations, however, increased between the final harvests of the typical farming and LTH periods. The data indicated that a typical farming period was sufficient to achieve a maximum CI and lipid content with lower concentrations of PCBs and PCDD/Fs in the fillets relative to the LTH farming period.

For the third stage of this research, a quantitative model was synthesised and applied to the PCB and PCDD/F (2,3,7,8-TeCDF) data detected in farmed SBT fillets. Assimilation efficiencies for PCBs and 2,3,7,8-TeCDF in the fillets of SBT were obtained. An assimilation efficiency, or percentage retention (efficiency expressed as a percentage), in the fillet of SBT is a measure of the uptake of a chemical residue from food (baitfish) to the SBT fillet. For the WHO-PCBs, assimilation efficiencies based on SBT fillets ranged

between 19.1 – 35.3 % with the exception of PCB 169. The highest assimilation efficiency of 35.3 %, with a range of 30.4 – 40.3 % (at the 95 % confidence level) was attributed to the most toxic PCB congener, PCB 126. An assimilation efficiency of 39.2 % was determined in SBT fillets for the congener 2,3,7,8-TeCDF, which was higher than the assimilation efficiencies determined for the WHO-PCB congeners. A residual plot as predicted value versus observed value indicated that the predictive model was neither under- or over-parameterised. However, when the predictive model was assessed against the data set from Farm Alpha Pty Ltd, the model over-predicted the actual PCB and PCDD/F concentrations. The over-prediction is attributed to possible overfeeding of SBT farmed by Farm Alpha Fishing Pty Ltd. From a food safety point of view, in the absence of ideal predictions because of a lack of ideal validation data sets, an over-prediction instead of under-prediction is preferred.

In the fourth stage, the practical application of the predictive model was demonstrated. Because SBT fillets are retailed as tissue group-specific, i.e. akami (low fat), chu-toro (medium fat) and otoro (high fat) fillets, PCB and PCDD/F analyses were carried out on the three tissue groups for selected SBT ($n = 7$). Dietary modelling on SBT consumption in humans was carried out using findings from the predictive model and tissue-specific data. The baitfish strategy employed for the feeding of farmed SBT consequently affects dietary exposure to SBT consumers. Exposure to PCBs and PCDD/Fs is approximately seven times lower for the consumption of a skin-free, boneless akami fillet than for a comparable otoro fillet of the same size. This dietary exposure assessment accounted only for consumption of SBT tissue-specific fillets.

The experimental field study and modelling work on PCB and PCDD/F concentrations in farmed SBT (fillets) outlined in this thesis importantly directs the need to re-evaluate a specific model to better cater for SBT farming practices where SBT fillets are produced for human consumption. Because conditions that normally pertain to commercial farming of wild-caught fish were studied, findings should be of interest to industries where other species of fish (for food) are farmed in sea-cages in the open ocean.

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