PRELIMINARY STUDY TO DETERMINE THE PROVENANCE OF BARRAMUNDI (*Lates calcarifer*) BASED ON ITS TRACE ELEMENT COMPOSITION

JOEL D'COSTA

BSc (Chemistry), Graduate Diploma (Forensic Science)

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

Centre for Forensic Science

School of Anatomy, Physiology and Human Biology

University of Western Australia

This thesis is presented in fulfilment of the requirements for the degree of Master of Forensic Science

2015

DEDICATION

I would like to dedicate this thesis to my Uncle Tony Carvalho and Aunty Dina Dias, who supported me unconditionally throughout this journey in completion of my Master degree.

ABSTRACT

Barramundi has a national and international reputation as a high quality commercial and sporting fish species with premium eating qualities and a price to match. Australian barramundi is a succulent eating fish with high nutrient and low fat characteristics making it doubly commercial in a weight conscious society. However, it is these characteristics that have made it a target for food fraud and substitution by cheaper and often inferior overseas equivalents. Consequently, there is an immediate imperative to safeguard Australian product and develop a robust scientific procedure to ensure that Australian product can be unambiguously provenanced and differentiated from all overseas “equivalents”.

Trace element analysis, using inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectroscopy (ICP-AES), have been extensively used to successfully determine the geographical origin of wide range of plant and animal based food products. However, there has been no detailed research into the development of equivalent methodologies to determine the provenance of fish and seafood products with the only detailed technology being associated with actual substitution of fish species using DNA bar-coding.

Statistical interpretation of the concentrations of 63 elements, determined using solution based ICP-MS and ICP-AES, was used to establish the provenance of 223 barramundi samples from 10 locations from Australia and internationally. The overall results of the study indicate that it was possible to distinguish geographical region within a large batch of Australian and overseas samples on the basis of the trace element association patterns. The results also confirm that there was no significant difference in the trace element composition of the dorsal and ventral muscles of the barramundi. In addition, when the samples from around Australia were analyzed separately, it was possible to achieve approximately 100% correct classification to their site of origin in all cases.

This research demonstrates the potential of using elemental composition, in combination with statistical classification methods, for accurate provenance establishment of barramundi samples from Australia and overseas.

ACKNOWLEDGEMENT

Completion of this research project has been a long journey, which would not have been possible without the support of number of people. I take this opportunity to offer my sincere gratitude to everyone who has helped me throughout this journey and made this research project possible.

First and foremost I want to thank Professor John Watling for all the support, patience and enthusiasm during this research project. I am extremely grateful for all his efforts in sticking by me during the difficult times and always making me believe that we would one day finish this project. I can't thank you enough for all that you have done for me. I would also like to thank my supervisor Professor Daniel Franklin for all his guidance and constant feedback on this project. Also, special thanks to Professor Ian Dadour for providing me with the funds to help me get this research started.

I would like to thank the staff of TSW analytical for all the assistance and technical support during this research project. I would also like to acknowledge the support I received from the students and staff of Centre for Forensic Science. Many thanks to Louise Wedlock and Joanne Edmondston from the Graduate Research School for all the help they provided me during this research project.

I want to thank my family here in Australia, specially my Uncle Tony Carvalho and Aunty Dina Dias for providing me more than I could ask for. Thanks also to my cousins Dolrech and Eliza, who have supported me throughout my journey. I would like to thank my family back home, specially my mom, brother and sister. Thank you for always being there for me and supporting me. Lastly, I want to thank all the kids, starting with my niece and nephew, and my cousin's kids for being such cuties.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Fraud in the Food Industry

The food industry has undergone exponential growth over the past century in line with the boom in human population growth. There has also been a commensurate increase in trade, with foods and food products constantly shipped globally to fulfill requirements for specific food items and exotic foodstuffs.[1] This globalization of the food trade has increased the distance that foods travel from producer to consumer, increasing the potential for fraudulent activities along the food supply chain.[1] Fraudulent activities, such as intentional counterfeiting, substitution, adulteration or mislabeling of foods have flourished concurrently with increasing global trade, which has in turn increased the potential for compromised food quality and safety.[1,2]

Food fraud is defined in a report commissioned by the U.S Department of Homeland Security as a collective term that encompasses the deliberate substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging, or false or misleading statements made about a product for economic gain.[3] Amongst the many ways food fraud can occur are: substitution of one ingredient by a similar but cheaper one; extension or adulteration of food with a cheaper base material; inclusion of undeclared ingredients; non-declaration or false declaration of processes; over-declaration of a quantitative ingredient; or false declaration of geographical and production origin.[4] Food fraud can occur at all levels of the food supply chain by producers, manufacturers, processors, distributors or retailers and is a highly lucrative business as it is relatively cheap and easy to falsify or misrepresent a food product.[2] Counterfeit food products are often very similar to the original item in terms of appearance and taste and in most cases are sold for the same price as the original. Food fraud is also difficult to detect as it is generally not reported because the food product is often consumed before the fraud is realized.[5] The fact that it is relatively easy to get away with food fraud, coupled with the enormous profits that are to be made by such activity, means that the longer the fraud goes unaddressed, the more likely the practice will increase in scope, scale, and threat.[6]

1.2 Economic and Social Threats to the Food Industry

As the production and consumption of food is central to all societies, food fraud not only has serious economic and social consequences,[1] but also may seriously compromise consumer safety. Consequently, food quality and safety are major concerns for the food industry.[1]

1.2.1 Economic Threats

The problem of food fraud is estimated to have an annual global cost of $US49 billion.[7] Approximately 10% of purchased food is thought to be adulterated, and 7% is thought to contain fraudulent ingredients.[7] The economic consequences of food fraud impacts on individuals, families, communities, businesses and countries[1] and a large amount of capital has been spent on health care services, incident investigation, surveillance, and public education.[8] Food fraud also impacts on trade and tourism, leading to loss of earnings and unemployment.[1] Scandal-hit branded companies have suffered huge losses due to the cost of product recall and replacement, and the loss of market value and reputation in some cases had led to bankruptcy and closure.[9]

1.2.2 Social Threats

The primary motivation for food fraud is economic, but it can potentially give rise to adverse social effects including impacts on public health and security.[2] Over the last 20 years the credibility of the food industry has been heavily challenged after a number of food crises that led to the outbreak of various food borne illnesses, including food poisoning from salmonella, faecal coliforms and melamine to milk, and have resulted in public panic and disorder.[10-12]

There is also the threat of contaminated food being used as a bioterrorist weapon.[13] Bioterrorism can be defined as terrorism by the intentional release or dissemination of biologic agents, such as bacteria, viruses, or toxins. Bioterrorism can target all stages of the farm-to-table food continuum including crops and livestock, food products in the processing and distribution chain, wholesale and retail facilities, storage facilities, transportation, and food and agriculture research laboratories.[13] The resulting food products could be used as a vehicle for introducing harmful toxic chemicals or infectious biological agents into the food supply to give rise to potential public health threats.[13]

1.3 Food Fraud Scandals and Surveys

Since the beginning of the 21st century there have been a number of major food fraud incidents that have resulted in long-lasting damage to human health, and diminution of consumer confidence in the food supply system. In a review of journal articles and media reports of food fraud incidents since 1980, Everstine et al.[14] grouped these food fraud incidents into various categories as shown in **Table 1.1**.

Table 1.1 Economically motivated adulterant incidents and examples of adulterants in various food categories.[14]

Food Category	Total Incidents	Adulterants
Fish and seafood	24	Species substitution, over glazing
Dairy products	15	Melamine, protein additives, vegetable fats
Fruit juices	12	Water, beet sugar, artificial flavorings
Oils and fats	12	Alternative fat sources
Grain products	11	Organic label fraud, bulking agents
Honey and other natural sweeteners	10	Chloramphenicol, high-fructose corn syrup
Spices and extracts	8	Various bulking agents, dyes
Wine and other alcoholic beverages	7	Methanol, diethylene glycol
Infant formula	5	Counterfeit or stolen formula, substandard nutritional profiles
Plant-based proteins	5	Melamine, urea
Other food products	28	Protein powders in meat products, clenbuterol in pork, organic fraud in eggs and produce

During the last decade there has been a rise in food fraud incidents around the world. In 2008, a major scandal occurred in the Chinese milk market when 22 Chinese food companies sold milk products (including baby formula) containing melamine.[12] Melamine, which is commonly used to make plastics and fertilizer, was mixed into raw milk to falsify protein tests. The tainted milk was blamed for the deaths of at least six children from kidney failure and caused considerable illness in nearly 300,000 others.[15] The incident not only damaged the reputation of China's food exports, but also damaged their booming domestic dairy industry. After the incident, Chinese consumers turned to foreign brands that had flooded the Chinese market.[16]

In the United States between 2010 and 2012, the international organization Oceana, conducted one of the largest seafood fraud investigations to date, collecting 1,215 seafood samples from 674 retail outlets in 21 states, to determine if they were correctly labelled. DNA testing showed that one-third (33 percent) (401) of the 1,215 samples analyzed nationwide were mislabeled, thereby suggesting the presence of high level of mislabeling across the US food industry.[17]

In Europe in 2011-2013, an INTERPOL-Europol coordinated operation known as Opson, seized tonnes of substandard potentially harmful food products.[18-20] The operation was initially carried out in 10 countries across Europe for a week. A year later the operation was extended to a further 29 countries from all regions of the world and in 2013 it was extended to an additional 33 countries. The operation involved police, customs, national food regulatory bodies, and private sector partners. Checks for counterfeit food products were performed in airports, seaports, shops and markets. Over 100 arrests were made during the operation and many recovered counterfeit food products were declared unfit for human consumption, including olive oil, seafood, meat, honey, dairy products, wine, spices, confectionary and cheese.[18-20]

The European Union (EU) is widely acknowledged as having some of the toughest food safety regulations in the world however in January 2013, the Food Safety Authority of Ireland revealed the results of a targeted study that found undeclared horse DNA in frozen beef burgers on sale in Tesco, Iceland, Aldi and Lidl supermarkets.[21] The beef burgers sold by the British supermarket Tesco were then tested and found to contain 29% horse meat. Other Tesco beef products tested contained up to 100% horse protein.[22,23] These tests resulted in the recall of around 10 million burgers in the U.K.[22,23] Thus far, there have been no reported health concerns from the incident, but the scandal severely damaged consumer confidence in the food industry. A poll after the scandal showed that consumer trust in the industry had fallen by a quarter (24%) and 60% of consumers had changed their food shopping habits, with 30% now buying less processed meat and 24% either buying fewer ready meals containing meat or choosing vegetarian options.[24]

Australia is also not immune to food fraud, with numerous cases of substitution and mislabeling being reported. In 2003, a pilot survey of the identity of fish species sold through retail food outlets was conducted. Sampling for the pilot survey was coordinated by the Environmental Health Service and the Health Department of Western Australia, and was performed by the Environmental Health jurisdictions of New South Wales, Northern Territory, South Australia, Queensland and Western Australia. Samples were also collected in the Australian Capital Territory by Food Standards Australia New Zealand (FSANZ). DNA testing was undertaken on 138 samples and the results indicated that 23% (32) of the fish sampled were mislabeled. The mislabeling was highest in food outlets such as restaurants and cafes, lower in supermarkets and least prevalent in wholesaler outlets.[25]

Other cases of food fraud in Australia include small goods, eggs and honey. In 2010, Primo SmallGoods, Australia's largest producer of meat products, were fined $237,575 for mislabeling a large quantity of bacon product as "Product of Australia" when the meat actually was imported from overseas.[26] In 2007, egg supplier from GO Drew Pty Ltd was fined $25,000 for substituting and selling non-organic eggs as organic produce[27] and in 2012, an egg producer from Glensung Pty Ltd, was fined $4,620 for wrongly labelling 38,000 dozen eggs as free-range.[28] In 2014, The Australian Competition and Consumer Commission fined the Victorian Basfoods Ltd company $30,000 for misleading consumers by labelling their honey as produced by honey bees, when the main ingredients were sugars from corn and sugar cane.[29]

1.4 Necessity for Food Provenancing

In the wake of these high profile food fraud scandals, it has become increasingly important, if purely from the safety aspect, to know the correct information about a food product being consumed. There is an increasing interest among consumers for high quality food products with correct labelling. Consumers want clear and accurate food labels to make informed choices about their diet and the foods they buy. This information is essential for consumers to enable them to choose one food product over another based on their lifestyle (vegetarianism, preference for organic products) or religious concerns (absence of pork for Jews and Muslims), or health concerns (e.g. absence of peanuts, lactose or gluten for individuals with particular allergies).[30]

Consumers are also concerned by the geographical origin of food, often called the country of origin protocols. Provenance information of a food product is often demanded for varied reasons ranging from patriotism to the desire for specific culinary or organoleptic qualities associated with regional products.[31] Provenance information is also commonly requested by consumers because of concerns with the quality or safety of products produced outside their local region or country, concerns about animal welfare or the desire to consume food generated from ‘environmentally friendly’ production methods more adopted by smaller regional producers.[31] The use of geographical identification associated with a particular food product allows producers to obtain and consolidate market recognition. This market recognition is often instrumental in ensuring a premium price for regionally specific products.[31-33]

False use of geographical indications by unauthorized parties are detrimental to consumers and legitimate producers and their brands, as it diminishes consumer confidence.[32] As yet there is no definitive, scientifically based, method that can identify the origin of a specific foodstuff as paperwork associated with that material can be easily falsified. The development of new and increasingly sophisticated techniques for determining the geographical origin of products, that can unambiguously determine the provenance of specific foodstuffs, is therefore highly desirable for consumers, farmers, retailers and administrative authorities.[31-34] Consequently, research undertaken in the present thesis is designed to investigate the development and application of a scientific provenance determination methodology. This methodology will be used to determine the provenance of barramundi from different geographical locations in Australia and internationally, using modified inter-element pattern discrimination based on analytical and statistic interpretational protocols to address this issue.

1.5 Determination Technology Investigated in this Thesis

Since the mid 1980's, there has been an increase in research and development of sophisticated and robust techniques to enable the food industry to determine the provenance of food products.[5] The use of inter-element association patterns in provenancing food is based on the fact that trace element composition of living organisms is influenced by their environment.[31,32,35,36] Trace elements exist naturally in soils and water in varying concentrations, with the composition of these materials largely determined by the underlying parent rock and the weathering processes such rocks have undergone.[35] Plants take in minerals from the soil they grow in while animals living on land and the sea take in minerals from the food that they eat.[31] Thus, plants and animals from different geographical locations will exhibit different trace elemental signatures and these signatures can be used to distinguish growing area differences in individual populations.[31,32,36]

Research into multi-element analysis to determine provenance initially focused on agricultural products (such as olive oil, wine, coffee and tea) as there were well established growing and production regions for these products.[5] But in 1992, with the introduction of legislation by the European Union to protect the reputation of regional foods, this multi-element analysis expanded to the provenance of a range of other food products[5] including plant based products (such as fruits,[36] potatoes,[37] pistachio nuts,[38] wheat,[39] tomatoes and tomato paste,[40] garlic,[41] wine,[42,43] Welsh onions,[44] tea,[45,46] coffee[47,48]) and animal based products (such as beef,[31,49] lamb,[50,51] pork,[5] honey,[52] milk,[53] cheese,[54] and butter).[55] Kelly et al.[31] and Watling et al.[5] have reviewed the range of foodstuffs analyzed, while Luykx and Van Ruth[32] and Peres et al.[56] have reviewed the technologies used to test provenance.

1.5.1 Provenance Establishment Studies

i. Franke et.al[49]

Franke et.al (2006) undertook a study in order to determine the geographic origin of poultry and dried beef using elemental signatures. Analysis of elements was undertaken using inductively coupled plasma high resolution mass spectrometry (ICP-HRMS). Additionally, gross chemical composition (GCC) was also analyzed. The 25 poultry breast fillets samples originated from Switzerland, France, Germany, Hungary, Brazil, and Thailand, and the 23 dried beef samples were produced in Switzerland, Austria, Australia, The United States, and Canada. A total of 66 and 46 of the elements and isotopes determined were detected in beef and poultry, respectively. For statistical analyses, only the most abundant isotopes per element were used. For both the poultry meat and dried beef, a differentiation of the origins was possible using those elements, which were significantly different across countries (As, Na, Rb, and Tl in poultry; B, Ca, Cd, Cu, Dy, Eu, Ga, Li, Ni, Pd, Rb, Sr, Te, Tl, Tm, V, Yb, and Zn in beef). No sufficient differentiation between origins was possible with GCC.

ii. Perez et.al[36]

Perez et.al (2006) carried out a study by combining elemental profiles with various modeling approaches to determine classifications of geographic origin of three fresh fruits. Elemental analysis of strawberry, blueberry, and pear samples was performed using inductively coupled plasma argon atomic emission spectrometry to determine the concentration of 13 elements (Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, V, and Zn). Bulk stable carbon and nitrogen isotope analysis in pears was performed using mass spectrometry as an alternative fingerprinting technique. Each fruit, strawberry, blueberry, and pear, was analyzed from two growing regions: Oregon vs. Mexico, Chile, and Argentina, respectively. Principal component analysis and canonical discriminant analysis were used for data visualization. The data were modeled using linear discriminant function, quadratic discriminant function, neural network, genetic neural network, and hierarchical tree models with successful classification ranging from 70 to 100% depending on commodity and model. Effects of Oregon sub-regional and variety classification were investigated with similar success rates.

iii. Pilgrim et.al[46]

Pilgrim et.al (2008) undertook a study to determine the provenance of tea using the intra-element association pattern of its trace element and stable isotope signatures. A total of 103 samples from four different countries and from the commercial sector were examined. Solution based ICP-MS and isotope ratio mass spectrometry (IR-MS) techniques were used for the analysis of tea samples. The application of linear discriminant analysis (LDA) of the isotope ratios and mineral concentrations permitted 97.6% correct classification of the tea samples using the following variables δD, δ^{13}C, ^{49}Ti, ^{53}Cr, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{71}Ga, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{93}Nb, ^{111}Cd, ^{133}Cs, ^{138}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{153}Eu, ^{203}Tl, ^{208}Pb and ^{209}Bi.

iv. Watling et.al[5]

Watling et.al (2010) performed a study to determine the provenance of selected food and drink materials, such as pork, wine, tea, coffee and olive oil. Quantitative determination of up to 55 elements was undertaken using solution based ICP-MS and ICP-AES, while counts per second data for 49 elements was used for samples analyzed using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). LA-ICP-MS was used for the direct analysis of olive oil and coffee beans. Additional information, to establish more detailed geographic resolution in provenance determination, especially for tea and coffee (plantation of origin), was provided by the incorporation of data for light stable isotope distribution patterns (^{2}H (D), ^{13}C and ^{15}N). Results from the overall study indicated that it was possible not only to establish country of origin of the study materials, but also in some cases to improve resolution of provenance to state of origin (wine and pork), and even plantation of origin (tea and coffee).

v. Lo Feudo et.al[40]

Lo Feudo et.al (2010) investigated the origin of tomatoes and triple concentrated tomato pastes through multi-element determination. The concentration of 32 elements (Al, As, Ba, Be, Ca, Cd, Ce, Cu, Dy, Fe, K, La, Lu, Mg, Mn, Na, Nd, Pb, Rb, Sm, Sr, Th, U, V and Zn) was determined in tomatoes harvested in four different Italian regions and in triple concentrated tomato paste samples coming from Italy, China, Greece and the USA. The closed-vessel microwave digested samples were diluted and analyzed by DRC-ICP-MS with CH_4 as reaction gas. The resulting multi-element profiles were processed using three chemometric techniques to evaluate the possibility of discrimination between different cultivation areas. The accuracy of the proposed method was considered acceptable (values in the range 75-120%) for 25 out of the 35 elements of the reference material NCS ZC85006 Tomato. The origin of tomato fruits and the areas of production as “Italy” and “non-Italy” of the triple concentrated pastes were evaluated by three supervised pattern recognition procedures, linear discriminant analysis (LDA), soft independent modeling of class analogy (SIMCA) and K-nearest neighbors (KNN). In this case, excellent results were achieved by all models and, in particular, the KNN method correctly classified all samples for both categories “Italy” and “non-Italy”.

vi. Martin et.al[42]

Martin et.al (2012) commenced a study to establish provenance and regionally distinguish Australian wine. The analysis of 1397 wines samples from 51 different regions, 39 grape varieties and 19 vintages, was undertaken using solution based ICP-MS and ICP-AES to determine the concentration of 56 elements. Interpretation of the data using LDA indicated that, within red and within white wines, the vintage and grape variety had little effect on the multi-element composition of the wine, although significant differences were observed between red and white wines. Wine growing regions from within different Australian states were generally easily discriminated, and good discrimination was typically observed between regions from within the same state.

vii. Pellerano et.al[52]

Pellerano et.al (2012) carried out a study to determine the provenance of multi-floral Argentine honeys from its trace elements composition. The concentrations of 14 trace elements (Br, Ce, Co, Cr, Cs, Eu, Fe, La, Rb, Sb, Sc, Sm, Th and Zn) was determined in 120 samples of light coloured honeys from the provinces San Luis, La Pampa and middle Argentina. Instrumental neutron activation analysis was used to determine the trace element composition. The elemental composition was used in multivariate statistical analysis to discriminate the honeys according to geographical origin. Results indicated that elemental analysis provides a good prospect for discriminating honeys by regions, even if the element composition is not dependent on the year of harvest. Eight key variables (Ce, Cr, Cs, Fe, La, Sb, Sc and Zn) were identified using LDA as providing the maximum discrimination between samples according to their provenance.

viii. Valentin & Watling[48]

Valentin & Watling (2013) undertook a study to determine the provenance establishment of coffee. Coffee samples from 15 countries across five continents were analyzed to determine the concentrations of 59 elements using solution based ICP-MS and ICP-AES. Data confirmed that the harvest year, degree of ripeness and whether the coffees were green or roasted had little effect on the elemental composition of the coffees. The application of linear discriminant analysis (LDA) and principal component analysis (PCA) of the elemental concentrations permitted up to 96.9% correct classification of the coffee samples according to their continent of origin. When samples from each continent were considered separately, up to 100% correct classification of coffee samples into their countries, and plantations of origin, was achieved.

1.5.2 Lack of Research with respect to Seafood

Multi-element analysis using hyphenated Inductively Coupled Plasma methods has not been tested to any significant extent in seafood. Most of the research and development in seafood has focussed on DNA testing for fish substitution. In North America,[57] Europe[58] and South Africa,[59] DNA sequencing of a standardized region of the cytochrome c oxidase I (COI) gene has been used to evaluate the incidence of fish species substitutions with a success rate of over 90%.

In this thesis it is hypothesized that trace element inter-relationships, which facilitate the provenance establishment of a range of other foodstuffs,[5,31,36-55] could be applied to barramundi to develop a robust method for their provenance. While DNA technology has been successfully used to differentiate Australian barramundi from overseas counterparts, it has failed to differentiate barramundi grown around Australia.[60] In the future, it is anticipated that barramundi samples from Australia may be taken to South-East Asia, farmed under less regulated conditions, shipped back to Australia and sold at a cheap price to consumers as Australian barramundi, which will negate that method of provenance identification. In such a scenario there is a high probability that the DNA technology may fail to correctly identify provenance, but trace element signature technology will be successful because this form of provenancing is based on where the individual is grown and not where it came from. Thus to stay one step ahead of fraudsters, it is increasingly necessary to develop the methodologies that could not only help forensic scientist to solve current problems, but also anticipated future problems.

1.6 Aims of the Research

The objective of this study is to determine the possibility of provenancing barramundi from its trace element composition to help in cases of food substitution and mislabeling.

i. **To determine if it is possible to provenance barramundi from different geographical locations on the basis of trace element profiles.**

This study will be the first to determine if it is possible to provenance barramundi on the basis of its trace element composition. A methodology successfully applied to a wide range of other foodstuffs will be applied to barramundi.

ii. **To establish provenance of Australian and overseas barramundi on the basis of site specific variations in their trace element profiles.**

If the development of this methodology is successful, then it would be possible to provenance barramundi from Australia as well as overseas on the basis of their site specific variations.

iii. **To establish a methodology to determine the site specific provenance of Australian barramundi.**

To develop a methodology (chemical fingerprinting and statistical/chemometrical interpretation of data) that would allow the provenancing barramundi from around Australia.

CHAPTER TWO

BARRAMUNDI SPECIES: BIOLOGY, FISHERIES AND THREATS

2.1 Introduction

Barramundi (*Lates calcarifer*) has a national and international reputation as a highly economical and commercial fish species, with the finest eating qualities.[61] Barramundi is also a highly prized game fish. Barramundi is an Aboriginal word meaning "large-scaled river fish" and it is commonly known as the Asian sea bass, or giant sea perch, in countries outside of Australia. This species is widely distributed throughout the East Indian Ocean, Western Central Pacific, Japanese Sea, Papua New Guinea, Northern Australia and also westward to East Africa **(Figure 2.1)**.[62] Within Australia its range extends from the Noosa river in South-East Queensland northwards around the entire northern coast to Ashburton River in Western Australia **(Figure 2.1)**.[63]

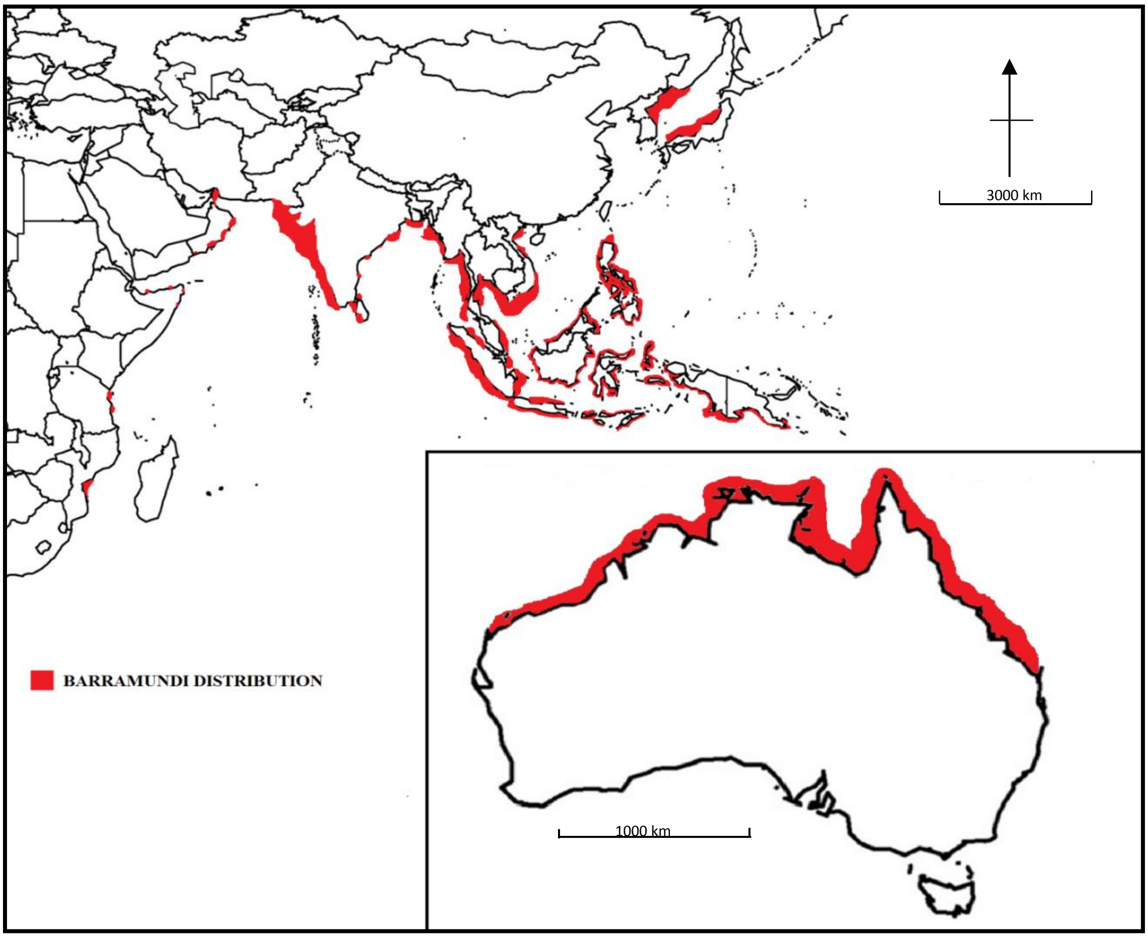


Figure 2.1 Geographical distribution of barramundi (*Lates calcarifer*).[62] (Inset) Barramundi distribution in Australia.[63]

2.2 Taxonomy, Morphology, Life History

Barramundi is a large centropomid fish originally classified as belonging to the family Centropomidae, subfamily Latinae, but have since been reclassified as belonging to the family Latidae.[64] The body of the barramundi is elongate and laterally compressed, with a relatively large, slightly oblique mouth and a protruding mandible that extends back beyond the eye.[65] The head profile is concave. The lower edge of the pre-operculum is serrated with a strong spine; the operculum has a small spine and a serrated flap above the origin of the lateral line. The scales are ctenoid having comb-like ctenii (spines) on the margin of each scale.[65] The first dorsal fin bears 8-9 spines and 10-11 soft rays. The ventral fins have spines and soft rays; the paired pectoral and pelvic fins have soft rays only; and the caudal fin has soft rays and is rounded **(Figure 2.2)**.[65]

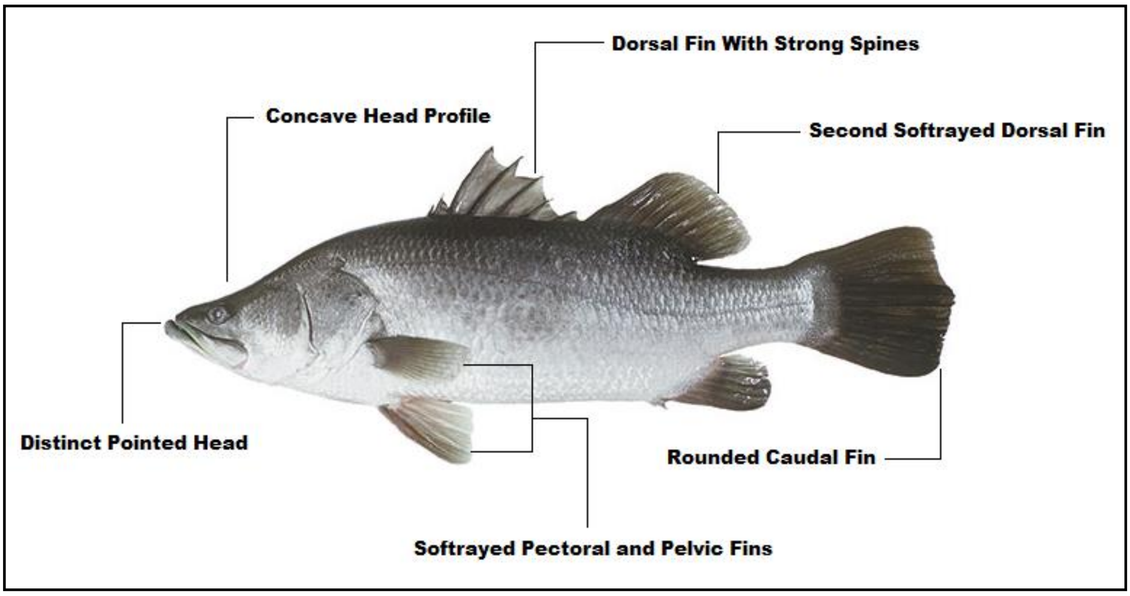


Figure 2.2 Distinct morphological features of barramundi (*Lates calcarifer*).[65]

Barramundi are tropical euryhaline fish that can tolerate a wide range of salinity levels and inhabit freshwater, brackish and marine habitats, including rivers, streams, lakes, billabongs, estuaries and coastal waters.[66] They display a catadromous life history strategy, where juveniles spend the beginning of their lives (2-3 years) in freshwater bodies (such as rivers and lakes) that are connected to the sea. They migrate to a brackish or marine environment to breed at 3-4 years of age.[67-69] Barramundi are protoandrous hermaphroditic and begin their lives as males, changing sex to females at a weight of approximately 5 kg.[70] Barramundi are predatory carnivores and feed on live prey such as fish and prawns. They can reach up to 1.8 m in length, weigh up to 60 kg, and live for over 25-30 years.[69,71] The timing of the spawning season of barramundi varies depending on geographic location. In Australia, barramundi generally spawn between September and March, with two spawning peaks in November-December and February-March.[72] During the spawning season, spawning takes place at night, generally at or after dusk, and appears to be related to the lunar cycle; the greatest activity occurs on nights following the full and new moons.[70] Barramundi are highly fecund and a large female (>120 cm TL) can produce several million eggs per spawning season. They are also pelagic spawners with eggs and sperm being broadcast into the water column for external fertilisation.[63]

2.3 Fishery

Barramundi are economically and socially important for both commercial and recreational fisheries, and in aquaculture.

2.3.1 Commercial Wild Capture

Barramundi species are fished commercially across most of the Indo-Pacific region. Globally, commercial fishing of this species has increased steadily since 1950 and in 2012 stood at 93,408 tonnes with Indonesia capturing 95% (88,338 tonnes) of this wild catch.[62] In Australia, the barramundi capture fishery is relatively small by world standards with an annual catch of just over 2,000 tonness.[62] The Australian fishery is governed by a range of operational restrictions that vary depending on individual State and Territory regulations. Common regulations include seasonal and area closures, gear restrictions, size restrictions on fish that can be taken.[73] Despite these restrictions, the total wild catch and its value in Australia has increased. In 2009/2010 the wild catch was 1658 tonnes and in 2011/2012 this increased to 2259 tonness.[74] Over this period, the value of the catch increased from AU$13 million to AU$ 18 million.[74]

2.3.2 Recreational Fisheries

Barramundi is a recognized game fish under the International Game Fishing Association rules[61] and is highly prized by recreational fishers and trophy hunters alike for its eating and angling qualities. In Australia, recreational fishing is a popular pastime and the expansion of recreational fishery for barramundi is being facilitated by the development of tourist infrastructure and improvement in access to remote localities. Fishing charter and safari operations, aimed primarily at barramundi, have increased significantly in northern Australia in recent years.[66] Recreational fishing for barramundi is of significant economic importance in parts of Australia. Recent surveys suggesting that the harvest by this sector is approximately 303 tonnes, (251 tonnes in the Northern Territory, 51 tonnes in Queensland and 1 tonne in Western Australia).[75-77]

2.3.3 Aquaculture

Aquaculture production of barramundi began in Thailand in the 1970s[78] and has since spread rapidly to other countries in Southeast Asia and Australia, thereby becoming an important aquaculture species in these regions.[79] Barramundi is an ideal candidate for aquaculture because it is a relatively hardy species that can tolerate crowded conditions and handling, and thrive in a wide range of physiological and environmental conditions, including high turbidity, and varying salinities and temperatures. Hatchery production of barramundi seed is relatively simple, and the female is highly fecund and provide plenty of material for hatchery production. Also, barramundi feed readily and grow rapidly on pelleted diets, reaching a harvestable size (350g-5kg) in six months to two years.[65] Recently, barramundi has been farmed in a range of countries, such as Indonesia, Malaysia, Singapore, Philippines, Brunei, Hong Kong, PR China, Thailand, Taiwan, Saudi Arabia, Iran, Guam, French Polynesia Israel and the USA.[65,78] Global aquaculture production of barramundi species from 2002 to 2012 based on Food and Agriculture Organization of the United Nations (FAO)[80] is shown in **Table 2.1.** The global production of barramundi in aquaculture is rapidly rising and has increased almost 300% from 2002 (25,194 tonnes) to 2012 (75,405 tonnes), with the top three producers being Taiwan (26,148 tonnes), Malaysia (20,089 tonnes) and Thailand (17,146 tonnes).[80]

Table 2.1 Global barramundi aquaculture production from 2002 to 2012 based on FAO[80] barramundi data.

Year	Quantity (tonnes)	Value (USDx1000)
2002	25,194	64,426
2003	28,698	96,826
2004	28,888	74,375
2005	31,388	84,045
2006	32,524	100,673
2007	34,801	117,027
2008	43,585	159,018
2009	49,172	165,964
2010	67,095	276,339
2011	68,949	310,722
2012	75,405	338,004

2.4 Australian Barramundi Aquaculture Industry

The barramundi aquaculture industry in Australia had its beginnings in Queensland in the late 1980’s when the Department of Primary Industries established a research programme aimed at adapting Thai culture techniques for Australian conditions.[66] Eggs for the programme were initially sourced from wild stocks and the larvae grown to fingerling size in the hatchery using intensive culture techniques.[81] The production technology for barramundi has since developed, and eggs are now sourced from captive broodstock, and both extensive and intensive systems are used for larval rearing.[73]

At present, commercial barramundi farms operate in all Australian mainland states and the Northern Territory. Farming methods used include land based ponds and raceways, open ocean sea cages, marine based sea cages, and recirculation aquaculture systems.[82] In northern regions where barramundi are endemic, the majority of commercial farmed production is land based in open fresh-and brackish-water ponds, as well as in saltwater flow-through concrete raceway systems. In southern climates outside the barramundi’s natural thermal range, production occurs in fully and semi-enclosed recirculating aquaculture systems, some of which utilize naturally occurring geothermal spring water to meet heating requirements.[82] Since its emergence in the late 1980’s, the Australian barramundi industry has experienced significant yearly growth in both production quantity and profits **(Table 2.2)**.

Table 2.2 Barramundi aquaculture production in Australia from 2002 to 2012, based on Australian Fisheries Statistics 2012.[74]

Year	Quantity (tonnes)	Value (USDx1000)
2002	1,150	5,397
2003	1,750	10,483
2004	1,517	9,888
2005	1,775	11,876
2006	2,249	14,028
2007	2,632	20,062
2008	3,361	29,085
2009	2,966	25,054
2010	3,628	29,449
2011	4,352	36,882
2012	4,498	42,530

Based on recent investigations the industry consists of approximately 100 licensed farmers producing 4,498 tonnes of products with an estimated value of US$ 42.5 million.[74] Production has increased 390% from 2002 (1,150 tonnes) to 2012 (4,352 tonnes), with Queensland being the highest producer (2,416 tonnes) followed by Western Australia (1,127 tonnes) and the Northern Territory (881 tonnes).[74]

The Australian industry is small, but technologically advanced compared to its Southeast Asian counterparts. The industry accounts for only approximately 6% of global farmed barramundi volume, but 13% of global value, reflecting the strong consumer preference and willingness to pay a premium for this Australian product.[82] The industry is expected to continue to expand in the future, with growth coming from existing farms and new entrants into the industry.[61]

2.5 Fraud and Threats to the Australian Barramundi Industry

Barramundi has an established reputation as one of Australia's finest eating fish. A recent market survey conducted in 2010 by the industry highlighted that Australian barramundi has a firm white flesh, succulent fine grained texture, and mild flavour.[83] It is also low in fat and cholesterol, high in protein, and contains significant quantities of the Omega 3 and Omega 6 fatty acids.[83] However, barramundi’s reputation as one of Australia’s premium fish has been the catalyst for fraud involving substitution by cheaper fish. Mislabeling and substitution can be intentional or accidental. The true extent of fish mislabeling is only now becoming apparent, and it is predicted to increase in the near future because of increasing consumer demand for seafood. Wholesalers, restaurants, supermarkets and fishmongers may rename or substitute fish species in order to achieve a higher sale price, or to meet consumer demand for a particular species.[25,84] In Western Australia, mislabeling of barramundi, which is an offence under the Health Act,[85] has been suspected for many years.[86] Surveys in other regions in Australia have revealed extensive mislabeling, for example a survey by the Australian Consumers’ Association found that 22% of fish in 30 restaurants and 30% in 12 high turnover retail shops were incorrectly labelled.[87] A survey in Victoria found that up to 75% of premises selling fish claimed to be barramundi had falsely labelled the fish.[88] As recent as 2005, a retailer in Sydney was fined $3,000 for selling imported Nile perch fillets to customers who thought they were buying the more expensive barramundi.[89] A pilot survey[25] on the identity of fish species sold through food outlets in Australia concluded that 13% of barramundi tested were mislabeled.[25]

Barramundi farming in Australia is also coming under increased pressure from cheaper imported barramundi (Asian sea bass) from South East Asia. The barramundi aquaculture industry in Australia, in conjunction with wild fishery, accounts for approximately 33% of the domestic product. The other 67% of barramundi product consumed in Australia is imported, primarily from Thailand and Taiwan.[82] Up to 8,000 tonnes of barramundi are imported to a range of countries from South East Asia each year. Production in these countries is cheap and less regulated, which is directly reflected in its low quality.[90] Australian barramundi is iconic and consumers consider it to be a premium, great tasting, appealing and authentic fish. While the high quality of Australian barramundi ensures it is popular and on tourist menus throughout Australia, once a consumer has had a negative experience, because of the inferior quality of a substituted product, it may be very difficult to get them to try it again. Thus it is necessary for Australian producers to implement systems of differentiation between Australian and overseas product, and to promote their product against their competitors.[90]

CHAPTER THREE

MATERIALS & METHODS

3.1 Materials

Barramundi samples for this study were acquired from various commercial fisheries and wholesalers across Australia. A list of all the barramundi samples obtained for the entire study is shown in **Table 3.1**. The samples were stored as frozen fillets or frozen whole fish.

Table 3.1 Barramundi samples used in these study.

Source	Number of Fish	Origin
Gulf of Carpentaria	12	Gulf of Carpentaria, Queensland, Australia
Australis Barramundi	18	Turners Falls, Massachusetts, USA
Taiwan Fish	6	Unknown site, Taiwan
Pejo Enterprises	13	Innisfail, Queensland, Australia
Robarra	28	Wingfield, South Australia, Australia
King Reef	15	Cowley, Queensland, Australia
Good Fortune Bay	15	Bowen, Queensland, Australia
Cone Bay	30	Cone Bay, Western Australia, Australia
Indonesia Fish	46	Unknown site, Indonesia
New Zealand Fish	28	Unknown site, New Zealand
Taiwan Fish (2)	12	Unknown site, Taiwan
“Unknown Taiwan Fish”	8	Unknown site, Taiwan
“Unknown Australian Fish”	8	Unknown site, Australia

The study was divided into two investigations. The first involved the analysis of ventral muscle in a series of 36 fish from Taiwan, USA and The Gulf of Carpentaria (**Table 3.1**). A preliminary investigation using fish from three geographically disparate countries was undertaken to establish if it was possible to associate the trace element assemblage from the individual groups of fish with their provenance. This investigation was necessary because if provenance establishment was not possible with these disparate, samples then it would not be feasible to undertake a more detailed study. For the initial investigation, a single sample of ventral muscle was used.

During the sampling of whole fish it was noticed that the dorsal muscle was slightly darker and less homogenous in colour than the ventral muscle. Consequently, it was decided, as part of the initial investigation, to determine if there were any elemental differences between dorsal and ventral muscle using dissected dorsal and ventral muscle from a single fish from each of four different sites (Innisfail, Queensland; Wingfield, South Australia; Indonesia and New Zealand). It was considered advisable to undertake this investigation because if this difference in color represented a variation in the trace element chemistry of the two types of muscle, not knowing which muscle was being used in a "real" study could lead to unrepresentative data being produced and potentially compromise accurate provenance identification.

Following this study (in which there appeared to be no significant difference between the trace element assemblage of dorsal and ventral muscles) the main investigation was undertaken where samples of ventral muscle were analyzed from a much larger (national and international) fish population. This study was followed by a "blind trial" of the methodology protocol by investigating the potential for the methodology to be used to determine the provenance of eight "unknown" Taiwanese and eight "unknown" Australian fish purchased from the Woolworths Supermarket in Bullcreek, Perth, Western Australia.

3.2 Analytical Techniques

Inductively Coupled Plasma Mass Spectrometry (ICP-MS)[5,42-46,48] and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)[5,36,42,45,47,48] are two of the modern analytical techniques commonly employed for the quantitation of trace element concentrations in food and food products. These techniques are highly sensitive and can be used to accurately determine a wide range of analytes. Furthermore, ICP-MS and ICP-AES have been successfully combined for dual analysis[5,42,44,45,48] to determine a wider range of analytes of interest.

ICP-MS and ICP-AES instruments have a common ionization source known as Inductively Coupled Plasma (ICP) which when coupled to these instruments allows researchers to undertake quasi-simultaneous multi-element analysis (ICP-MS) and simultaneous multi-element analysis (ICP-AES).[32] For analysis using ICP-MS and ICP-AES, the sample must first be in solution from where it can be nebulized in an argon gas stream.[90,91] The nebulized sample is then introduced into a spray chamber where particles greater than approximately 2μm in diameter are removed and drained to waste. The remaining smaller particles are introduced into the plasma via the innermost quartz tube of the plasma torch and passed through the centre of the plasma itself where the analyte particles are broken up and ionized.[91,92] In the case of ICP-MS, the ionized analytes enter the mass spectrometer through a series of two holes in either nickel or platinum cones and from there into the ion lenses contained in the main body of the spectrometer. The ion lenses focus the ions into a beam which enters the quadrupole mass analyzer where they are separated on the basis of their mass to charge ratio *(m/z).* These separated ions are then sampled using a mass detector, often a discrete dynode type, where the frequency of ion collision with the detector elements results in an electrical charge that can be measured and quantified.[91-94] The signal for each *m/z* ratio is proportional to the mass of the individual analyte present in the sample and quantitation is achieved by comparison of this signal to equivalent signals produced by the analysis of calibration standard solutions.[93-94] The components of an ICP-MS instrument are shown in **Figure 3.1**.

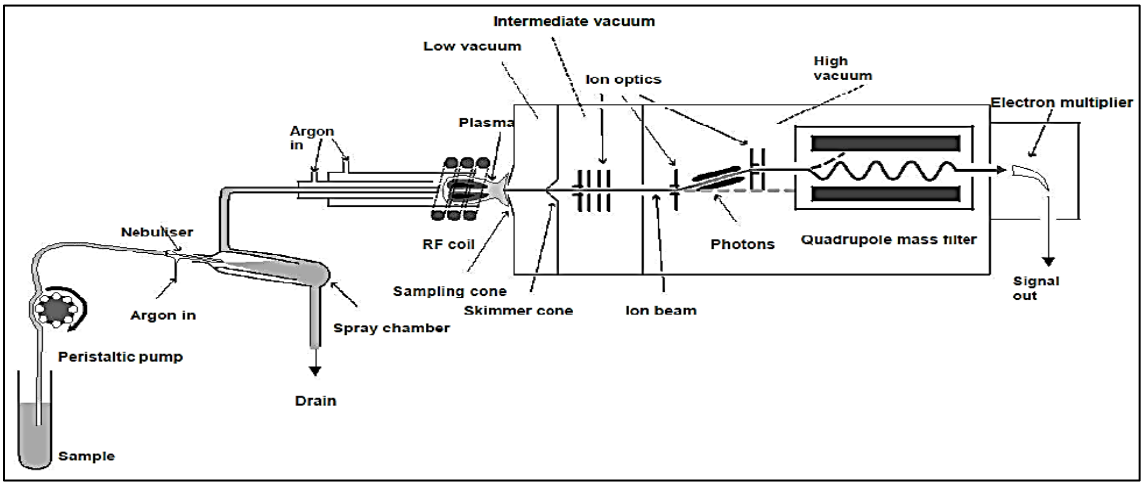


Figure 3.1 Schematic diagrams of the major components of an ICP-MS instrument. Reproduced from Linge and Javis.[94]

For AES, the light emitted from excited ions and atoms returning to less excited states, in the region of the plasma above the induction coils, is recorded using a detector.[92,95] As energy is lost in the region of the plasma above the induction coils, excited atoms and ions return to their stable and meta-stable states and emit characteristic wavelengths of light that are separated using an Eschelle Polychromator and detected using one of a variety of possible electron multiplier based devices depending on the manufacturer of the instrument.[92,95] This measurement is then converted into an elemental concentration by comparing the counts per second data for the calibration standards with equivalent data for samples.[92] The major components of an ICP-AES instrument are shown in **Figure 3.2**.

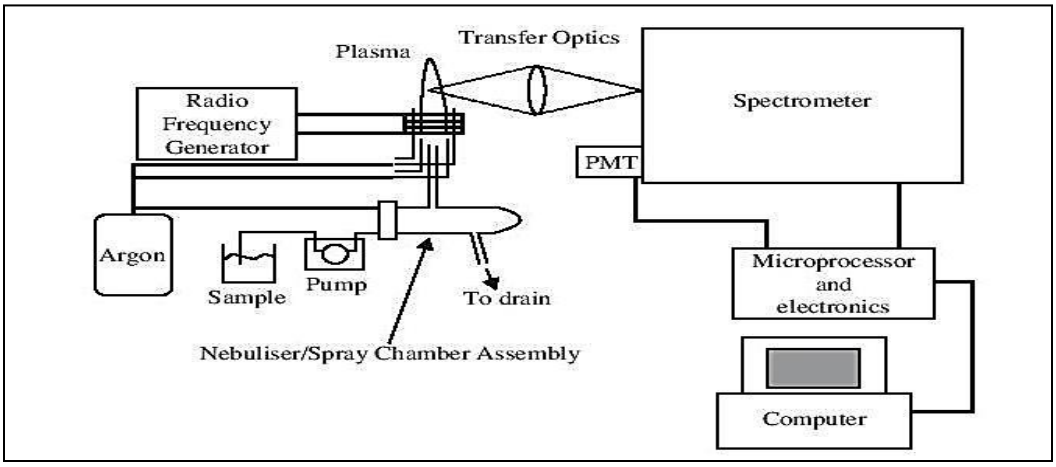


Figure 3.2 Schematic diagrams of the major components of an ICP-AES instrument. Reproduced from Hill et al.[96]

3.3 Sample Dissolution and Analysis for Solution Based ICP-MS and ICP-AES

3.3.1 Sample Preparation

All barramundi samples were defrosted and whole fish were filleted prior to analysis. In the initial investigation, Samples were taken from the ventral muscle of thirty six fish, taking care to sample only bulk protein. In all cases the mass of the sample taken was approximately 2g and was recorded to three decimal places. For the investigation into any potential variation between the elemental composition of dorsal and ventral muscle, one dorsal and one ventral muscle sample (2g accurately recorded to three decimal places) was taken from each of four fish. In the more detailed investigation, 187 samples of approximately 2g mass were taken from the ventral muscle of an equivalent number of fish, again taking care to sample only bulk protein.

The barramundi samples were accurately weighed and placed into 50 mL polyethylene screw topped tubes. Approximately 10 mL of nitric acid (HNO_3) (Ajax Finechem, NSW, Australia, sub-boiling quartz still redistilled) were added to each sample and the mixture left to react overnight at room temperature with the tube lids resting loosely on top of the tubes. After this time, 2 mL of hydrogen peroxide (H_2O_2) (Univar, AR, 30%) were added to each tube and the tubes were transferred to a water bath, and suspended in water at approximately 90^{o}C for a further 12 hours to ensure complete digestion of the barramundi protein. The mouths of the tubes were loosely closed with the original tube tops to provide limited reflux of acid vapours. After 12 hours the tops of the tubes were removed and the mixture was allowed to evaporate to a volume of approximately 2 mL. Finally, approximately 20 mL of 18MegΩ deionized water were added to the mixture and the samples stored prior to ICP-MS and ICP-AES analysis.

Triplicate samples of two Certified Reference Materials (CRMs) from National Research Council Canada, DORM-4 (Fish protein certified reference sample) and DOLT-5 (Dogfish liver certified reference material) were included in each acid digestion batch. Approximately 0.5g of each CRM underwent the same acid/peroxide digestion procedure as the barramundi samples. Three analytical blanks, which had been taken through the entire digestion procedure, were also included in each digestion batch.

3.3.2 Elemental Analysis

All prepared solutions were analyzed using solution based ICP-MS (7500CS, Agilent Technologies, Tokyo, Japan) and solution based ICP-AES (iCAP 6500, Thermo Fisher Scientific Inc., North Ryde New South Wales, Australia). An average set of operating parameters for ICP-MS and ICP-AES analysis are shown in **Table 3.2**.

Table 3.2 Generalized operating parameters for Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) analysis.

Parameter	ICP-MS	Parameter	ICP-AES
RF Power	*1500 W*	**RF Power**	*1500 W*
Carrier Gas Flow	*1.02 L/min*	**Auxiliary Gas Flow**	*0.8 L/min*
Auxiliary Gas Flow	*0.9 L/min*	**Nebulizer Gas Flow**	*0.60 L/min*
Nebulizer Pump	*0.13 rps*	**Coolant Gas Flow**	*12 L/min*
Interface Cones	*Platinum*	**Flush Pump Rate**	*100 rpm*
Omega Bias	*-50 V*	**Analysis Pump Rate**	*70 rpm*
Omega Lens	*10.5 V*	**Pump Stabilization Time**	*10 seconds*
Cell Entrance Aperture	*-40 V*	**Peristaltic Pump Tubing**	*PVC 0.76 mm diameter*
Cell Exit Aperture	*-52 V*	**5% v/v HNO_3 Rinse Time**	*15 seconds*
Plate Bias	*-43 V*	**Sample Flush Time**	*25 seconds*
Helium Gas Flow	*0 mL/min*	**Maximum Integration Time**	*30 seconds*
Octapole RF	*160 V*		
Octapole bias	*-11 V*		
Quadrupole	*-6 V*		
5% v/v HNO_3 Rinse Time	*20 seconds*		
Sample Flush Time	*25 seconds*		
Integration Time	*0.1 seconds*		

A total of 57 elements were determined using solution based ICP-MS and a total of 12 elements were determined using solution based ICP-AES. Elemental isotopes determined using solution based ICP-MS are shown in **Figure 3.3**, while the wavelength of analytes determined using ICP-AES are shown in **Figure 3.4** respectively.

$^{7}\mathrm{Li}$	$^{9}\mathrm{Be}$											$^{11}\mathrm{B}$					
												$^{27}\mathrm{Al}$					
		$^{45}\mathrm{Sc}$	$^{49}\mathrm{Ti}$	$^{51}\mathrm{V}$	$^{53}\mathrm{Cr}$	$^{55}\mathrm{Mn}$	$^{57}\mathrm{Fe}$	$^{59}\mathrm{Co}$	$^{28}\mathrm{Ni}$	$^{65}\mathrm{Cu}$	$^{66}\mathrm{Zn}$	$^{71}\mathrm{Ga}$	$^{74}\mathrm{Ge}$	$^{75}\mathrm{As}$	$^{77}\mathrm{Se}$		
$^{85}\mathrm{Rb}$	$^{88}\mathrm{Sr}$	$^{89}\mathrm{Y}$	$^{90}\mathrm{Zr}$	$^{93}\mathrm{Nb}$	$^{98}\mathrm{Mo}$		$^{101}\mathrm{Ru}$		$^{108}\mathrm{Pd}$	$^{109}\mathrm{Ag}$	$^{111}\mathrm{Cd}$	$^{115}\mathrm{In}$	$^{120}\mathrm{Sn}$	$^{121}\mathrm{Sb}$	$^{126}\mathrm{Te}$		
$^{133}\mathrm{Cs}$	$^{138}\mathrm{Ba}$		$^{178}\mathrm{Hf}$	$^{181}\mathrm{Ta}$	$^{182}\mathrm{W}$						$^{202}\mathrm{Hg}$	$^{203}\mathrm{Ti}$	$^{208}\mathrm{Pb}$	$^{209}\mathrm{Bi}$			

$^{139}\mathrm{La}$	$^{140}\mathrm{Ce}$	$^{141}\mathrm{Pr}$	$^{146}\mathrm{Nd}$		$^{147}\mathrm{Sm}$	$^{153}\mathrm{Eu}$	$^{157}\mathrm{Gd}$	$^{159}\mathrm{Tb}$	$^{163}\mathrm{Dy}$	$^{165}\mathrm{Ho}$	$^{166}\mathrm{Er}$	$^{169}\mathrm{Tm}$	$^{172}\mathrm{Yb}$	$^{175}\mathrm{Lu}$
	$^{232}\mathrm{Th}$		$^{238}\mathrm{U}$											

Figure 3.3 Isotopes determined using solution based ICP-MS analysis following acid digestion of barramundi sample.

												$\mathrm{Al}^{396.1}$	$\mathrm{Si}^{251.6}$	$\mathrm{P}^{177.4}$	$\mathrm{S}^{180.7}$		
	$\mathrm{Mg}^{279.5}$																
$\mathrm{K}^{766.4}$	$\mathrm{Ca}^{422.6}$					$\mathrm{Mn}^{257.6}$	$\mathrm{Fe}^{239.5}$				$\mathrm{Zn}^{213.8}$						
	$\mathrm{Sr}^{407.7}$																
	$\mathrm{Ba}^{455.4}$																

Figure 3.4 Elements (together with spectral analytical lines used) determined using solution based ICP-AES analysis following acid digestion of barramundi sample. Analytical wavelength are given in nanometers.

Analytical wavelengths (nm) used for ICP-AES determinations are given as a suffix to the analyte (**Figure 3.4**). Certain duplication of analytes (Al, Mn, Fe, Zn, Sr, and Ba) between techniques was undertaken to facilitate inter-comparison of data between analytical techniques. Data quantitation was achieved with reference to multi-element standards (1, 2, 5 and 10 μgL^{-1} for ICP-MS and 1, 2, 5 and 10 μgmL^{-1} for ICP-AES). Standard solutions were prepared by diluting a 10 μgmL^{-1} stock multi-element standard solution for ICP-MS (AccuTrace, Choice Analytical Pty., Ltd., NSW, Australia) and 1000 μgmL^{-1} stock multi-element standard solution for ICP-AES (AccuTrace, Choice Analytical Pty., Ltd., NSW, Australia). A multi-element standard was run after every 10 samples to facilitate drift correction. However, in all analytical runs drift was less than

+/-2% relative from the first to the last sample and consequently drift correction was not applied.

All samples analyzed using ICP-MS were made up in a solution containing 2µgL^{-1} Rh and Ir, as internal standards to achieve normalization of data with respect to drift and correction of data with respect to any variations in the ionization effects of the matrix. Drift correction using ICP-AES was achieved by running an in-house “bulk sample” every eleven samples and normalizing all data to equivalent analyte data in this standards at the end of the analytical run.

3.4 Data Analysis and Interpretation

Data from all solution analyses from both ICP-MS and ICP-AES determinations were imported into Excel spreadsheets as counts per second. Background correction and internal standard based normalization was undertaken and data compared to equivalent data for the standards to produce concentrations in solution for all analytes. Finally, using the relationship between sample mass and initial solution volume, together with any subsequent dilutions undertaken before analysis, calculations were undertaken to determine the analyte concentrations in each sample. Analytical data for analytes determined using ICP-AES are given in parts per million while those determined using ICP-MS are given in parts per billion. All data analysis and manipulation was carried out using XLSTAT 2014 for Windows Microsoft Office Excel 2010.

3.4.1 Statistical Techniques

Linear Discriminant Analysis (LDA) is commonly used in provenancing studies[5,40,42,44,48,52] because it allows the known geographic origins to be defined in the model.[5] Thus, it was undertaken throughout this study to establish the grouping of the barramundi samples. LDA generates a set of discriminant functions based on linear combinations of the predictor variables that provide the highest group discrimination. The functions are generated from a sample of cases for which group membership is known; the functions can then be applied to new cases that have measurements for the predictor variables, but have unknown group membership, thus allowing the group membership to be predicted. LDA was carried out using the stepwise method in which the model is built step by step. Variables are evaluated at each step; the variable that gives the best discrimination between groups is included in the analysis.[5]

LDA provides a range of statistics associated with the degree to which a sample can be correctly classified. One classification test that can be performed on the data is cross-validation. In this test, each of the known data points is entered into the database as an unknown and the classification for that sample determined according to the functions derived from the remainder of the known variables. The percentage obtained at the end of this (% cross validated cases correctly classified) provides an indication of the number of samples that will be correctly classified in a given dataset.[5]

Following LDA, principal component analyses (PCA) was usually performed using various combinations of elements for each data set in an attempt to further visualize barramundi sample groupings. Unlike LDA, PCA is an unsupervised technique that requires no information from the user regarding actual groupings.[48] PCA allows a multidimensional data set to be plotted in a smaller number of dimensions in order to visualize any structure in the data set. PCA finds the maximum variations in the data and converts this information to create new uncorrelated variables known as principal components.[97] The data is output as a score plot with the PCs plotted against each other. PCA is a powerful visualization tool as it creates natural groupings of the data.[48]

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Preliminary Investigations to Determine Provenance

4.1.1 Feasibility Test

The preliminary study involved the determination of the feasibility of the model to estimate the provenance of barramundi. A total of 36 fish samples from Taiwan, USA, and Gulf of Carpentaria, Australia were taken. As shown in **Figure 4.1**, the samples from three locations were clearly separated geographically. Sample dissolution procedure (as outlined in Chapter Three) were applied to all 36 samples and the concentration of 63 elements was determined using solution based ICP-MS and ICP-AES. Only the ventral muscle of the 36 barramundi samples were considered in the feasibility test. Statistical analysis of the data obtained from solution ICP-MS and ICP-AES analyses were performed in several steps in order to classify the barramundi samples according to their geographic origin.

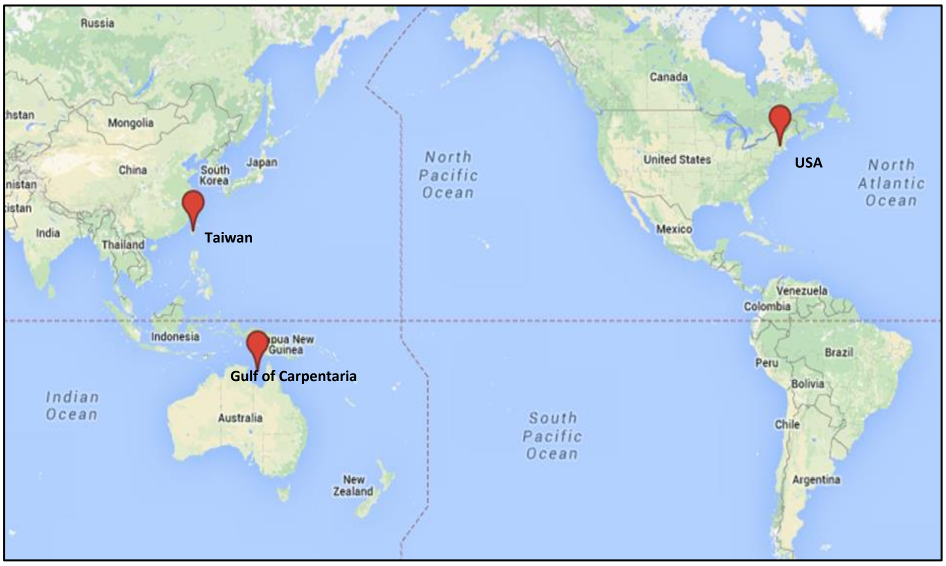


Figure 4.1 A geographical map indicating the location of the three barramundi samples.

4.1.2 Results of the Feasibility Test

4.1.2.1 LDA Separation of Samples

Linear Discriminant Analysis (LDA) was applied to the data in order to classify barramundi samples according to their geographic origin: Taiwan, USA and Gulf of

Carpentaria, Australia. **Figure 4.2** shows the four LDA data plot of data for barramundi samples from the three locations.

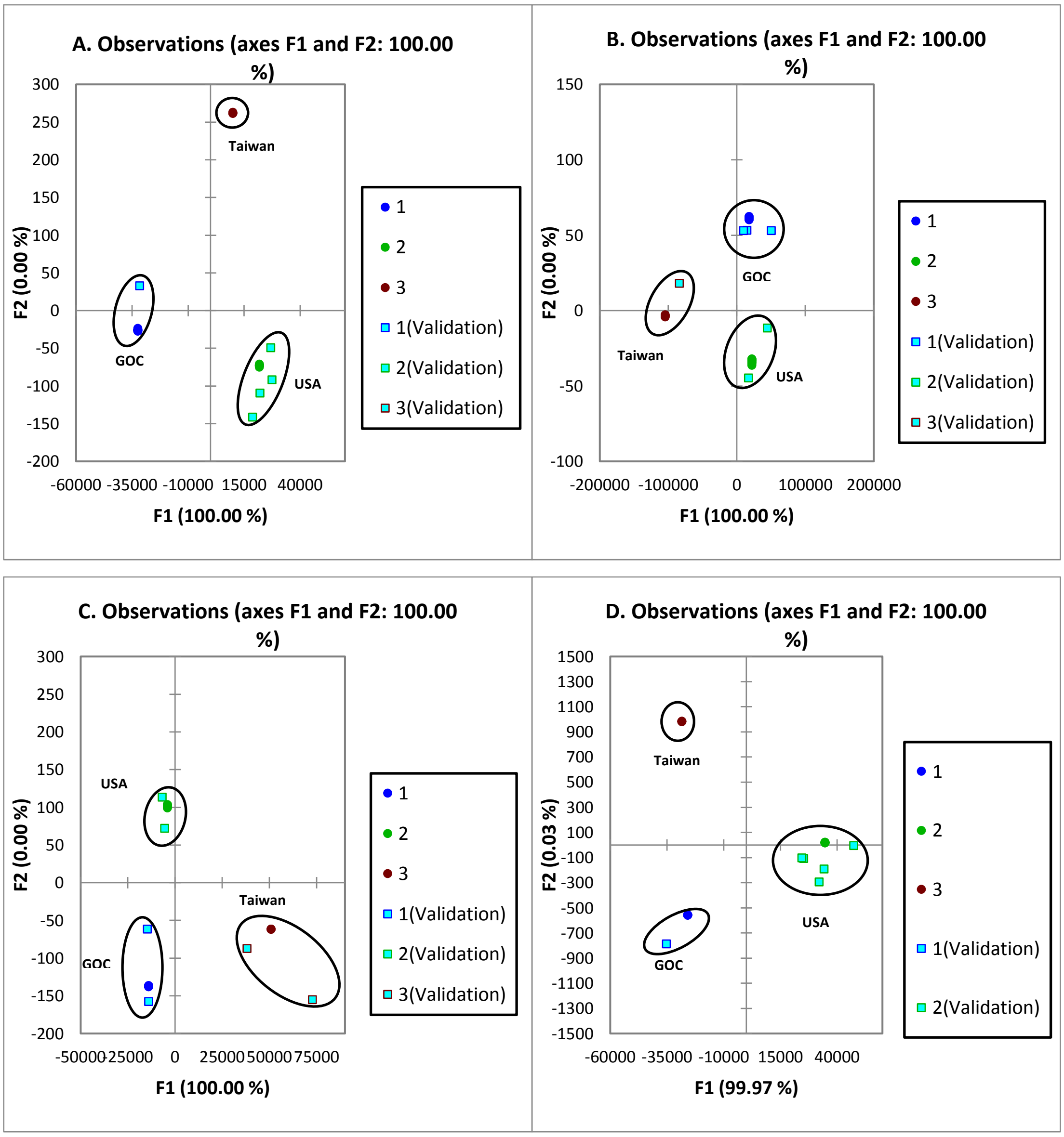
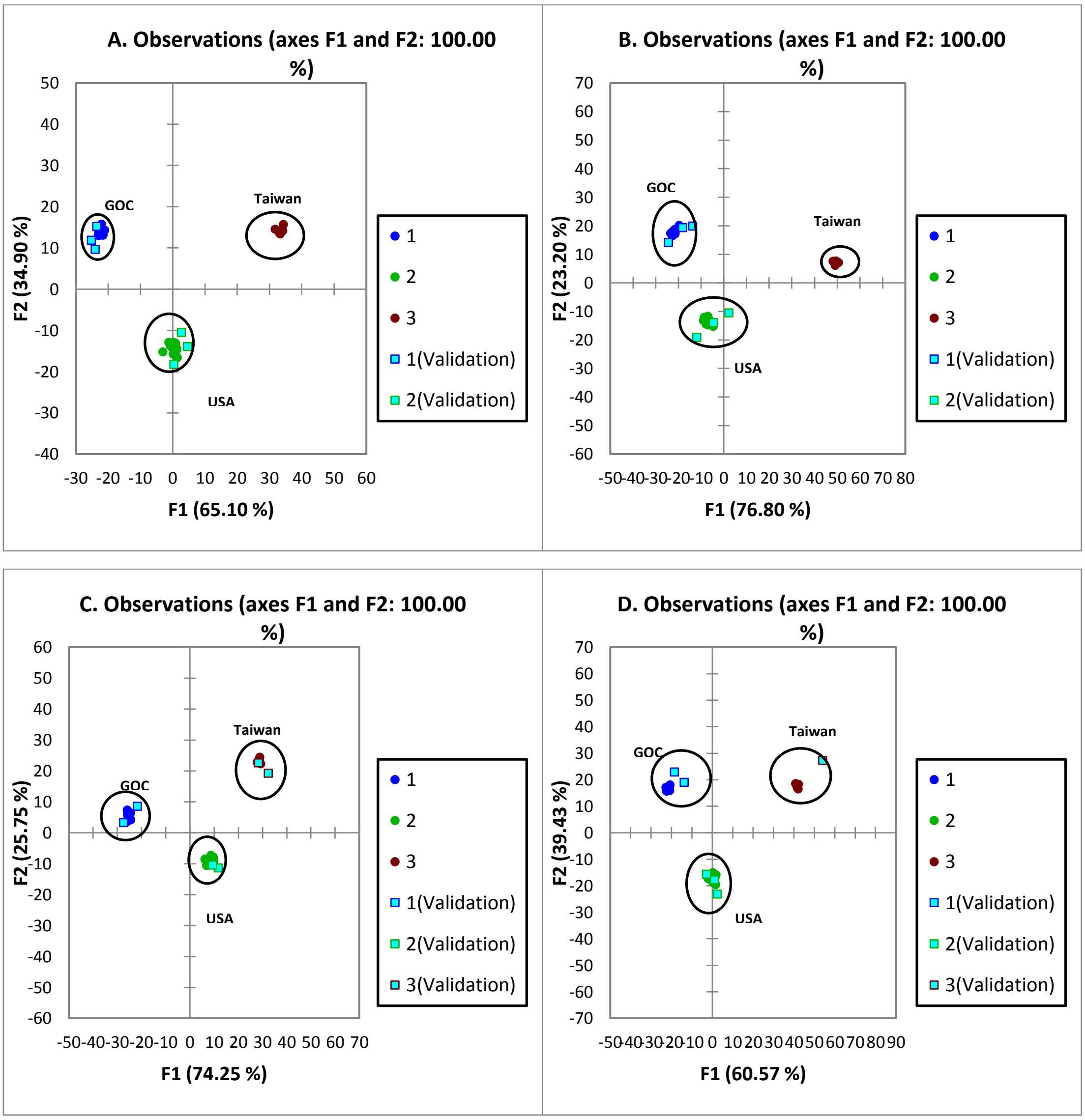


Figure 4.2 Four LDA plot showing the separation of barramundi samples from Gulf of Carpentaria (GOC) (1), USA (2), and Taiwan (3) based on elemental concentrations obtained from acid digestion.

The geographical distribution of samples from the Gulf of Carpentaria, Australia (GOC) (1), USA (2), and Taiwan (3) is detailed in **Figure 4.1** and the LDA data plots in **Figure 4.2**, confirm that their chemical signature allow them to be easily discriminated. This confirms the feasibility of the analytical and interpretive protocols to separate barramundi samples from different origins with high level of accuracy. However, it was still apparent from the LDA plots detailed in **Figure 4.2** that each population still had a reasonable degree of scatter. This could be due to the fact that some analytes were at concentrations at (or near) their detection limit and their incorporation into the LDA resulted in a reduction in population specificity. Consequently a group of 22 analytes (Mg, P, S, K, Ca, Li, B, Al, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Cs, Ba and Hg) that had concentrations significantly above their detection limits, were used to develop a new LDA model to classify barramundi samples according to their geographic origin: Taiwan, USA and Gulf of Carpentaria, Australia; **Figure 4.3** shows the 4 LDA data plot of barramundi samples from the three locations.



A. Observations (axes F1 and F2: 100.00 %)

B. Observations (axes F1 and F2: 100.00 %)

C. Observations (axes F1 and F2: 100.00 %)

D. Observations (axes F1 and F2: 100.00 %)

Figure 4.3 Four LDA plot showing the separation of barramundi samples from Gulf of Carpentaria (GOC) (1), USA (2), and Taiwan (3).

From the LDA data plot in **Figure 4.3**, barramundi samples from Gulf of Carpentaria, Australia (GOC) (1), USA (2), and Taiwan (3) could be distinguished to a much higher level of specificity using the reduced analyte data set than previously determined using the entire 63 analyte matrix.

4.1.2.2 PCA Separation of Samples

In addition to the LDA protocol, PCA was also undertaken for the three sets of data. The PCA plot for all analytes (63) is shown in **Figure 4.4 A**, while a reduced analyte plot of the nine analytes (Mg, P, K, Li, Ti, Fe Rb, Ba and Sn) which were used to give rise to the distinction between the three populations is detailed in **Figure 4.4 B**.

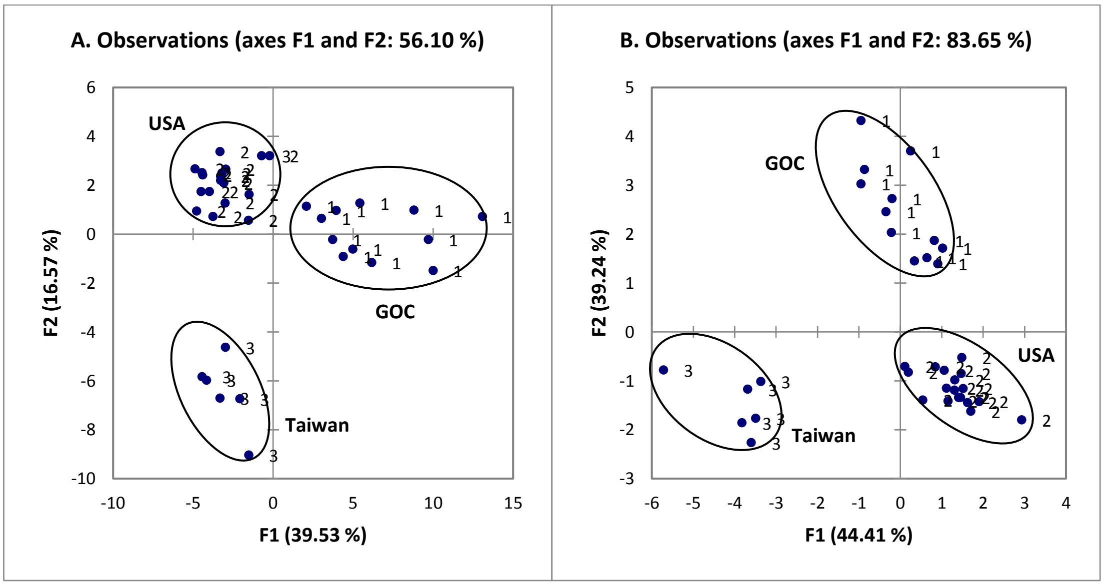


Figure 4.4 A and B PCA plots of three populations of Barramundi; Gulf of Carpentaria (1), USA (2) and Taiwan (3).

The plots in **Figure 4.4 A and B** confirm the LDA plots and identify separate populations for the barramundi from the three continents. From these plots it is obvious that even unsupervised data are capable of being used to provide unambiguous evidence of the differences between populations of barramundi, reared on the three different continents. In addition, it is apparent from the plots that the populations themselves are consistent and therefore the suppliers of the fish have likely obtained their fish from the same source within each country.

However, there is one further extremely interesting aspect of the trace element data. The fish from the Gulf of Carpentaria are relatively high in uranium and thorium **Figures 4.5 A and 4.5 B**; two elements that are significant in the lithology of that region as this is one of the world's most important areas of uranium mineralization. From this data it would appear that weathering of the rocks has transferred soluble uranium compounds into both the sea and estuaries in the areas where barramundi are grown and this uranium has been bio-accumulated by the fish. While the levels of uranium and thorium in the fish are extremely low and do not pose a health threat they do provide two extremely reliable indicator elements for determining the provenance of fish grown in that area; further research will be undertaken to determine the robustness of this discovery.

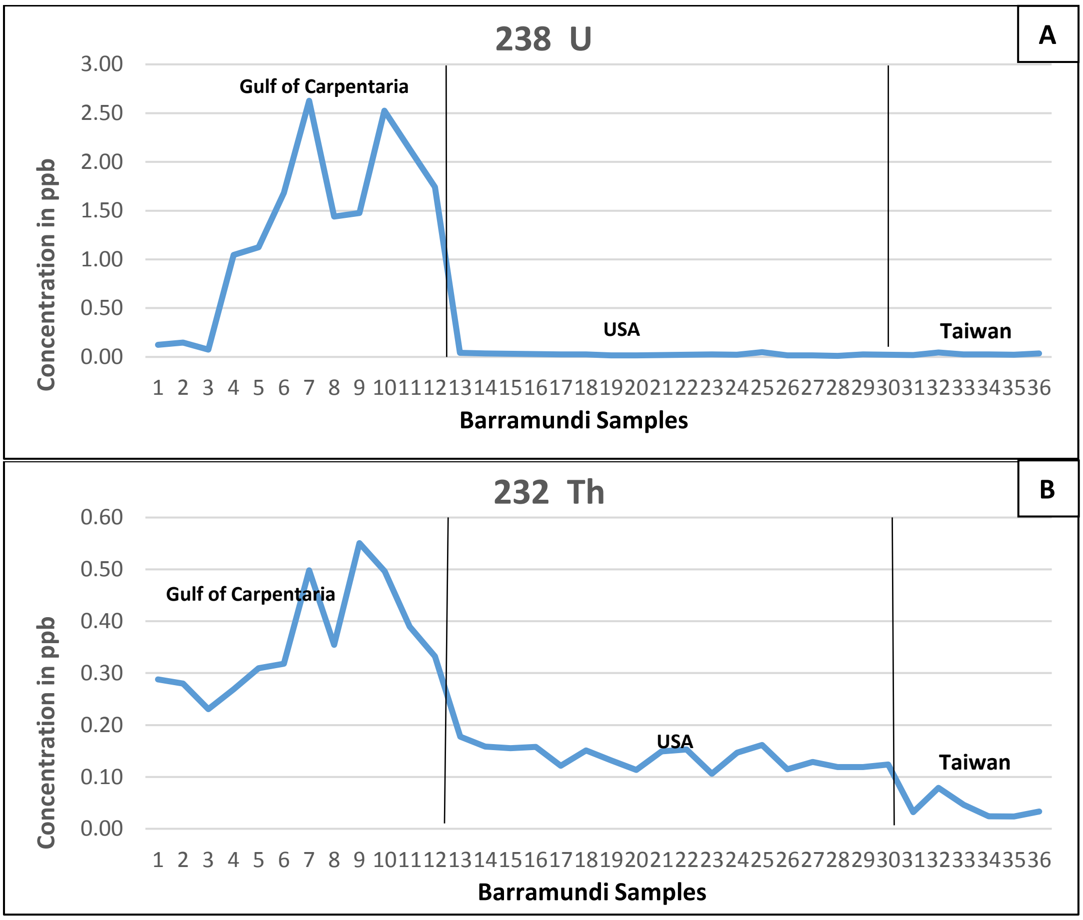


Figure 4.5 Relative concentrations of uranium (4.5 A) and thorium (4.5 B) between barramundi samples from the Gulf of Carpentaria. Australia, USA and Taiwan, highlighting the high levels of these elements associated with the uranium mineralization in the Australian samples.

4.1.3 Comparison of Trace Element Signature of Dorsal and Ventral Muscle

Following the analysis of the barramundi samples from solution based ICP-MS and ICP-AES, the data was acquired for the concentration of the 63 analytes. The data acquired from the analysis of dorsal and ventral muscle from four samples of fish (Innisfail, Queensland; Wingfield, South Australia; Indonesia and New Zealand) were initially plotted and then compared to investigate the difference in concentration of trace elements in the ventral and dorsal muscles. Graphical representation of concentration of elements from the dorsal and ventral muscle from the four study fish are shown in **Figures 4.6-4.9**; average data for the four fish are shown in **Figure 4.10**.

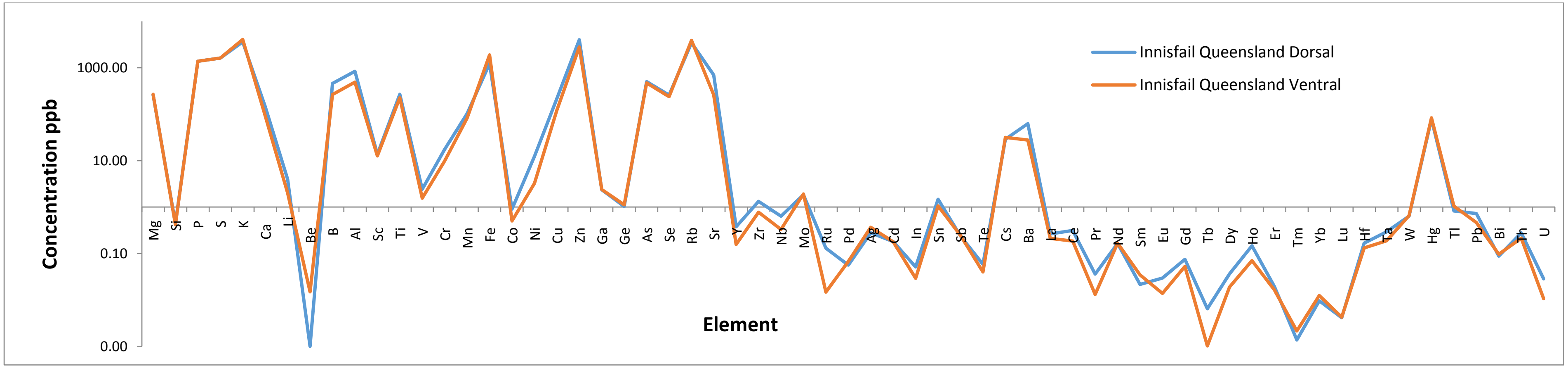


Figure 4.6 Reproducibility of dorsal and ventral trace element distribution profiles for a Barramundi sample from Innisfail, Queensland.

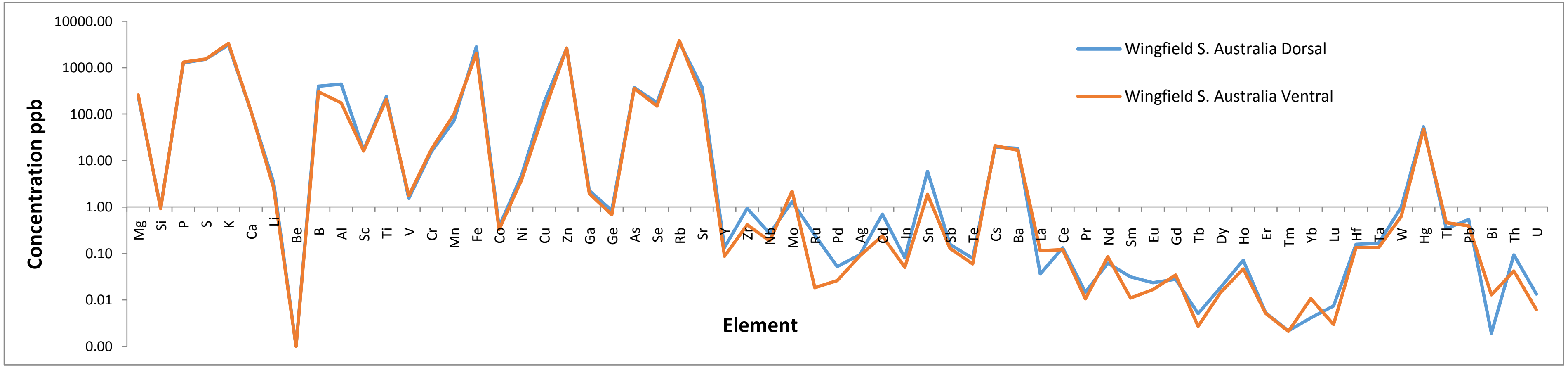


Figure 4.7 Reproducibility of dorsal and ventral trace element distribution profiles for a Barramundi sample from Wingfield, South Australia.

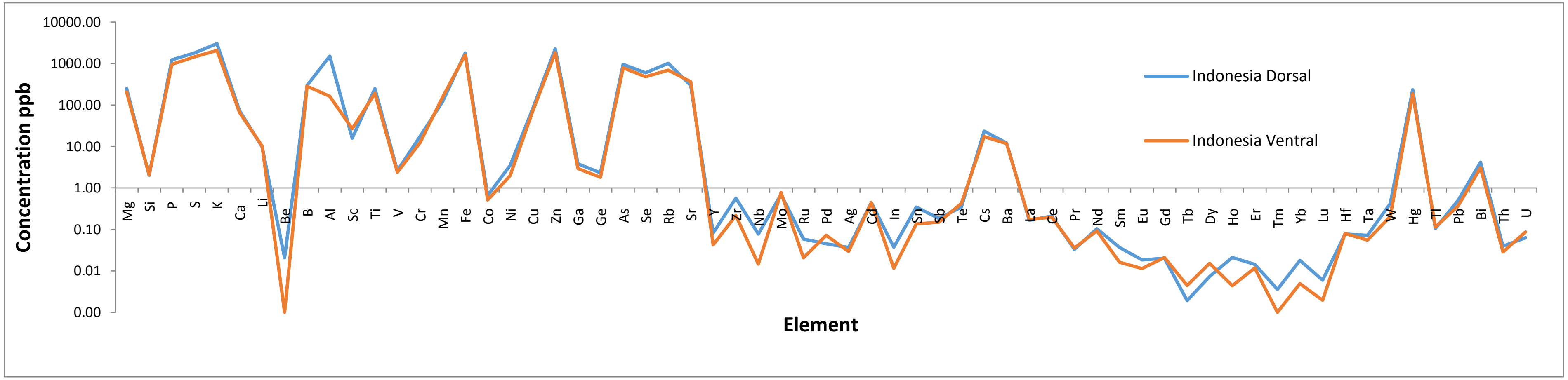


Figure 4.8 Reproducibility of dorsal and ventral trace element distribution profiles for a Barramundi sample from Indonesia.

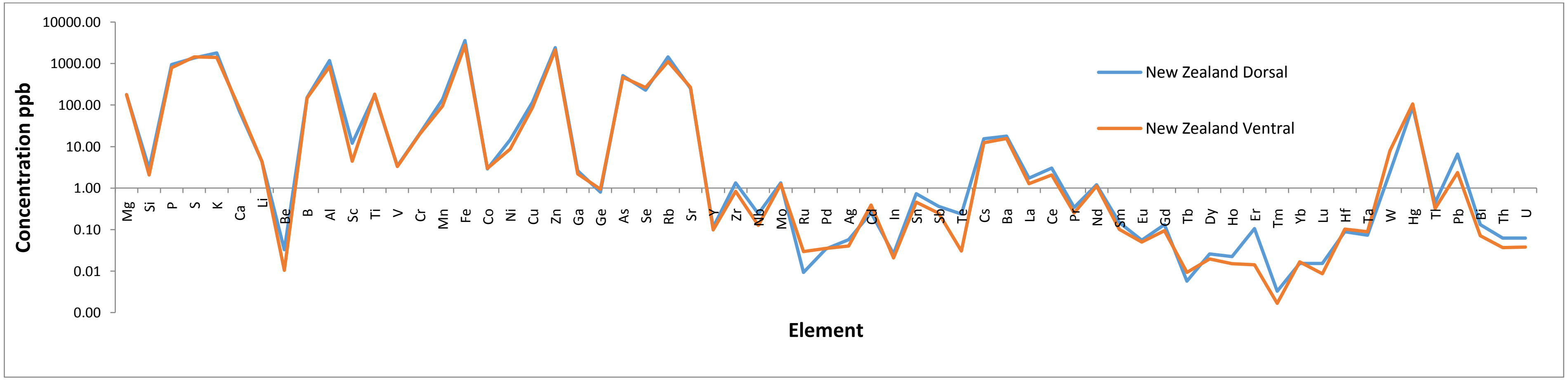


Figure 4.9 Reproducibility of dorsal and ventral trace element distribution profiles for a Barramundi sample from New Zealand.

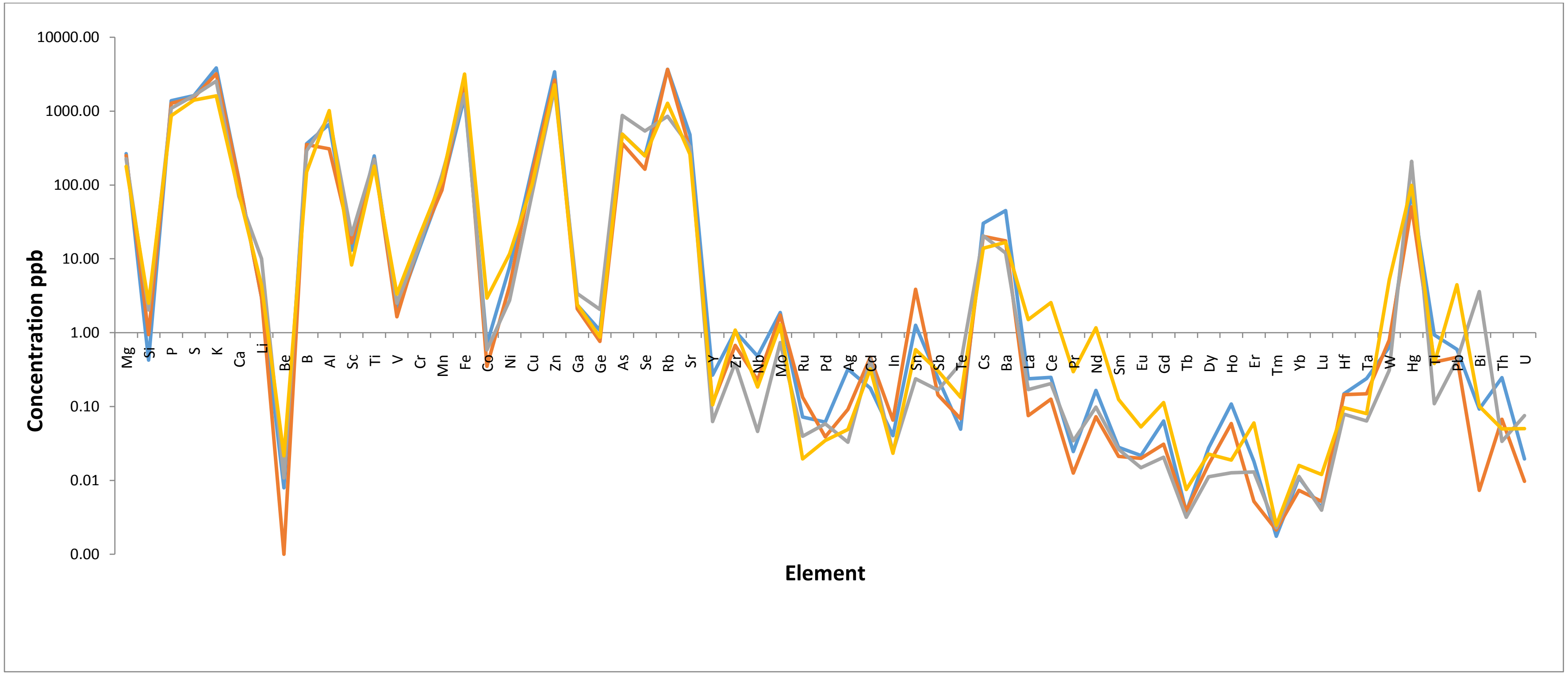


Figure 4.10 Overlay of the average trace element profiles from barramundi from the four dorsal/ventral muscle study sites indicating the differences between sites.

(The differences in the trace element profiles between sites are significantly greater than the differences between dorsal and ventral muscle from the same site, making it possible to use data for either dorsal or ventral muscle in a provenance determination study).

The plots for all samples **Figures 4.6-4.9** indicate that there is high reproducibility of the elemental signature between the values for dorsal and ventral muscle. The slight differences that do occur are not specific to a specific analyte and in general the trace element patterns are the same for both muscles in all fish. When average data for the two samples are compared between fish **Figure 4.10**, it is obvious that there are differences that can easily identify an individual fish from any of the other three in the experiment. Consequently, it is the authors opinion that there is no advantage in determining the elemental content of both muscles for each fish and that the ventral muscle will therefore be used throughout the rest of this study. To confirm this an LDA plot of data for fish from the four areas used in this study have been plotted in **Figure 4.11**.

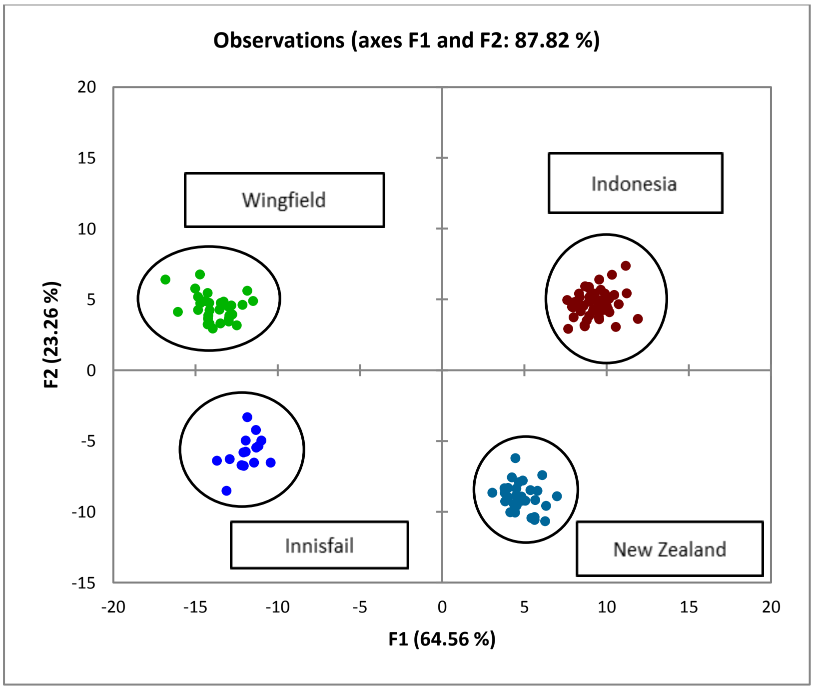


Figure 4.11 LDA plot of data for the four areas where fish dorsal and ventral muscle have been analyzed confirming that there is no difference between provenance identification using data for both muscle groups combined.

From this **Figure 4.11** it is absolutely apparent that differences between the provenances of samples are far greater than any minor difference between the elemental patterns of dorsal and ventral muscle. The decision to use only dorsal muscle for provenance determination makes even more sense when it is considered that for the most part the Barramundi sold in supermarkets are in the form of a white meat fillet which implies that ventral muscle is the main material that is passed on to customers.

4.2 Provenance Establishment of Barramundi Samples

4.2.1 Samples and Test

After successfully establishing a methodology using the reduced sample set in the preliminary study, it was necessary to test the protocols on a much larger data set. A total of 223 samples of ventral muscle from fish from 10 locations around Australia and internationally were analyzed. Identical analytical and interpretational procedures were undertaken with this data as those established using the reduced data set. Details of all the barramundi samples are given in **Table 4.1.** Similarly, as with the preliminary study, solution based ICP-MS and ICP-AES were used to determine the concentration of 63 analytes.

Table 4.1 Summary of source locations of barramundi samples used in the provenance studies.

Source	Number of Fish	Reference for Figures	Origin
Gulf of Carpentaria	12	1	Gulf of Carpentaria, Queensland, Australia
Australis Barramundi	18	2	Turners Falls, Massachusetts, USA
Pejo Enterprises	13	3	Innisfail, Queensland, Australia
Robarra	28	4	Wingfield, South Australia, Australia
King Reef	15	5	Cowley, Queensland, Australia
Good Fortune Bay	15	6	Bowen, Queensland, Australia
Indonesia Fish	46	7	Unknown site, Indonesia
Taiwan	12	8	Unknown Site Taiwan
New Zealand Fish	28	9	Unknown site, New Zealand
Cone Bay	30	10	Western Australia, Australia

4.2.2 Results

4.2.2.1 LDA Separation of Samples

Because of the large number of data points in each LDA, the process of separating individual populations may not be possible in a single plot, as the procedure attempts to identify the most obvious outlier populations. Therefore, the basis of the distinction of outliers may not provide absolute separation of other samples or sub-populations in the data set and their generic association may be compromised by the requirement to isolate initially the easily identifiable subgroups. Consequently it may be necessary to undertake a series of iterative LDA plots, progressively removing outlier population until complete resolution, if possible, of all groups in the data set is achieved.

Following LDA analysis, the data plot of the entire data set from ten locations is shown in **Figure 4.12**. From the plot it is evident that barramundi samples from the Gulf of Carpentaria, Queensland (1) and Turners Falls, Massachusetts, USA (2) are isolated from rest of the sample clusters and are also isolated from themselves, forming two distinct groups.

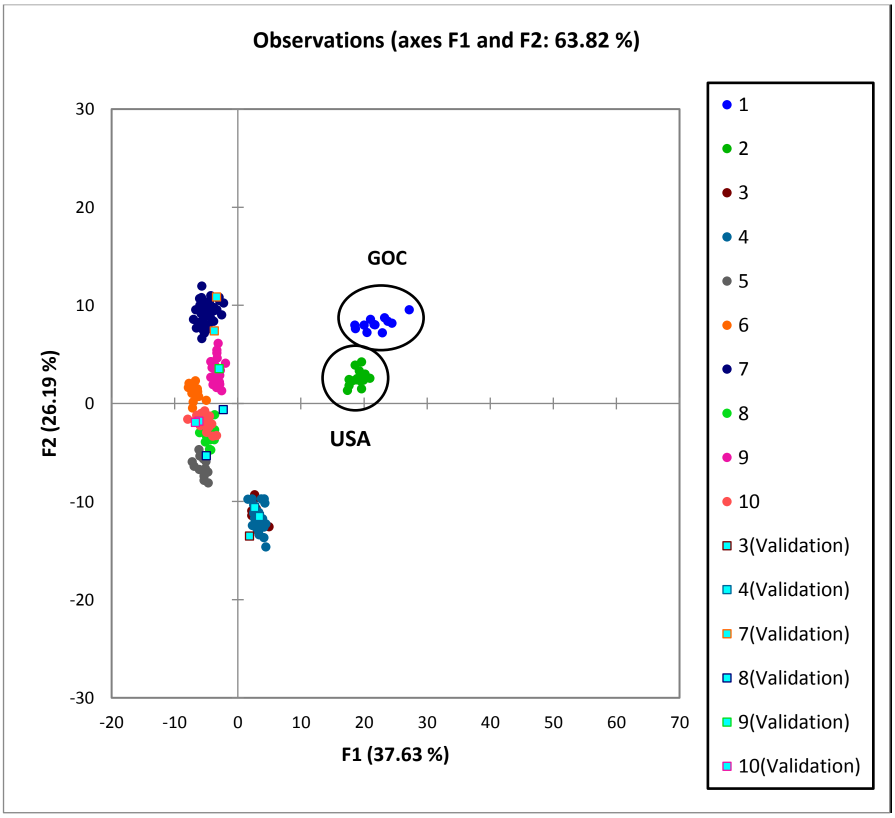


Figure 4.12 LDA plot showing the sub-group separation of the data set and separation of barramundi samples from the Gulf of Carpentaria (1) and USA (2).

Following this result, the barramundi samples from the Gulf of Carpentaria, Queensland (1) and Turners Falls, Massachusetts, USA (2) were removed from the data set and the LDA was re-plotted for the remaining samples, the results are plotted in **Figure 4.13**. There are a number of data sets that cluster together and separate from each other. However, it was decided that the most robust isolation was that for data set (7), which are the samples of barramundi from Indonesia.

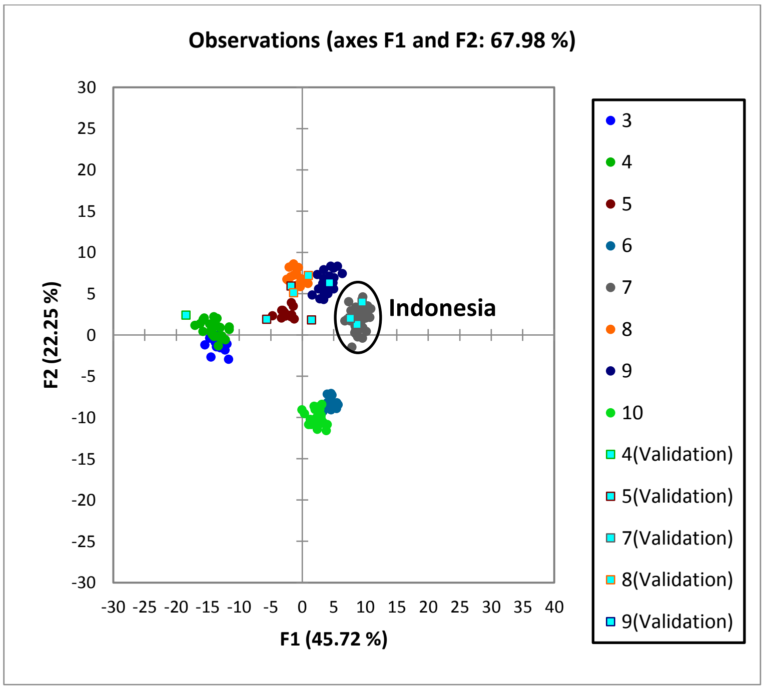


Figure 4.13 LDA plot showing the sub-group separation of the remaining data set and separation of barramundi samples from the Indonesia (7).

Consequently these samples were removed and the LDA re-run for the remaining samples (**Figure 4.14**).

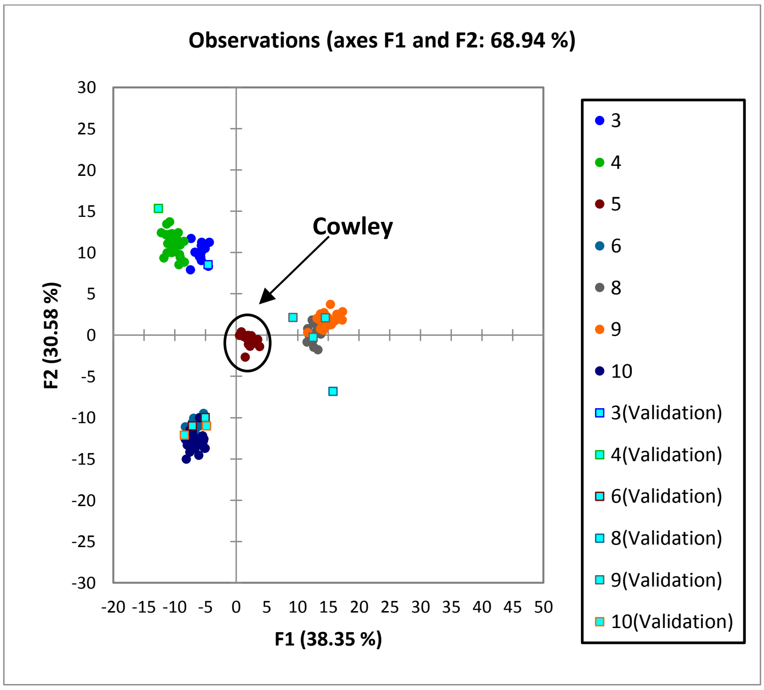


Figure 4.14 LDA plot showing the sub-group separation of the remaining data set and separation of barramundi samples from Cowley (5).

Following this result, the barramundi samples from Cowley, Queensland (5) were then removed from the data set and an LDA was again re-plotted using the remaining data set to distinguish samples from the remaining data set. The resulting LDA plot is seen in **Figure 4.15**.

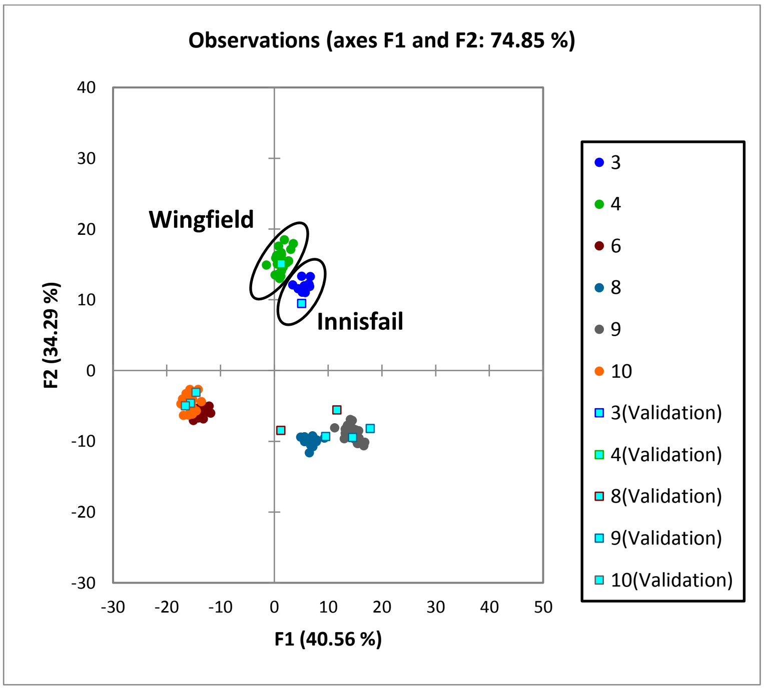


Figure 4.15 LDA plot showing the sub-group separation of the remaining data set and separation of barramundi samples from Innisfail (3) and Wingfield (4).

From the LDA data plot in **Figure 4.15**, there is a clear visual distribution between barramundi samples from Innisfail, Queensland (3) and Wingfield, South Australia (4), and a clear separation of these samples from the rest of the data set samples. While it would be perfectly valid to remove both of the sets of data for these two sites and re-plot the LDA, it was nonetheless decided to only remove the Innisfail, Queensland (3) set prior to re-plotting. In this way more samples would be represented in the LDA and it would be possible, on re-plotting, to confirm that the Wingfield, South Australia (4) set of data still formed a distinctive subgroup. Consequently for the next data set, samples from Innisfail, Queensland (3) were removed and an LDA plotted for the remaining samples. Results are detailed in **Figure 4.16**.The results clearly indicate a complete separation between all remaining sample groups.

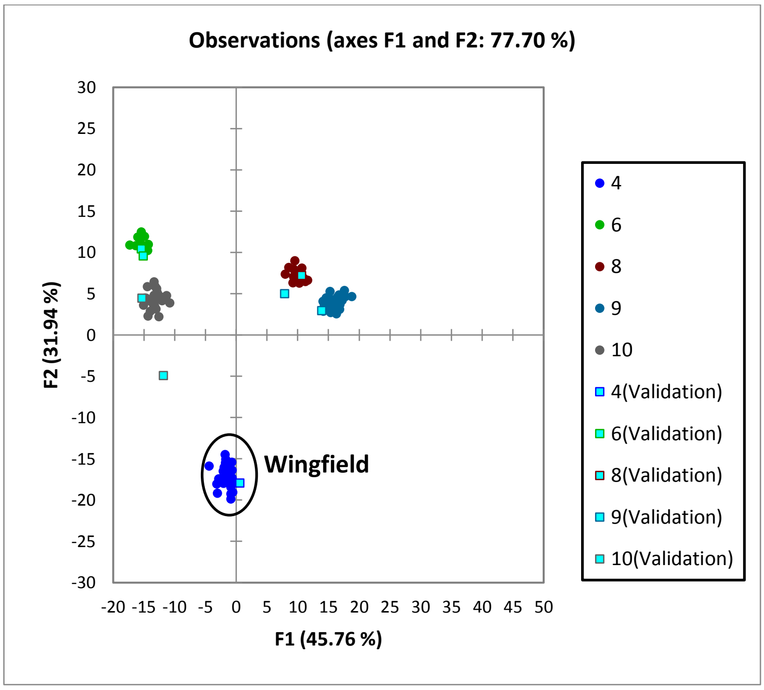


Figure 4.16 LDA plot showing the separation of the remaining barramundi samples from Wingfield (4).

Nonetheless, in order to further confirm the robustness of the above separation, data for samples from the Wingfield, South Australia (4) group that have previously been separated from the other groups (**Figures 4.13** to **Figure 4.16**) were removed and the data re-plotted (**Figure 4.17**).

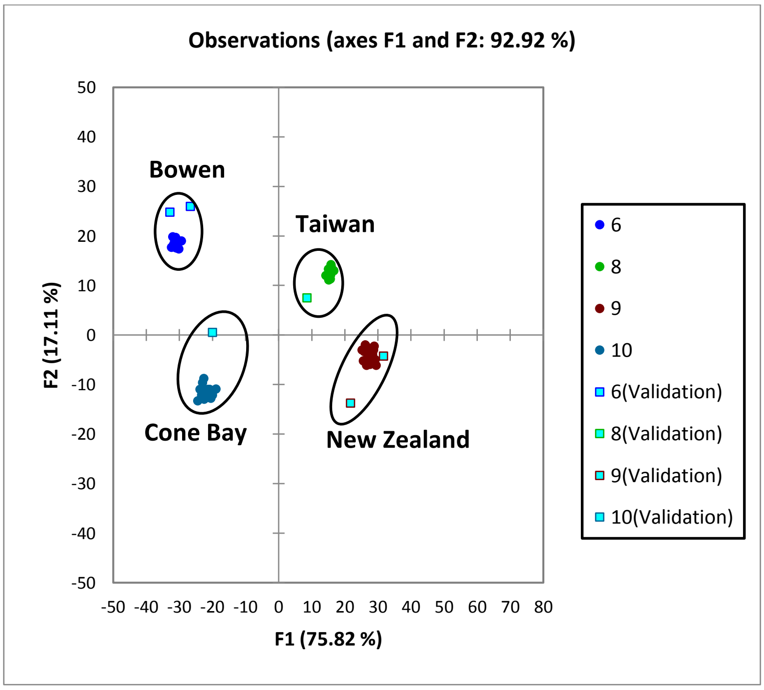


Figure 4.17 LDA plot showing complete separation of the remaining barramundi growing sites of Bowen (6), Taiwan (8), New Zealand (9) and Cone Bay (10).

Thus, the robustness of this method was confirmed in **Figure 4.17** which show a clear separation of the last remaining samples of the data from Bowen, Queensland (6), Taiwan (8), New Zealand (9) and Cone Bay, Western Australia (10).

From the overall results obtained in this interpretation, using all analytes it was possible to cluster all samples associated with specific growing areas into unique sub-populations and to unambiguously identify these populations. Consequently, using the protocols, both analytical and interpretive detailed in this thesis, it was confirmed that it is possible to determine the provenance of all study samples and distinguish between large batches of Australian as well as overseas barramundi on the basis of their trace element association patterns.

As it was determined in the feasibility test **Figure 4.3** that the grouping of samples and the robustness of the association of samples from an individual growing site was much better when analytes that were significantly above their detection limits were used to establish the LDA. A similar interpretational protocol that was used to produce **Figure 4.3** was repeated for the entire data to establish if an improvement could also be made on the results already obtained using seventeen selected analytes (Si, Li, V, Mn, Co, As, Se, Rb, Cs, Ba, La, Ce, Pr, W, Hg, Tl and U). This procedure was undertaken even though it had been possible to unambiguously separate all populations using the entire data set.

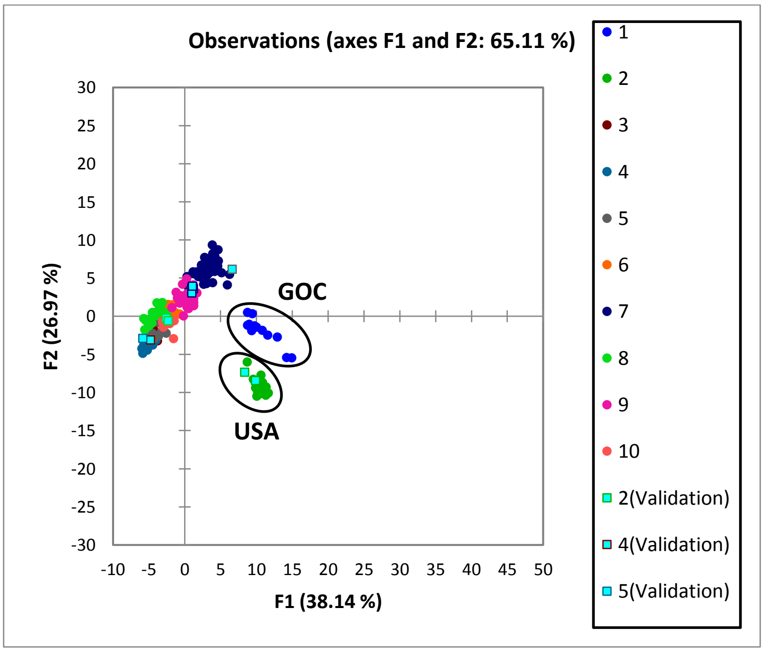


Figure 4.18 LDA plot showing the separation of barramundi samples from 10 locations based on seventeen selected analytes and the separation of samples grown in the Gulf of Carpentaria, (1) and USA (2).

In the initial LDA plot **Figure 4.18**, it is easily possible to isolate the sample subpopulations from the Gulf of Carpentaria, Queensland (1) and Turners Falls, Massachusetts, USA (2) as it was with the first LDA interpretation using all analytes **Figure 4.3**. However, when the two sets of data corresponding to these two areas were removed and the LDA re-plotted it was not possible to unambiguously separate samples from Bowen, Queensland, (6) and Cone Bay, Western Australia, (10) **Figure 4.19**.

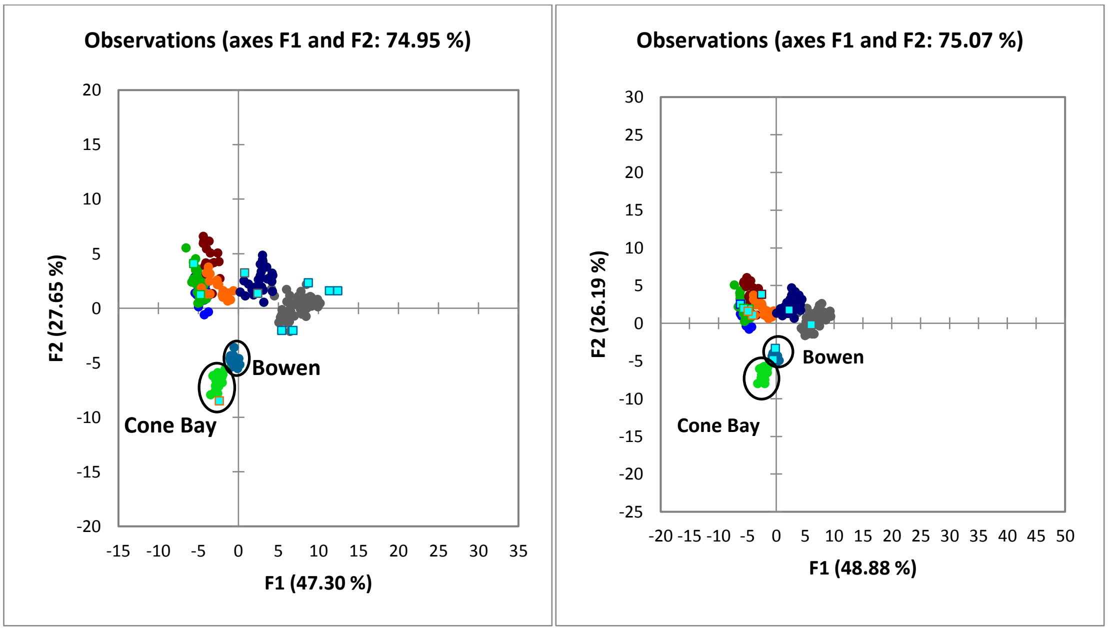


Figure 4.19 Two LDA plots showing separation of barramundi samples from Bowen (6) and Cone Bay (10).

However, the two LDA plots indicated that while samples from Bowen, Queensland (6) and Cone Bay, Western Australia (10) could be separated from the other groups in the survey, they were not unambiguously separated from each other in these plots and therefore the use of only seventeen analytes was not suitable for larger sample batches. Thus, on the basis of this study it was considered sensible to use all analytes when constructing LDA's in future and only to undertake LDA analysis using a limited set of analytes when this approach failed.

4.2.2.2 PCA Separation of Samples

In addition to undertaking LDA analysis of samples it was also decided to subject the data for five sites in Australia and single sites from, Taiwan, New Zealand and Indonesia, to PCA. In this way it was hoped to confirm the LDA results and to increase the robustness of the interpretational protocols. Sample sites are referred to numerically as detailed in **Table 4.2**.

Table 4.2 Samples used for detailed PCA based provenance confirmation study.

Source	Number of Fish	Reference for Figures 4.19-4.21	Origin
Pejo Enterprises	13	4	Innisfail, Queensland, Australia
Robarra	28	5	Wingfield, South Australia, Australia
King Reef	15	6	Cowley, Queensland, Australia
Good Fortune Bay	15	7	Bowen, Queensland, Australia
Indonesia Fish	46	8	Unknown site, Indonesia
Taiwan	12	9	Unknown Site Taiwan
New Zealand Fish	28	10	Unknown site, New Zealand
Cone Bay	30	11	Western Australia, Australia

The initial LDA was undertaken using seventeen analytes (Si, S, Li, B, V, Mn, Co, Ge, As, Se, Rb, Ce, W, Hg, Tl, Bi and U. These analytes were chosen as being amongst those that gave the best discrimination vectors in the LDA plots. The result of this investigation is graphically represented in **Figure 4.20**.

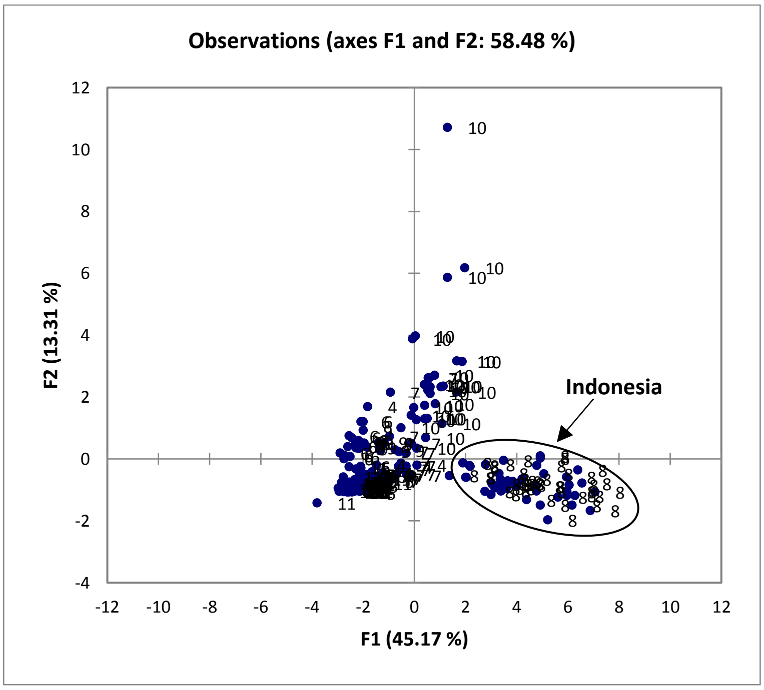


Figure 4.20 PCA plot of all data associated with barramundi samples detailed in Table 4.2. The plot confirms the isolation of samples originating in Indonesia (8).

When an iterative procedure is initiated and the Indonesian (8) population removed prior to the data being are-plotted using the same analytes, separation of subpopulations from Bowen, Queensland (7), New Zealand (10) and Cone Bay, Western Australia (11) is observed **Figure 4.21**.

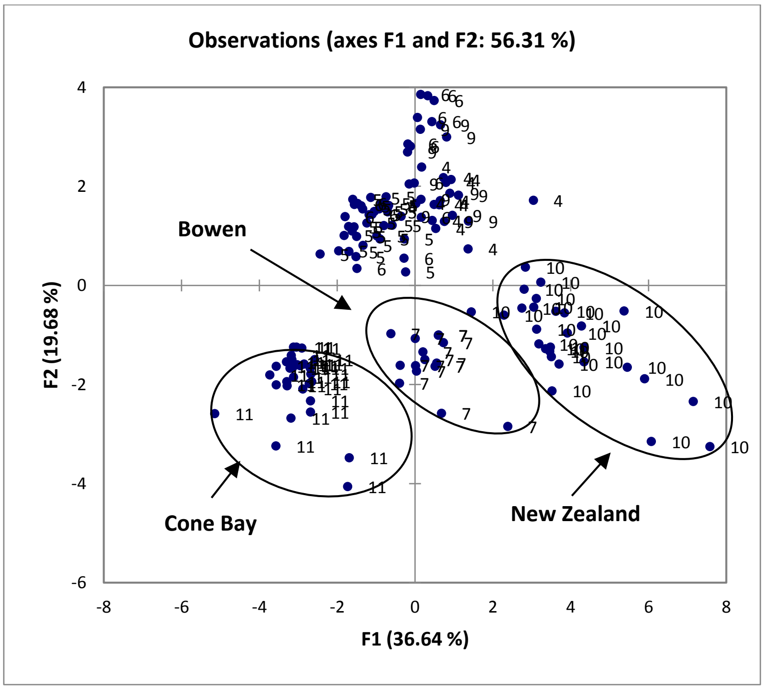


Figure 4.21 PCA plot of all remaining sample data and the separation of barramundi samples originating from Bowen (7), New Zealand (10) and Cone Bay (11).

Finally, using a third iterative plot, it is possible to separate and identify the provenance of the remaining samples from Innisfail, Queensland (4), Wingfield, South Australia (5) and Taiwan (9). The resulting PCA plot is detailed in **Figure 4.22.**

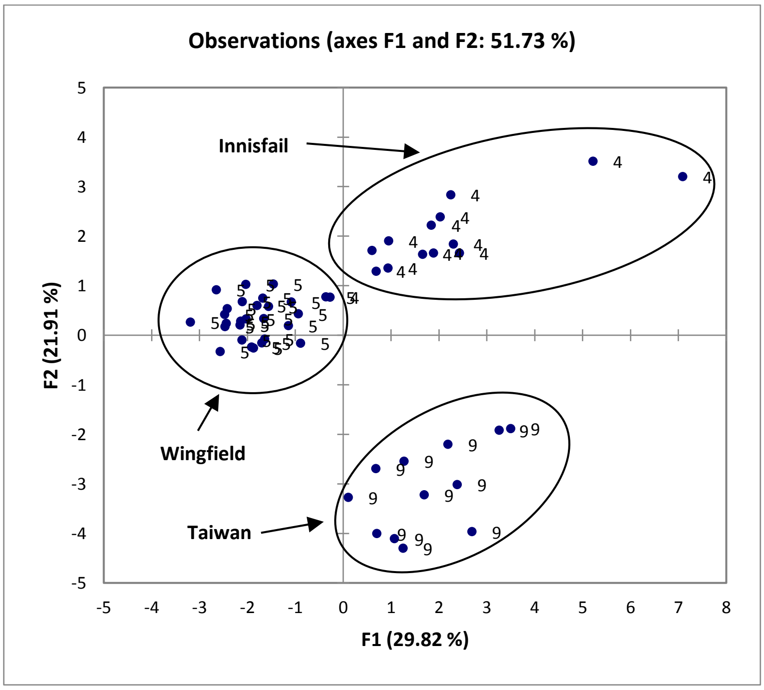


Figure 4.22 PCA plot of all remaining sample data showing the separation of barramundi samples originating from Innisfail (4), Wingfield (5) and Taiwan (9).

Using an iterative PCA it is also possible to isolate all populations of barramundi to their theoretical place of origin, however, there are two fish from Innisfail that are somewhat distal from the main grouping of the Innisfail population. It may be that these fish come from a different sub-population in the area or that the Innisfail population definition is not completely robust and requires more samples to be analyzed and data incorporated into the algorithms that define the population distribution. This latter comment is, in the opinion of the author, extremely important and emphasizes that while in a preliminary study such as this, it is possible to confirm the principle of sub-population separation based on trace metal association patterns, far more research needs to be undertaken to develop robust models that will allow scientists to unambiguously confirm provenance in a court of law.

4.2.3 Unknown Test

In this study, 16 samples from unknown locations from Australia and Taiwan were analyzed together with the samples from the 10 locations given in **Table 4.1**. These extra samples consisted of eight samples from Taiwan (11) and eight samples from Australia (12) respectively. These 16 samples from the two unknown locations were incorporated into the original data base of 223 samples (making 239 samples) and the new data set subjected to LDA analysis. The objective of this study was to determine if the two new sets of samples, which were obtained from two different supermarkets and labelled as coming from Taiwan and Australia, could be generically associated with samples in the data base known to come from those countries.

4.2.3.1 Results

An LDA plot showing the associations of all study samples is shown in **Figure 4.23**. From the resultant data plot, there is a visible discrimination of samples from Indonesia from the rest of data set. However, the two unknown samples from Taiwan (11) and Australia (12) are in close proximity with each other and are surrounded by samples from Cowley (5), Bowen (6), Taiwan (8) and Cone Bay (10). The complexity of this plot makes it necessary to undertake an iterative LDA series of plots and consequently, the samples from Indonesia (7) were removed from the data base and the remaining samples re-plotted (**Figure 4.24**).

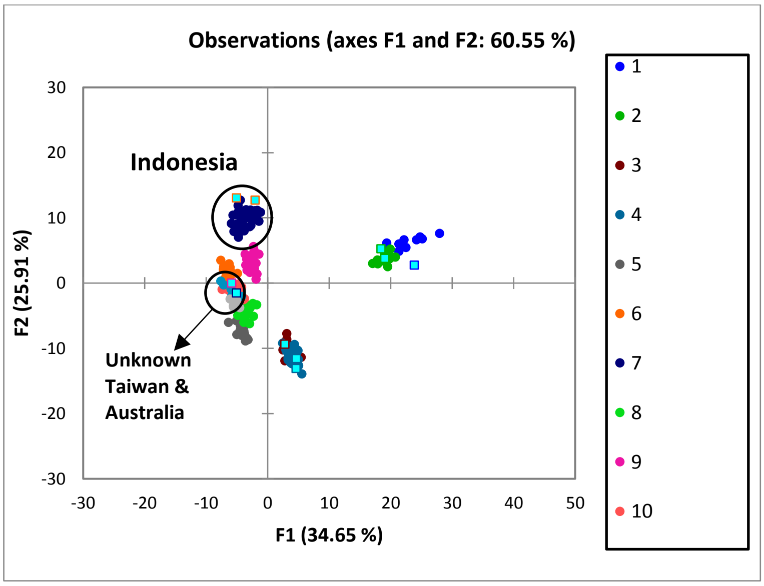


Figure 4.23 LDA plot showing the separation of barramundi samples from Indonesia (7) from the remaining sample locations in the data set.

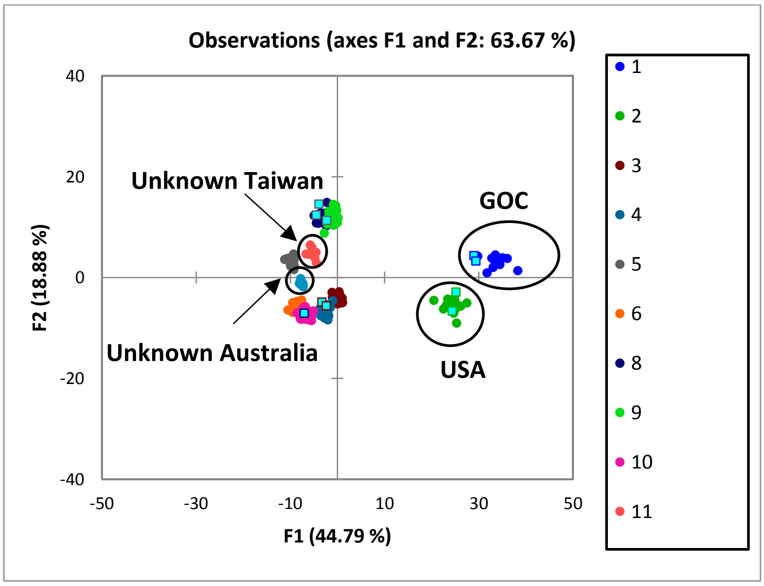


Figure 4.24 LDA plot showing the separation of barramundi samples from Gulf of Carpentaria (1) and USA (2) based on elemental concentrations obtained from acid digestion.

From the LDA plot detailed in **Figure 4.24,** it is apparent that the samples from Gulf of Carpentaria (1) and USA (2) are both clearly separated from the rest of the data set and from each other. However the unknown samples from Taiwan (11) and Australia (12) were still in the bulk of the remaining samples but had started to isolate themselves into individual groups. Thus, samples from Gulf of Carpentaria (1) and USA (2) were taken out of the data set and an LDA was rerun and plotted for these remaining samples. The results of the LDA plot are shown in **Figure 4.25**.

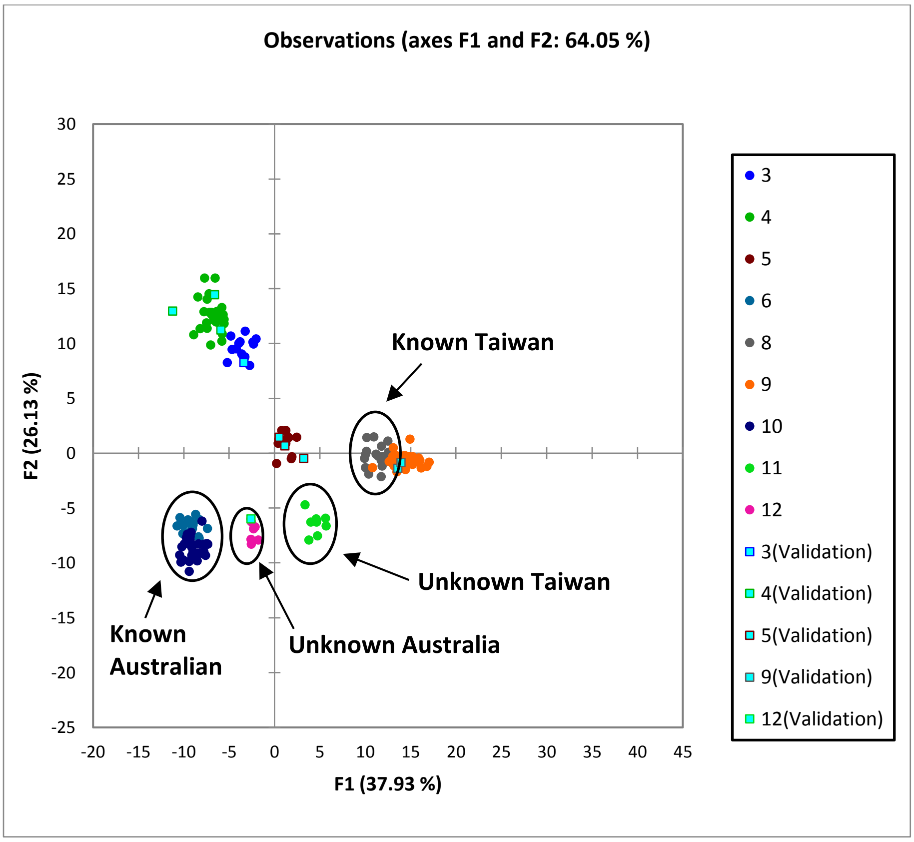


Figure 4.25 LDA plot showing the separation of barramundi samples from unknown sites in Taiwan (11) and Australia (12) based on elemental concentrations obtained from acid digestion.

From the resulting data plot in **Figure 4.25** it was noted that the two unknown samples from Taiwan (11) and Australia (12) were separated from each other. It was also very evident that unknown samples from Taiwan (11) were in close proximity with the other samples from Taiwan (8). While the unknown samples from Australia (12) were in close proximity with samples from other Australian site samples Bowen (6) and Cone Bay (10). The association of the unknown samples with equivalent samples from the areas they were supposed to come from indicates that there is a high probability of the samples originating from where the labels indicate they come from and that the protocols used to identify the provenance of barramundi in this thesis have an extremely good probability of being robust and applicable to intentional farmed and caught samples of the fish.

If groups 3, 4, 5 are removed and the data set re-plotted (**Figure 4.26**) it becomes apparent that the unknown Australian samples (12) lie extremely closely to the known samples from Cone Bay (10). However, the Taiwanese samples plot closer to samples from Australia than they do from Taiwan.

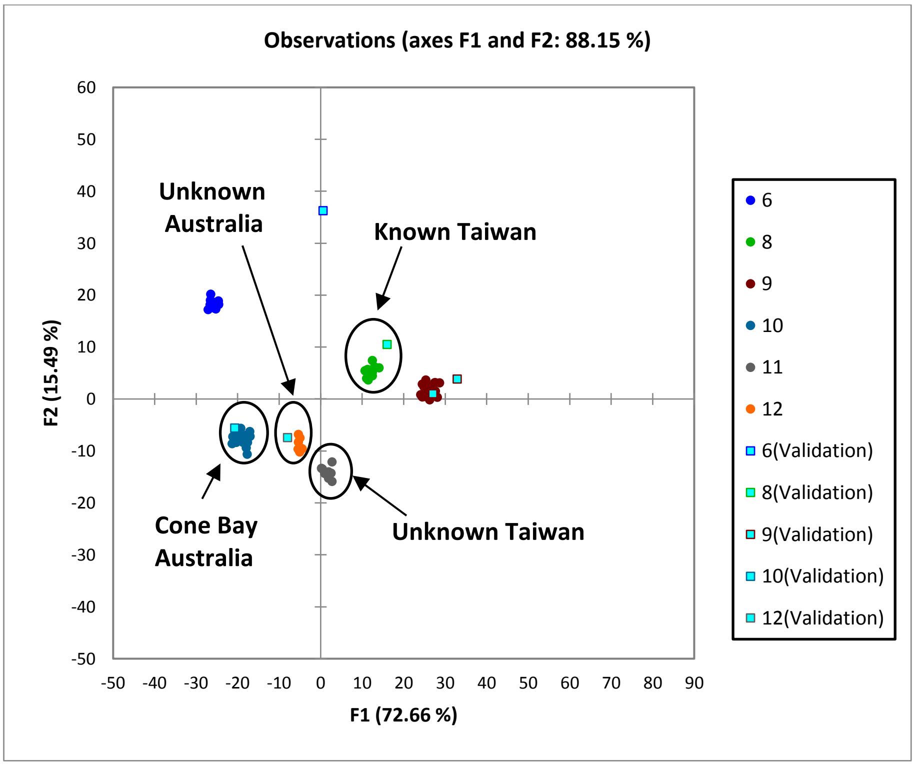


Figure 4.26 LDA plot showing complete separation of all sample groups and association of unknown samples with those groups.

This is not surprising as the data set does not represent all growing areas and quite obviously it needs to have considerably more samples added before the provenance determination algorithms can have a hope of being robust enough for commercial release. However, this is a preliminary survey and it is quite likely that the actual growing site of the samples is different from any in the data base; however, the close association of the samples to their "theoretical" growing site is extremely encouraging for the further development of the technology into the future. However, one aspect of the study that may not be apparent on cursory inspection is that we know that the "unknown" Australian and Taiwanese barramundi samples do not come directly from any of the sites surveyed and we also know the degree of that non-association by tracing the LDA plots backwards. Consequently it is possible to say where the samples do not come from which in itself is a major step forward in provenance establishment for the fish.

4.3 Provenance Establishment of Australian Barramundi Samples

4.3.1 Samples and Test

After the success of the two earlier studies, another study was undertaken to determine if it was possible to distinguish between barramundi that had been grown in Australia alone. The study was undertaken as DNA analysis had successfully distinguished between barramundi samples from overseas and Australia, but the use of DNA had failed to distinguish between samples that were grown around Australia.[60] In this study, a total of 113 samples were taken from six locations around Australia. The geographical locations of these samples from the six locations in Australia are shown in **Figure 4.27** and detailed in **Table 4.3.**

Figure 4.27 A geographical map indicating the location of the barramundi samples from Australia.

Sample dissolution procedures which were successfully used in the two previous studies were repeated using the 113 samples for this study and the same statistical interpretation procedures were also used.

Table 4.3 Summary of barramundi samples used from different locations in Australia.

Source	Number of Fish	Reference for Figures	Origin
Gulf of Carpentaria	12	1	Gulf of Carpentaria, Queensland, Australia
Pejo Enterprises	13	3	Innisfail, Queensland, Australia
Robarra	28	4	Wingfield, South Australia, Australia
King Reef	15	5	Cowley, Queensland, Australia
Good Fortune Bay	15	6	Bowen, Queensland, Australia
Cone Bay	30	10	Western Australia, Australia

4.3.2 Results

The distribution of the sub-populations resulting from the initial LDA analysis of the 113 samples is shown in **Figure 4.28**. This plot identifies a clear and distinct separation between samples from Gulf of Carpentaria, Queensland (1) and Cone Bay, Western Australia (10). These two sets of samples are also clearly separated from the remaining samples in the data set.

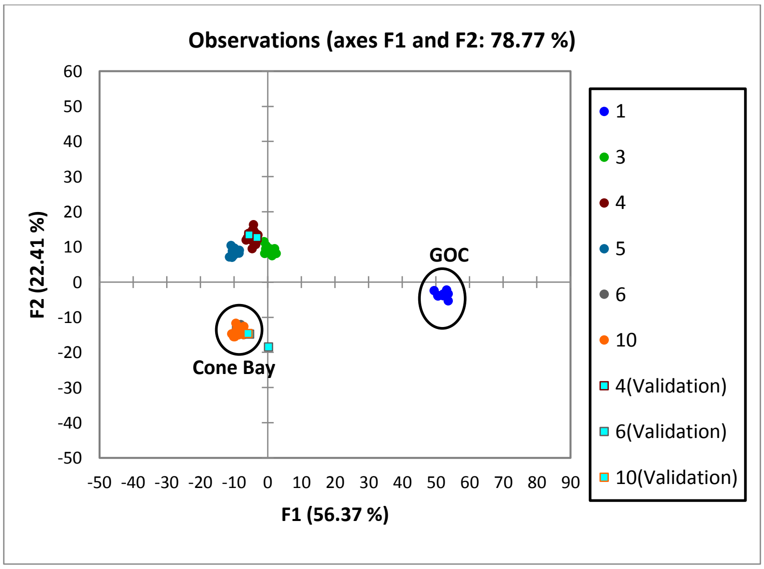


Figure 4.28 LDA plot showing the separation of barramundi samples from Gulf of Carpentaria (1) and Cone Bay (10).

Gulf of Carpentaria, Queensland (1) and Cone Bay, Western Australia (10) sample data were then removed from the data set and the results re-plotted **Figure 4.29**.

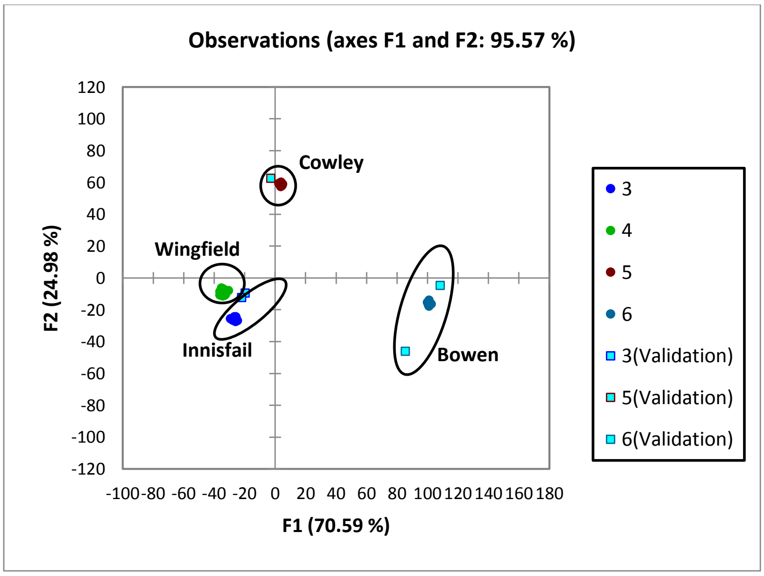


Figure 4.29 LDA plot showing the separation of the rest of barramundi samples from Innisfail (3) Wingfield (4) Cowley (5) and Bowen (6).

Based on the data detailed in **Figure 4.29**, there was a clear separation between Bowen, Queensland (6) samples and the other three groups from Innisfail, Queensland (3) Wingfield, South Australia (4) Cowley, Queensland (5). Consequently to further confirm the robustness of this separation, the data for the Bowen, Queensland (6) samples were removed from the data set and LDA for the remaining three locations re-plotted in **Figure 4.30**.

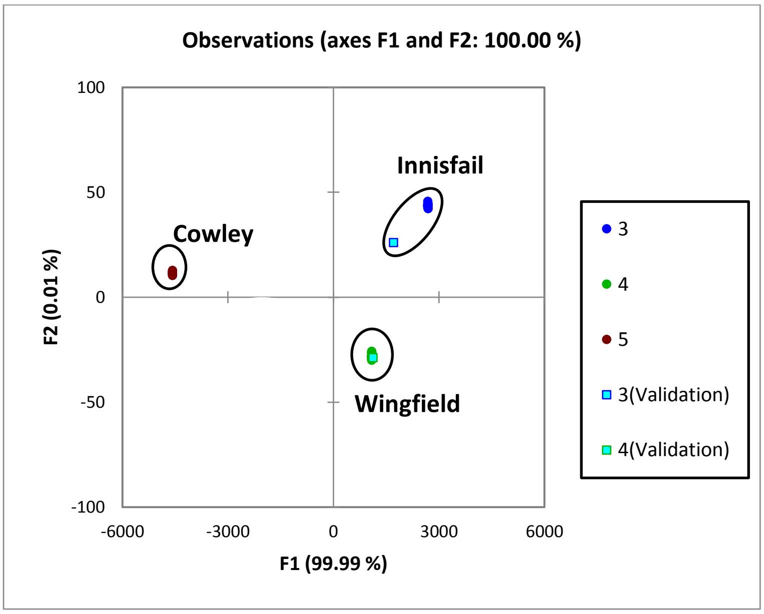


Figure 4.30 LDA plot showing the separation of the remaining samples grown at Innisfail (3) Wingfield (4) Cowley (5).

As seen in **Figure 4.30** there was a clear separation of the last remaining samples from Innisfail, Queensland (3) Wingfield, South Australia (4) Cowley, Queensland (5). Thus it was confirmed from the LDA plots in (**Figures 4.28** to **4.30)** that it is possible to determine the provenance the barramundi of the samples grown around Australia with a high degree of accuracy.

CHAPTER FIVE

CONCLUSIONS

The primary aim of this study was to determine if it is possible to develop a methodology that would facilitate the unambiguous determination of the provenance of Australian and overseas barramundi on the basis of the element signatures in their ventral muscle. Previously used methodologies which had successfully provenanced a wide range of food products like coffee, wine, pork, olive oil etc. were trialed on barramundi for the first time to test the effectiveness of this hypothesis.

The feasibility test for the method involved the analysis of 36 barramundi samples from three locations (Taiwan, USA and the Gulf of Carpentaria, Australia) using solution based ICP-MS and ICP-AES. Results for the data obtained using the relative concentration of 63 analytes indicated that it was possible to distinguish between barramundi grown in these three areas, on the basis of their trace element composition in ventral muscle, with a high level of accuracy. Additionally, it was noted that the results further improved when a set of 22 analytes, that had concentrations significantly above the detection limits of the technique, were used to interpret the final data set.

After successfully establishing that the methodology was appropriate for distinguishing between barramundi grown in areas a considerable distance apart, a larger set of 223 samples from 10 locations both around Australia and internationally were analyzed. These samples formed the basis of the tests to be used to distinguish between both national and international growing regions and to ultimately determine absolute geographical provenance of the barramundi. In addition, tests were also performed to find if there were differences in chemical composition of the dorsal and ventral muscles of the barramundi.

The results of these tests confirmed that there was no significant difference in the trace element composition of these two muscle groups. Additionally, the overall results of the study indicated that it was possible to distinguish and specify growing region within a large batch of Australian and overseas samples on the basis of the trace element association patterns in the ventral muscle. However, removal of analytes that had concentrations at or near the detection limits of the techniques used, did not provide better growing area discrimination in this larger set of samples and consequently it was decided to use all analytes to establish the LDA’s used in provenance determination.

Furthermore, when an additional set of 16 samples, from unknown locations “theoretically” within Australia and Taiwan (according to the suppliers of the fish samples) were added to the data set and re-interrogation of the data set undertaken, the results indicated that the unknown samples were a closer fit to their “theoretical” growing sites than to any others. This close association was extremely encouraging for the further development of the technology into the future. However, it is absolutely essential to analyze and incorporate more samples into the data base to increase the robustness of the interpretation protocols.

Finally, the interpretational protocols were tested on samples that were grown around Australia. This study was undertaken because while the widely used DNA technology to identify Australian growing areas could distinguish between Australian and foreign imports of barramundi, it could not in fact produce site specific information. A total of 113 samples of ventral muscle from six locations around Australia were analyzed for their trace element composition. Following an iterative LDA procedure, all samples could be attributed to their growing sites in Australia with a high level of accuracy.

The methodology trialed in this thesis and the data obtained from it demonstrates the potential of new analytical and interpretive protocols which can be used in the determination and verification of the geographical origin of Australian and overseas barramundi. The analytical techniques used in this study are fast, accurate and relatively easy to undertake. Data produced have been used, in association with LDA statistical analysis, to identify both the country of origin for overseas barramundi as well as the growing region for local produce.

CHAPTER SIX

FUTURE WORK

It is essential that before the protocols described in this thesis are used commercially, a significant number of additional samples must be analyzed and the robustness of the interpretive protocols are-tested and perhaps modified, in a much more detailed study. An additional study should be undertaken to test the effect of cooking or processing on the barramundi fish samples. The current study only investigated barramundi samples which were raw and unprocessed. Studies should be carried out to determine if cooking or processing will change the trace element signature of the barramundi. If this is the case then it will be necessary to undertake an additional study to establish a data base of cooked material to be able to accurately undertake provenance studies of barramundi using this material.

Future research should also be undertaken on barramundi scales to determine if the provenance of live fish can be estimated by analyzing this material. Both Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) and the solution based techniques already used in the current study, should be trialed using barramundi scales as if successful this type of sampling will allow live fish to be provenanced and will be able to be used to establish the provenance of international fish stocks as it is infinitely easier to ship scales around the world than fish for this process. In this way it may be possible to stimulate an international incentive to establish data bases of fish scales and encourage the international adoption of the technology without infringing international border biological protection requirements.

If the use of trace element inter-relationships in scales is as effective in determining fish provenance as using equivalent concentrations of metals in protein, it would be an easy matter to create a data base of this material. Scales would not degrade over time, which would facilitate development of new analytical and statistical protocols and cross comparison of results well into the future when new technologies are invented and could be trailed on known samples to prove their effectiveness. This is not possible with fish protein, even if it is frozen.

REFERENCES

1. Aung, M. M., Chang, Y. S. **“Traceability in a food supply chain: Safety and quality perspectives”**, *Food control* **2014,** 39, 172-184.
2. Spink, J., Moyer, D. C. **“Defining the Public Health Threat of Food Fraud”,** *Journal of Food Science* **2011**, 76 (9), 157-163.
3. Moore, J., Spink, J., Lipp, M. **“Development and application of a database of food ingredient fraud and economically motivated adulteration from 1980 to 2010”**, *Journal of Food Science* **2012**, 77 (4), 118-126.
4. Primrose, S., Woolfe, M., Rollinson, S. **“Food forensics: methods for determining the authenticity of foodstuffs”**, *Trends in food science & technology* **2010**, 21(12), 582-590.
5. Watling R.J, Lee G.S, Scadding C.J, Pilgrim T.S, Green R.L, Martin A.E, May C.D, Valentin J.L. “**The Application of Solution and Laser Ablation Based ICP-MS and Solution Based AES for the Provenance Determination of Selected Food and Drink Produce”**, *The Open and Biomedical Methods Journal* **2010**, 3, 179-196.
6. Spink, J. **“Defining Food Fraud and the Chemistry of the Crime”**, *In: Improving Import Food Safety,* Editors: Ellefson, W., Zach, L., Sullivan, D. Oxford: John Wiley & Sons; **2012**: 195-214.
7. Bail, J. **“Trends and Solutions in Combating Global Food Fraud”,** *Article from NFS international* **2014**, [Cited 25 February 2015], Available from: http://www.aig.com/Jan-2014-NSF-Article_3171_567084.html.
8. Abelson, P., Forbes, M., Hall, G. “**The Annual Cost of Foodborne Illness in Australia”**, *Australian Government, Department of Health and Ageing, Canberra;* **2006**, [Cited 25 February 2015], Available from: http://www.ozfoodnet.gov.au/internet/ozfoodnet/publishing.nsf/content/137D93E765468F17CA2572130080B157/$File/cost-foodborne.pdf.
9. Bosona, T., Gebresenbet, G. **“Food traceability as an integral part of logistics management in food and agricultural supply chain”,** *Food Control* **2013**, 33(1), 32-48.
10. Bertolini, M., Bevilacqua, M., Massini, R. **“FMECA approach to product traceability in food industry”,** *Food Control* **2006**, 17, 137-145.

11. Mace, R. **"A Case Study of Melamine as a Counterfeit Food Product Additive in Chinese Human and Animal Food Supply Chain Networks",** *Anti-Counterfeiting and Product Protection Program Paper Series* **2009**, [Cited 25 February 2015], Available from: http://acapp.msu.edu/sites/default/files/files/MelamineCaseStudy_Final.pdf.
12. Ingelfinger, J. R. **"Melamine and the global implications of food contamination",** *New England Journal of Medicine* **2008**, 359(26), 2745-2748.
13. Solodoukhina, D. **"Food Safety and Bioterrorism from Public Health Perspective",** *In: Advances in Food Protection*, Editor: Hefnawy, M. Springer, Netherlands; **2011**: 17-25.
14. Everstine, K., Spink, J., Kennedy, S. **"Economically motivated adulteration (EMA) of food: Common characteristics of EMA incidents",** *Journal of Food Protection* **2013**, 76(4), 723-735.
15. Glendinning, L. **"China dairy chief on trial over tainted milk",** *The Guardian* 31 December **2008,** [Cited 26 February 2015], Available from: http://www.theguardian.com/world/2008/dec/31/china-milk-scandal-trial.
16. Huang, H. **"The 2008 Milk Scandal Revisited"**, *Forbes* 16 July **2014**, [Cited 26 February 2015], Available from: http://www.forbes.com/sites/yanzhonghuang/2014/07/16/the-2008-milk-scandal-revisited/.
17. Warner, K., Timme, W., Lowell, B., Hirshfield, M. **"Oceana study reveals seafood fraud nationwide",** *Oceana Report*, February **2013**, [Cited 27 February 2015], Available from: http://oceana.org/reports/oceana-study-reveals-seafood-fraud-nationwide.
18. Interpol **"Tonnes of illicit foods seized across Europe in INTERPOL-Europol led operation",** *Interpol Media Release,* 06 December **2011**[Cited 26 February 2015], Available from: http://www.interpol.int/en/News-and-media/News/2011/PR101.
19. Interpol ***"INTERPOL-Europol operation results in global seizures of fake and illicit food",*** *Interpol Media Release,* 14 December **2012** [Cited 26 February 2015], Available from: http://www.interpol.int/News-and-media/News/2012/PR099.

20. Interpol **“Thousands of tonne of fake food and drink seized in INTERPOL-Europol operation,** *Interpol Media Release,* 14 February **2014** [Cited 26 February 2015], Available from: http://www.interpol.int/News-and-media/News/2014/N2014-022.
21. Lawrence, F. **“Horsemeat scandal: timeline”,** *The Guardian,* 11 May **2013**, [Cited 26 February 2015], Available from: http://www.theguardian.com/uk/2013/may/10/horsemeat-scandal-timeline-investigation.
22. Pogatchnik, S. **“10 Million Burgers with Horsemeat Recalled from British, Irish Supermarkets”,** *The Huffington Post,* 16 January **2013**, [Cited 26 February 2015], Available from: http://www.huffingtonpost.com/2013/01/16/burgers-with-horsemeat_n_2487969.html.
23. Hickman, M., Masters, S. **“Tests reveal Findus frozen beef lasagnes contain 'up to 100 per cent horsemeat”,** *The Independent,* 7 February **2013**, [Cited 26 February 2015], Available from: http://www.independent.co.uk/news/uk/home-news/tests-reveal-findus-frozen-beef-lasagnes-contain-up-to-100-per-cent-horsemeat-8485962.html.
24. Smithers, R., **“Six in 10 have changed shopping habits since horsemeat scandal, survey finds”,** *The Guardian,* 13 March **2013**, [Cited 26 February 2015] Available from: http://www.theguardian.com/uk/2013/mar/13/shopping-habits-horsemeat-scandal-survey.
25. Food Standards Australia New Zealand (FSANZ) **“A pilot survey on the identity of fish species as sold through food outlets in Australia”,** *FSANZ Report,* **2003,** [Cited 27 February 2015], Available from: http://www.foodstandards.gov.au/publications/documents/FishSpeciationReportfinal.pdf.
26. **“Huge fine for labelling bacon Australian”,** *The Sydney Morning Herald* 9 June **2010**, [Cited 27 February 2015], Available from: http://www.smh.com.au/nsw/huge-fine-for-labelling-bacon-australian-20100609-xvqb.html.
27. Grayson, M. **“Mislabeled eggs attract big fine”**, *ABC News,* 24 August **2007**, [Cited 27 February 2015], Available from: http://www.abc.net.au/site-archive/rural/qld/content/2007/s2014347.htm.

28. Food Authority NSW **“Producer fined for mislabeling eggs”,** *NSW Food Authority: Media Release,* 7 October **2012**, [Cited 27 February 2015], Available from: http://www.foodauthority.nsw.gov.au/news/media-releases/mr-07-Oct-12-producer-fined-mislabelling-eggs#.VPacr-EW2z4.

29. Worthington, B. **“ACCC fines Melbourne company for misrepresenting its honey”,** *ABC News,* 24 June **2014**, [Cited 27 February 2015], Available from: http://www.abc.net.au/news/2014-06-23/victoria-honey-fine/5544240.

30. Woolfe, M., Primrose, S. **“Food forensics: using DNA technology to combat misdescription and fraud”,** *TRENDS in Biotechnology* **2004**, 22(5), 222-226.

31. Kelly, S., Heaton, K., Hoogewerff, J., **“Tracing the geographical origin of food: The application of multi-element and multi-isotope analysis”,** *Trends in Food Science & Technology* **2005**, 16, 555-567.

32. Luykx, D. M., Van Ruth, S. M. **“An overview of analytical methods for determining the geographical origin of food products”,** *Food Chemistry* **2008**, 107(2), 897-911.

33. Schwägele, F. “**Traceability from a European Perspective**”, *Meat Science* **2005**, 71(1):164-173.

34. Bosona, T., Gebresenbet, G. **“Food traceability as an integral part of logistics management in food and agricultural supply chain”,** *Food Control* **2013**, *33*(1), 32-48.

35. Pais, I., Jones, J.B “**The Handbook of Trace Elements”**, Boca Raton: St. Lucie Press; **1997**.

36. Perez, A.L., Smith, B.W., Anderson, K.A. **“Stable isotope and trace element profiling combined with classification models to differentiate geographic growing origin for three fruits: Effects of sub region and variety”,** *Journal of Agricultural and Food Chemistry* **2006**, 54 (13), 4506-4516.

37. Anderson, K.A., Magnuson, B.A., Tschirgi, M.L., Smith, B. **“Determining the geographic origin of potatoes with trace metal analysis using statistical and neural network classifiers”,** *Journal of Agricultural and Food Chemistry* **1999**, *47*(4), 1568-1575.

38. Anderson, K.A, Smith, B.W “**Use of Chemical Profiling to Differentiate Geographic Growing Origin of Raw Pistachios**”, *Journal of Agricultural and Food Chemistry* **2005**, 53(2), 410-418.

39. Branch, S., Burke, S., Evans, P., Fairman, B., Wolff Briche, C.S.J "**A Preliminary Study in Determining the Geographical Origin of Wheat Using Isotope Ratio Inductively Coupled Plasma Mass Spectrometry with ^{13}C, ^{15}N Mass Spectrometry**", *Journal of Analytical Atomic Spectrometry* **2003**, 18(1),17-22.
40. Lo Feudo, G., Naccarato, A., Sindona, G., Tagarelli, A "**Investigating the Origin of Tomatoes and Triple Concentrated Tomato Pastes through Multielement Determination by Inductively Coupled Plasma Mass Spectrometry and Statistical Analysis**" *Journal of Agricultural and Food Chemistry* **2010**, 58(6):3801-3807.
41. Smith, R.G. "**Determination of the Country of Origin of Garlic (*Allium sativum*) Using Trace Metal Profiling**", *Journal of Agricultural and Food Chemistry* **2005**, 53(10), 4041-4045.
42. Martin, A.E., Watling, R.J., Lee, G.S. "**The Multi-Element Determination and Regional Discrimination of Australian Wines**", *Food Chemistry* **2012**, 133(3), 1081-1089.
43. Taylor, V.F., Longerich, H.P., Greenough, J.D. "**Multielement Analysis of Canadian Wines by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Multivariate Statistics**", *Journal of Agricultural and Food Chemistry* **2003**, 51(4), 856-860.
44. Ariyama, K., Horita, H., Yasui, A. "**Chemometric Techniques on Inorganic Elements Composition for the Determination of the Geographic Origin of Welsh Onions**", *Analytical Sciences* **2004**, 20(5), 871-877.
45. Moreda-Piñeiro, A., Fisher, A., Hill, S.J. **"The classification of tea according to region of origin using pattern recognition techniques and trace metal data",** *Journal of Food Composition and Analysis*, **2003**, 16(2), 195-211.
46. Pilgrim, T.S., Watling, R.J., Grice, K. **"Application of trace element and stable isotope signatures to determine the provenance of tea (Camelliasinensis) samples",** *Food Chemistry,* **2010**, 118(4), 921-926.
47. Anderson, K.A., Smith, B.W. **"Chemical profiling to differentiate geographic growing origins of coffee"**, *Journal of Agricultural and Food Chemistry,* **2002**, *50*(7), 2068-2075.

48. Valentin, J.L., Watling, R.J. **“Provenance establishment of coffee using solution ICP-MS and ICP-AES”,** *Food chemistry,* **2013,** 141(1), 98-104.

49. Franke, B., Haldimann, M., Reimann, J., Baumer, B., Gremaud, G., Hadorn, R., et al. “**Indications for the Applicability of Element Signature Analysis for the Determination of the Geographic Origin of Dried Beef and Poultry Meat**”, *European Food Research and Technology* **2007**, 225(3), 501-509.

50. Sacco, D., Brescia, M.A., Buccolieri, A., Caputi, J.A. **“Geographical origin and breed discrimination of Apulian lamb meat samples by means of analytical and spectroscopic determinations”**, Meat Science **2005**, 71, 542-548.

51. Franke, B.M., Gremaud, G., Hadorn, R., Kreuzer, M. “**Geographic Origin of Meat: Elements of an Analytical Approach to its Authentication**” *European Food Research and Technology* **2005**, 221(3), 493-503.

52. Pellerano, R.G., Uñates, M.A., Cantarelli, M.A., Camiña, J.M., Marchevsky, E.J. **“Analysis of Trace Elements in Multifloral Argentine Honeys and their Classification According to Provenance**”, *Food Chemistry* **2012**, 134(1), 578-582.

53. Renou, J.P., Deponge, C., Gachon, P., Bonnefoy, J.C., Coulon, J.B., Garel, J.P. **“Characterization of animal products according to geographic origin and feeding diet using nuclear magnetic resonance and isotope ratio mass spectrometry: Cow milk”,** *Food Chemistry* **2004,** 85(1), 63–66.

54. Camin, F., Wietzerbin, K., Cortes, A.B., Haberhauer, G., Lees, M., Versini, G. “**Application of Multielement Stable Isotope Ratio Analysis to the Characterization of French, Italian, and Spanish Cheeses**”, *Journal of Agricultural and Food Chemistry* **2004**, 52(21), 6592-6601.

55. Rossmann, A., Haberhauer, G., Hölzl, S., Horn, P., Pichlmayer, F., Voerkelius, S. “**The Potential of Multielement Stable Isotope Analysis for Regional Origin Assignment of Butter**”, *European Food Research and Technology* **2000,** 211(1), 32-40.

56. Peres, B., Barlet, N., Loiseau, G., Montet, D. **“Review of the current methods of analytical traceability allowing determination of the origin of foodstuffs”,** *Food Control* **2007**, 18, 228-235.

57. Wong, H.K., Hanner, R.H. **“DNA barcoding detects market substitution in North American seafood”,** *Food Research International* **2008**, 41, 828-837.

58. Miller, D.D., Mariani, S. **“Smoke, mirrors, and mislabeled cod: poor transparency in the European seafood industry”,** *Frontiers in Ecology and the Environment* **2010**, 8, 517-521.

59. Cawthorn, D.M, Steinman, H.A, Witthuhn, R.C. **“DNA barcoding reveals a high incidence of fish species misrepresentation and substitution on the South African market”,** *Food Research International* **2012**, 46 (1), 30-40.

60. Sharif, D.M.I, “**Discrimination of Australian and South East Asia Barramundi (*Lates calcarifer*) Using 14 Microsatellite Markers**”, MSc Thesis (University of Western Australia) to be submitted 2015.

61. The Australian Barramundi Farmers Association, **“Barramundi”**, [Cited 25 April 2014], Available from: http://www.abfa.org.au/barramundi.html.

62. Fact Sheet: **“*Lates calcarifer* (Bloch 1790)”** *FAO Species Fact Sheets*, [Cited 25 April 2014], Available from: http://www.fao.org/fishery/species/3068/en.

63. Schipp, G., Bosmans, J., Humphrey, J. **“Barramundi Farming Handbook”**, *Department of Primary Industry, Fisheries and Mines, Northern Territory Government:* **2007**.

64. Nelson, J.S., **“Fishes of the World”**, 3rd ed. New York: John Wiley & Sons; **1994**.

65. Rimmer, M.A. **“Cultured Aquatic Species Information Programme: *Lates calcarifer*”**, *In: FAO Fisheries and Aquaculture Department,* **2006,** [Updated 3 June 2006, Cited 27 April 2014], Available from: http://www.fao.org/fishery/culturedspecies/Lates_calcarifer/en#tcNA0078.

66. Grey, D.L. **“An overview of *Lates calcarifer* in Australia and Asia”,** *In: Management of Wild and Cultured Sea Bass/Barramundi (Lates calcarifer),* Editors: Copland, J.W., Grey, D.L., Proceedings of an International Workshop held at Darwin, Australia, 24-30 September 1986. Australian Centre for International Agricultural Research Proceedings No. 20. **1987:** 15-21.

67. Almendras, J.M., Duenas, C., Nacario, J., Sherwood, N.M., Crim, L.W. **“Sustained hormone release. III. Use of gonadotropin releasing hormone analogues to induce multiple spawnings in sea bass, *Lates calcarifer*”**, *Aquaculture* **1988**, 74, 97-111.

68. Guiguen, Y., Cauty, C., Fostier, A., Fuchs, J., Jalabert, B. **“Reproductive cycle and sex inversion of the sea bass, *Lates calcarifer,* reared in sea cages in French Polynesia: histological and morphometric description”,** *Environmental Biology of Fishes* **1994**, 39(3), 231-247.

69. Job, S. **(2011) “Barramundi Aquaculture”**, *In: Recent Advances and New Species in Aquaculture,* Editors: Fotedar, R. K., Phillips, B. F. Hoboken: Wiley & Sons; **2011**: 199-230.
70. Schipp, G. **“Barramundi farming in the Northern Territory”,** *Department of Primary Industry and Fisheries, Darwin, Australia*: **1996.**
71. Staunton-Smith J., Robins, J.B., Sellin, M.J., Halliday, I.A., Mayer, D.G. **“Does the quantity and timing of fresh water flowing into a dry tropical estuary affect year-class strength of barramundi (*Lates calcarifer*)?”** *Marine and Freshwater Research* **2004**, 55 (8), 787-797.
72. Makaira Pty Ltd **“The Translocation of Barramundi: A discussion paper”**, *Fisheries Management Paper 127, WA Department of Fisheries, Perth:* **1999**.
73. Russell, D.J., Rimmer, M.A. **“Stock enhancement of barramundi in Australia”,** *In: ‘FAO Fishery Technical Paper 429, Marine Ranching,* Editors: Bartley, D.M., Leber, K.M. FAO, Rome; **2004:** 73-108.
74. Skirtun, M., Sahlqvist, P., Vieira, S. “**Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)”**, “*Australian Fisheries Statistics 2012”*, [Cited 30 April 2014], Available from: http://data.daff.gov.au/data/warehouse/9aam/afstad9aamd003/2012/AustFishStats_2012_v1.0.0.pdf.
75. Coleman, A.P.M. **“The National Recreational Fishing Survey: The Northern Territory”,** *Northern Territory Department of Business, Industry and Resource Development. Fishery Report 72,* **2004**.
76. McInnes, K. **“Experimental results from the fourth Queensland recreational fishing diary program 2005”,** *Queensland Department of Primary Industries and Fisheries, Brisbane,* **2008**.
77. Newman, S.J., Skepper, C., Mitsopoulos, G., McAuley, R., Green, R. **(2011) “North coast near shore and estuarine fishery status report”**, *In: State of the fisheries and aquatic resources report 2010/11,* Editors: Fletcher W.J, Santoro K. *Western Australia Department of Fisheries, Perth;* **2004** 183–189.
78. Yue, G.H., Zhu, Z.Y., Lo, L.C., Wang, C.M., Lin, G., Feng, F. et.al **“Genetic variation and population structure of Asian sea bass (*Lates calcarifer*) in the Asia-Pacific region”,** *Aquaculture* **2009**, 293(1), 22-28.
79. Tucker, J.W. Jr, Russell, D.J., Rimmer, M.A. **“Barramundi culture: A success story for aquaculture in Asia and Australia”,** *World Aquaculture* **2002**, 33 (3), 53-59.

80. FAO Fisheries and Aquaculture Department, **"FishStat Plus"** *Fisheries and aquaculture software* **2012** [Cited 5 May 2014], Available from: http://www.fao.org/fishery/statistics/software/fishstat/en.

81. MacKinnon, M.R. **"Rearing and growth of larval and juvenile barramundi (*Lates calcarifer*) in Queensland",** *In: Management of wild and cultured sea bass/barramundi (Lates calcarifer),* Editors: Copland, J.W., Grey, D.L., Proceedings of an International Workshop held at Darwin, Australia, 24-30 September 1986. Australian Centre for International Agricultural Research Proceedings No. 20. **1987:** 148-153**.**

82. Harrison, P., Calogeras, C., Phillips, M. **"Farming of Barramundi/Asian Seabass: An Australian Industry Perspective",** *In: Biology and Culture of Asian Seabass Lates calcarifer,* Editors: Jerry, D.R., Boca Raton: Taylor and Francis; **2013**: 258-272.

83. Birch, D., Lawley, M. **"Repositioning Australian Farmed Barramundi: Online Consumer Survey Findings",** *Australian Seafood Cooperative Research Centre and the University of the Sunshine Coast,* September **2010**.

84. Jacquet, J.L., Pauly, D., **"Trade secrets: renaming and mislabeling of seafood",** *Marine Policy* **2008,** 32(3), 309-318**.**

85. **"Health Act of 1985",** WA. [Cited 7 May 2014], Available From: https://www.health.wa.gov.au/publications/documents/HealthAct1911.pdf.

86. Hoare, M., **"Fish species substitution identification: When Barra on Mundi may be Nile perch on Tuesday",** *Chemistry In Australia,* **1995**, 62, 12-13.

87. Choice, **"Fish out of Water"**, *Australia Consumers Association*, **1988**, July 3-8.

88. Tam, J., **"Identification of Meat and Fish Species using High Performance Liquid Chromatography",** *Research Project CSC3292 Practicum 2, Edith Cowan University.* **1994**.

89. **"Butcher fined for selling perch as barramundi",** *ABC News* 12 July **2005**, [Cited 8 May 2014], Available from: http://www.abc.net.au/news/2005-07-12/butcher-fined-for-selling-perch-as-barramundi/2057004.

90. Phillips, M. **"*The Australian Barramundi Industry Addressing Cheap Imports*"**, *Nuffield Australia Farming Scholars Report* **2010**, [Cited 7 May 2014], Available from http://www.nuffieldinternational.org/rep_pdf/1295000212Marty_Phillips_Report_FINAL_2010_.pdf.

91. Hoffman, E.D., Stroobant, V. “**Mass Spectrometry: Principles and Applications**”, 3rd Edition, West Sussex: Wiley & Sons; **2007**.

92. Skoog, D.A., Holler, F.J., Nieman, T.A. “**Principles of Instrumental Analysis**”, 5th Edition, Philadelphia: Harcourt Brace & Company; **1998**.

93. Ammann, A.A. **“Inductively coupled plasma mass spectrometry (ICP MS): a versatile tool”,** *Journal of Mass Spectrometry*, **2007**, 42(4), 419-427.

94. Linge, K.L., Jarvis, K.E. **“Quadrupole ICP-MS: Introduction to Instrumentation, Measurement Techniques and Analytical Capabilities”**, *Geostandards and geoanalytical research*, **2009**, 33(4), 445-467.

95. Moore, G.L. **“Introduction to inductively coupled plasma atomic emission spectrometry”,** Amsterdam: Elsevier Science Publishers; 2002.

96. Hill, S.J., Fisher, A., Foulkes, M. **“Basic Concepts and Instrumentation for Plasma Spectrometry”,** *In: Inductively coupled plasma spectrometry and its applications*, Editor: Hill, S.J. Oxford: John Wiley & Sons; **2008**, 61-97.

97. Rencher, A.C. “**Methods of multivariate analysis”** 2nd Edition, New York: John Wiley & Sons; **2003**, 380-407.

APPENDIX

(Trace Element Data of Barramundi Samples after analysis from solution based ICP-AES and ICP-MS)

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
Study 1A Country of Origin																
Carpentaria 1	222	2.83	1280	1720	2750	81.1	13.4	< 0.100	1400	731	9.93	249	3.69	32.9	76.9	2100
Carpentaria 2	194	3.67	1250	1670	2430	98.6	15.2	< 0.100	2200	981	22.3	244	4.49	34.7	96.8	3080
Carpentaria 3	216	2.2	1170	1610	2670	76.6	14.4	0.155	1360	849	16.5	252	3.11	25.4	72.1	1930
Carpentaria 4	234	3.49	1410	1700	2850	79.3	11	< 0.100	834	168	34.3	240	2.6	17.6	61.2	2230
Carpentaria 5	233	4.04	1430	1690	2670	86.3	12.9	< 0.100	799	269	18.6	234	2.48	19.1	63.9	2320
Carpentaria 6	187	4.14	1210	1480	2130	77.3	15.2	< 0.100	1100	1240	12.9	210	2.45	17.5	64.1	1990
Carpentaria 7	199	5.48	1460	1610	2330	100	14.9	< 0.100	1320	1380	11	229	2.99	35.3	102	2650
Carpentaria 8	233	3.94	1410	1630	2730	80.7	11.9	< 0.100	928	895	9.56	240	1.89	19.2	86.3	1770
Carpentaria 9	209	3.93	1230	1480	2500	75.2	13	< 0.100	843	264	41	226	2.07	21.2	84.9	1870
Carpentaria 10	177	5.26	1280	1500	1840	95.3	17.1	< 0.100	1070	733	10.1	203	3.37	24.8	87.3	1820
Carpentaria 11	181	3.81	1210	1480	2000	78	15.7	< 0.100	778	377	15.8	215	2.95	23.4	76.7	1750
Carpentaria 12	204	3.95	1270	1540	2300	79.4	14.4	< 0.100	714	4560	7.69	217	2.6	25.2	76.5	1600
USA 1	255	1.18	1390	1720	3730	87.3	10.1	< 0.100	699	3390	14.5	242	1.28	15.9	47.8	1930
USA 2	257	1.33	1410	1730	3710	80.3	10.1	< 0.100	713	291	8.54	243	0.711	15	44.3	1890
USA 3	242	1.32	1380	1710	3600	84	8.99	< 0.100	677	1480	23.1	247	0.921	14.2	42.3	2000
USA 4	256	1.03	1430	1780	3970	85	9.49	< 0.100	731	308	9.4	261	0.424	15.2	46.6	1700
USA 5	243	1.13	1310	1700	3760	83.9	9.64	< 0.100	686	1240	19.3	253	0.902	14.8	44.4	1790
USA 6	257	1.01	1400	1740	3960	80.1	10.6	< 0.100	678	1520	54.9	258	0.62	12.6	55.1	3340
USA 7	261	1.2	1410	1760	3710	87.1	7.31	< 0.100	635	761	23	242	0.319	7.67	43.3	1400
USA 8	239	1.02	1310	1630	3600	74.2	7.42	< 0.100	651	313	6.66	248	0.661	11.6	43.7	2250
USA 9	258	0.752	1430	1790	3900	81.6	8.96	< 0.100	572	384	22.2	258	0.475	9.8	36.1	2000
USA 10	249	1.77	1410	1790	3510	80.9	9.29	< 0.100	799	68.2	13.6	256	0.146	17.1	48.3	1750
USA 11	255	1.25	1390	1770	3850	78.3	8.49	< 0.100	711	581	39.2	256	0.666	12.8	44.3	1410
USA 12	250	1.18	1380	1740	3690	82.9	9.65	< 0.100	816	190	11.7	257	0.356	15.8	46.8	1570
USA 13	245	2.53	1250	1740	2990	93.9	6.47	< 0.100	789	1460	11.1	238	0.274	16	79.2	1890
USA 14	237	1.47	1180	1570	3230	87	9.83	< 0.100	626	2110	7.37	235	0.766	12.1	62.6	1390
USA 15	263	1.49	1320	1730	3410	101	8.9	< 0.100	754	129	31	250	0.137	8.19	74.5	1650
USA 16	268	1.15	1290	1770	3390	107	10.8	< 0.100	592	26.2	6.66	261	0.601	10.8	94.9	1830
USA 17	253	1.76	1220	1720	3160	103	10.6	< 0.100	634	329	11	251	0.629	11.3	99.8	1550
USA 18	293	1.21	1460	1970	3750	121	10.6	< 0.100	750	2810	30.3	289	0.691	9.93	106	1890
Taiwan 1	213	0.876	1200	1500	2280	117	2.17	< 0.100	154	788	12.4	182	2.57	18.3	74.3	3280
Taiwan 2	175	1.79	1030	1550	1610	79.4	3.44	< 0.100	188	815	7.2	186	2.58	23.5	102	6740
Taiwan 3	204	1.53	1010	1740	1560	79.9	4.7	< 0.100	170	1270	6.87	224	1.93	22.8	98.2	3320
Taiwan 4	208	1.58	936	1490	1670	71.8	4.65	< 0.100	177	522	32.2	201	1.65	34.6	98.9	2270
Taiwan 5	217	1.36	1130	1610	2200	64.7	2.44	< 0.100	149	401	25.9	201	1.41	28.4	65.1	3100
Taiwan 6	202	1.61	1080	1470	1970	67.8	2.45	< 0.100	165	665	16.1	201	1.18	18.3	69.7	2480
Study 1B Dorsal vs. Ventral Muscle																
Innisfail Queensland 14	260	0.437	1380	1620	3620	146	3.98	< 0.100	457	839	13.6	269	2.41	17.5	103	1230
Innisfail Queensland 15	269	0.414	1380	1620	4060	92	2	< 0.100	265	488	12.6	225	1.55	9.89	82	1890
Wingfield S. Australia 29	242	0.952	1260	1510	3070	117	3.39	< 0.100	398	445	16.8	240	1.53	15.6	71.6	2820
Wingfield S. Australia 30	257	0.925	1310	1540	3340	117	2.59	< 0.100	303	173	16.1	206	1.75	17.5	98.9	2040
Indonesia 47	248	2	1230	1800	3030	73.6	9.79	< 0.100	297	1500	15.8	249	2.62	17.5	120	1790
Indonesia 48	204	2.07	950	1440	2070	66.7	10.2	< 0.100	282	163	26.6	190	2.4	12.4	154	1630
New Zealand 29	178	2.95	940	1370	1810	70.5	4.43	< 0.100	151	1190	12	177	3.38	20.7	137	3580
New Zealand 30	179	2.07	790	1440	1400	82.7	4.34	< 0.100	148	843	4.45	182	3.29	20.1	94.7	2760

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
Study 2A National and International Provenance Data Base																
Innisfail Queensland 1	240	0.421	1230	1440	3270	183	2.79	< 0.100	486	1350	13.1	260	1.83	17.7	124	2830
Innisfail Queensland 2	257	0.424	1260	1530	3810	105	1.71	< 0.100	417	1470	15.1	226	1.03	10.5	88	2280
Innisfail Queensland 3	261	0.397	1250	1580	3720	110	2.15	< 0.100	334	439	16.2	228	1.56	10.8	122	1770
Innisfail Queensland 4	265	0.543	1350	1530	3770	480	2.87	< 0.100	399	1440	15.2	231	2.13	12.6	245	1530
Innisfail Queensland 5	269	0.514	1360	1570	3950	110	1.85	< 0.100	350	1030	11.1	218	1.98	12.1	109	2250
Innisfail Queensland 6	279	0.505	1340	1600	3800	112	2.17	< 0.100	344	504	14.2	224	1.83	11.3	148	1930
Innisfail Queensland 7	245	0.522	1210	1440	3350	164	2.8	< 0.100	422	513	16.5	222	1.84	16.8	109	2320
Innisfail Queensland 8	267	0.584	1300	1580	3930	95.5	1.56	< 0.100	245	299	7.62	216	0.99	9.49	107	2100
Innisfail Queensland 9	268	0.52	1330	1620	3640	123	2.33	< 0.100	247	591	11.8	214	1.56	11.4	149	1970
Innisfail Queensland 10	265	0.488	1270	1520	3500	132	2.37	< 0.100	335	500	12.6	227	1.71	15	114	2520
Innisfail Queensland 11	283	0.499	1420	1620	4000	231	2.06	< 0.100	251	317	10.9	230	1.77	12.5	134	2320
Innisfail Queensland 12	253	0.29	1270	1490	3280	97.6	2.23	< 0.100	190	222	6.9	185	1.23	9.23	120	1290
Innisfail Queensland 13	258	0.312	1290	1520	3580	94.3	1.78	< 0.100	233	247	8.12	205	1.33	10.1	93	1930
Wingfield S. Australia 1	247	0.746	1430	1450	3110	881	4.11	< 0.100	421	3790	12.1	273	1.9	15.7	99.2	1410
Wingfield S. Australia 2	222	0.672	1140	1370	3120	93.9	1.91	< 0.100	180	252	10.2	180	1.26	8.7	73.8	1570
Wingfield S. Australia 3	211	0.587	1120	1270	2930	79.2	1.7	< 0.100	243	276	13.2	163	1.44	8.67	59.2	1430
Wingfield S. Australia 4	223	1.24	1170	1410	3110	84	3.03	< 0.100	309	429	12.9	195	1.45	9.82	60.9	2050
Wingfield S. Australia 5	215	0.756	1190	1340	3140	116	2.04	< 0.100	268	384	4.23	165	1.1	8.06	54.6	1660
Wingfield S. Australia 6	270	1.2	1350	1580	3840	102	1.7	< 0.100	310	474	16.9	213	0.828	8.3	80.6	1700
Wingfield S. Australia 7	272	0.972	1370	1630	3560	136	2.99	< 0.100	296	423	18.1	256	1.55	14.8	63.5	2390
Wingfield S. Australia 8	268	0.958	1370	1590	3800	109	2.19	< 0.100	176	263	22.6	212	1.56	10.4	66.4	1730
Wingfield S. Australia 9	263	0.918	1340	1570	3600	105	2.06	< 0.100	170	173	20.7	203	1.49	11.4	72.7	1640
Wingfield S. Australia 10	265	1.13	1460	1510	3730	848	3.56	< 0.100	365	425	15.6	234	1.79	17	114	1990
Wingfield S. Australia 11	267	1.15	1290	1580	3870	119	1.91	< 0.100	227	270	14.2	221	0.796	9.97	105	2170
Wingfield S. Australia 12	254	1.15	1250	1530	3550	101	2.68	< 0.100	356	1300	13.4	248	0.99	10.9	85.9	3980
Wingfield S. Australia 13	250	0.891	1240	1470	3490	98.9	2.15	< 0.100	290	296	16.7	219	0.484	9.67	80.7	3050
Wingfield S. Australia 14	241	0.748	1220	1480	3220	97.4	1.96	< 0.100	275	211	25.8	190	1.26	9.76	87	1720
Wingfield S. Australia 15	247	0.82	1290	1510	3570	91	1.49	< 0.100	252	350	15.1	212	0.555	9.22	73.9	1930
Wingfield S. Australia 16	262	0.821	1340	1550	3430	113	2.21	< 0.100	311	587	25.8	250	0.783	15	61.6	2200
Wingfield S. Australia 17	256	0.721	1300	1590	3540	118	2.44	< 0.100	212	333	11.5	206	1.84	11.2	91.4	1760
Wingfield S. Australia 18	240	0.651	1300	1480	3460	93.6	1.89	< 0.100	227	698	12.7	186	1.48	9.54	67.7	1580
Wingfield S. Australia 19	257	0.802	1360	1530	3470	558	3.26	< 0.100	242	458	14.9	220	1.53	11.4	82.2	2600
Wingfield S. Australia 20	287	0.809	1450	1700	3920	123	2.54	< 0.100	217	305	16.7	221	2.15	13.8	83.1	2300
Wingfield S. Australia 21	303	0.792	1530	1670	4150	218	2.71	< 0.100	262	217	21.1	230	2.33	13.9	74.1	1850
Wingfield S. Australia 22	290	1.03	1380	1670	3830	137	2.24	< 0.100	190	308	17.3	222	1.56	12.7	128	2050
Wingfield S. Australia 23	266	1.06	1440	1580	3480	584	3.4	< 0.100	251	456	11.8	234	1.35	13.3	95.3	2510
Wingfield S. Australia 24	237	0.947	1250	1490	3090	176	3.19	< 0.100	293	876	13.1	196	2.05	12.3	77.4	2580
Wingfield S. Australia 25	236	1.1	1280	1380	3230	274	2.37	< 0.100	433	743	13.8	228	0.585	14.9	72.7	3690
Wingfield S. Australia 26	272	1.16	1470	1590	4010	112	1.43	< 0.100	264	607	41.9	238	0.565	10.7	88.4	2560
Wingfield S. Australia 27	236	0.811	1290	1470	3200	100	2.39	< 0.100	226	285	7.77	186	1.36	8.91	87	1570
Wingfield S. Australia 28	258	1.07	1270	1510	3450	113	2.05	< 0.100	404	308	11.7	203	0.731	9.91	90.4	2310
Cowley Queensland 1	271	1.92	1360	1530	3440	79.7	0.492	< 0.100	113	1740	19.9	252	1.91	12.7	95.9	2560
Cowley Queensland 2	273	1.74	1460	1570	3530	98.4	0.515	< 0.100	126	2590	12.9	270	1.77	19.8	79.7	2730
Cowley Queensland 3	210	1.59	1170	1180	2380	279	0.574	< 0.100	205	6440	33.5	244	2.24	22.3	93.9	4220
Cowley Queensland 4	216	1.28	1260	1480	3310	86.2	0.358	< 0.100	89.9	611	22.8	247	2.35	13.7	44.1	2940
Cowley Queensland 5	210	1.21	1300	1390	3370	76.8	0.283	< 0.100	83.7	693	11.2	227	2.26	9.63	32.6	3300
Cowley Queensland 6	201	1.26	1280	1260	3270	73.6	0.482	< 0.100	89.8	1080	10.6	207	2.2	24.1	32.6	3440
Cowley Queensland 7	250	1.83	1260	1420	3320	68.8	0.475	< 0.100	99	609	11.7	242	1.33	16	104	2670
Cowley Queensland 8	266	1.74	1260	1460	3270	86.4	0.417	< 0.100	95.2	859	11.7	254	1.52	19.5	127	2520

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
Cowley Queensland 9	226	1.71	1120	1310	2630	149	0.625	< 0.100	127	997	10.5	232	1.36	17.9	99.5	2880
Cowley Queensland 10	225	1.62	1140	1400	3020	82.6	0.404	< 0.100	78	1270	27.9	222	1.96	12.5	59.5	1830
Cowley Queensland 11	215	1.58	1170	1370	2970	68.3	0.369	< 0.100	80.5	1050	20.8	214	1.91	11.7	44	1940
Cowley Queensland 12	210	1.8	1170	1350	2880	75.4	0.539	< 0.100	89.7	1240	17.1	224	1.87	14.7	55	2350
Cowley Queensland 13	227	1.49	1180	1380	2690	79.2	0.761	< 0.100	89.9	711	11.4	225	1.72	9.33	52.4	2180
Cowley Queensland 14	220	2.34	1200	1330	2660	61.4	1.23	< 0.100	97.2	3090	17.6	255	2.55	11.6	38.7	3130
Cowley Queensland 15	179	1.24	1080	1010	2120	229	0.704	< 0.100	162	2400	8.76	183	2	31.1	55.2	3790
Good Fortune 1	246	0.623	1270	1550	3170	71.7	9.32	< 0.100	394	1490	20.3	257	1.8	22.2	92.9	5650
Good Fortune 2	239	0.64	1340	1490	3090	66.8	7.21	< 0.100	399	2460	19.5	275	1.82	25.1	101	9330
Good Fortune 3	243	0.718	1230	1350	3160	80	7.65	< 0.100	398	2070	8.21	236	1.63	24.2	89.8	3120
Good Fortune 4	262	0.685	1250	1460	3340	97.2	7.02	< 0.100	373	1660	24.1	244	1.35	15.6	110	2700
Good Fortune 5	268	0.679	1300	1560	3320	85.1	6.72	< 0.100	380	247	14.6	283	1.7	17.2	172	2940
Good Fortune 6	270	0.648	1340	1530	3420	102	5.91	< 0.100	383	539	10.2	250	1.38	20.6	93.5	2950
Good Fortune 7	274	0.878	1320	1540	3410	88.8	7.53	< 0.100	422	734	22.2	254	1.9	34.5	95.1	2410
Good Fortune 8	299	0.823	1410	1680	3520	136	6.8	< 0.100	387	2300	14	266	1.79	18	128	3190
Good Fortune 9	221	0.652	1170	1230	2680	83.8	8.05	< 0.100	426	1240	16.4	227	1.53	38.5	96.3	3340
Good Fortune 10	308	1.18	1510	1750	3580	110	10.8	< 0.100	468	1340	16.7	302	2.66	28.5	113	6340
Good Fortune 11	283	0.785	1320	1590	3370	119	7.72	< 0.100	449	593	14	294	1.86	29.6	147	3130
Good Fortune 12	272	0.716	1330	1530	3270	98.7	6.87	< 0.100	406	1130	18	262	1.64	40.1	114	2860
Good Fortune 13	264	0.693	1330	1520	3280	81.7	6.13	< 0.100	389	645	9.12	243	1.36	24	92.2	2320
Good Fortune 14	256	0.891	1320	1560	3150	80.1	11.1	< 0.100	442	696	10.6	267	1.89	26.6	97.9	2880
Good Fortune 15	227	0.587	1200	1240	3090	71.9	6.56	< 0.100	409	665	8.79	235	1.25	27.9	84.4	2090
Indonesia 1	235	2.33	1100	1690	2760	67.9	10.4	< 0.100	301	1460	15.1	267	2.79	12.8	112	1970
Indonesia 2	237	2.42	1180	1690	2870	66.4	11.2	< 0.100	275	663	12.7	270	2.55	27.9	134	1980
Indonesia 3	228	3.01	1030	1680	2270	84.9	13.2	< 0.100	436	1680	18.8	269	3.6	27.7	194	2530
Indonesia 4	267	3.23	1110	1890	2690	90.4	3.57	< 0.100	447	2070	17.4	287	3.18	13.6	243	2390
Indonesia 5	282	3.32	1140	2040	2740	92.8	3.42	< 0.100	417	1240	16.9	302	3.4	12.6	305	2280
Indonesia 6	283	3.67	1010	1880	2290	102	4.59	< 0.100	558	739	24.5	280	4.28	15.2	362	2740
Indonesia 7	256	2.7	1140	1840	2890	84.7	13.7	< 0.100	354	561	8.49	305	3.03	14.6	137	1940
Indonesia 8	283	2.85	1230	2110	3120	91	11.4	< 0.100	325	285	30.8	299	2.69	11.3	139	2070
Indonesia 9	259	2.6	1150	1880	2990	84.2	9.81	< 0.100	343	715	10.4	286	2.75	13.4	162	1680
Indonesia 10	272	2.78	1200	2020	2980	92.7	12.1	< 0.100	366	496	31.1	303	2.97	12.3	164	1750
Indonesia 11	275	3.03	1200	1920	2800	97.1	13.4	< 0.100	507	433	17.3	290	3.89	13.5	242	1870
Indonesia 12	266	3.1	1060	1860	2450	113	17	< 0.100	571	539	10.9	305	4.81	21.9	278	2760
Indonesia 13	262	3.07	1090	1700	2680	76.1	26.6	< 0.100	555	821	23.1	266	2.87	14.5	195	2730
Indonesia 14	241	3.9	1030	1480	2360	83	22.7	< 0.100	681	1080	32.5	217	3.97	16.5	281	6100
Indonesia 15	315	3.9	1150	1920	2440	93.3	20.8	< 0.100	831	1290	6.99	281	4.51	17	369	2890
Indonesia 16	269	1.46	1290	2080	3310	100	12.5	< 0.100	275	328	14.3	314	2.61	12.8	136	1800
Indonesia 17	257	2.64	1130	1870	2710	101	14.5	< 0.100	346	360	14.5	284	3.23	13.3	192	2480
Indonesia 18	273	1.8	1280	2120	3050	101	14.3	< 0.100	367	572	49.9	312	2.59	13.9	141	1910
Indonesia 19	258	2.82	1130	1660	2610	70.6	13.5	< 0.100	524	510	32.1	255	2.74	11.8	148	1800
Indonesia 20	263	3.05	1150	1670	2730	68.7	13	< 0.100	511	194	26.5	225	2.74	13.2	200	1970
Indonesia 21	280	4.05	1030	1680	2090	87.7	13.8	< 0.100	739	877	7.26	243	4.82	14.8	402	2510
Indonesia 22	263	2.4	1180	1720	3070	71	16.4	< 0.100	560	287	14.1	250	2.87	15.9	155	2020
Indonesia 23	274	3.57	1240	1700	2850	75.2	16.2	< 0.100	671	398	28.5	243	3.56	14.1	255	1610
Indonesia 24	268	3.69	1070	1620	2370	92.7	17.6	< 0.100	831	857	12.2	232	4.2	16.7	281	2410
Indonesia 25	280	1.65	1350	1990	3230	80.4	12.6	< 0.100	359	862	14.4	278	2.52	15.7	107	2240
Indonesia 26	273	2.46	1210	1870	3060	93.6	10.4	< 0.100	375	1340	7.84	280	3.44	16.9	213	2240
Indonesia 27	285	2.87	1230	1870	3050	81.8	10.2	< 0.100	490	254	19.5	270	3.55	13.8	287	1880
Indonesia 28	290	1.91	1270	2030	3170	94.9	14.8	< 0.100	368	662	13.7	278	3.05	12.2	161	2140
Indonesia 29	252	3.62	1030	1830	2350	111	19.3	< 0.100	544	286	14.8	251	3.77	17.9	211	4110

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
Indonesia 30	281	3.12	1200	1860	2790	101	16.1	< 0.100	479	406	21.8	247	3.82	18.1	258	2500
Indonesia 31	251	3.32	1230	1820	2910	68.2	9.23	< 0.100	281	333	20.1	248	2.54	11.9	116	2030
Indonesia 32	264	3.33	1290	1940	3040	73.1	10.5	< 0.100	286	769	25.6	258	2.61	13.7	111	1440
Indonesia 33	262	2.91	1270	1930	2770	75.6	11.5	< 0.100	350	466	12.3	255	2.89	14.3	138	1500
Indonesia 34	253	2.75	1130	1780	2630	71.5	8.6	< 0.100	392	306	29.1	241	2.9	14.4	187	1800
Indonesia 35	255	3.59	1040	1680	2270	80.7	9.06	< 0.100	512	301	20.7	221	4.17	16.1	299	1900
Indonesia 36	273	3.77	1080	1950	2380	85.5	9.07	< 0.100	576	15600	14.3	261	4.44	17.8	346	2530
Indonesia 37	253	2.69	1250	1920	2960	60.1	3.97	< 0.100	278	828	34	249	2.45	12.5	154	2030
Indonesia 38	236	2.51	1250	1740	2860	59.9	4.22	< 0.100	259	540	16.7	225	2.66	12.5	133	3570
Indonesia 39	240	2.11	1210	1780	2930	62.6	4.05	< 0.100	240	677	17.4	229	2.06	13.5	117	1740
Indonesia 40	282	2.66	1340	2130	2830	79.8	12.4	< 0.100	438	519	13.1	267	3.08	16.4	167	1660
Indonesia 41	263	2.52	1280	1910	2850	71.5	13.7	< 0.100	396	308	12.3	245	2.71	21.8	167	2060
Indonesia 42	269	2.49	1270	1910	2920	73.5	12.5	< 0.100	415	284	23.4	247	2.91	18	195	1650
Indonesia 43	272	4.03	1130	1870	2450	91.9	10.2	< 0.100	573	1050	21.1	241	4.7	21.2	351	2120
Indonesia 44	277	3.88	1090	1820	2280	99	11.3	< 0.100	549	1240	27.4	223	4.64	18.7	351	4440
Indonesia 45	242	3.76	908	1680	1830	102	11.5	< 0.100	637	783	12.8	211	4.81	20.1	354	2260
Indonesia 46	294	2.51	1400	2120	3490	87	10.8	< 0.100	330	454	10.2	278	2.73	16.2	162	2810
Taiwan 7	190	0.92	1190	1470	2170	54.7	2.37	< 0.100	151	517	9.97	179	2.82	18.2	73.4	7180
Taiwan 8	236	1.18	1130	1650	2310	91.7	3.04	< 0.100	167	922	20.6	200	2.31	42.4	93.3	2510
Taiwan 9	239	0.83	1290	1660	2650	86.8	2.04	< 0.100	148	651	9.86	205	1.97	18.8	85.6	2640
Taiwan 10	237	0.959	1160	1660	2530	89.2	1.8	< 0.100	140	533	22.2	209	1.76	15	90.6	2160
Taiwan 11	243	1.03	1150	1580	2390	92.3	4.54	< 0.100	120	512	11.7	202	1.56	16.4	98.1	1870
Taiwan 12	241	0.797	1180	1590	2680	79	3.24	< 0.100	126	335	9.7	205	1.36	15.5	79.9	1660
Taiwan 13	221	0.913	1110	1480	2400	73.9	3.38	< 0.100	135	421	11.5	196	1.79	18.4	83.9	2310
Taiwan 14	223	1.49	1010	1530	1950	84.8	4.2	< 0.100	159	803	12.8	199	1.75	15.3	101	2200
Taiwan 15	234	1.21	1180	1630	2520	91	1.86	< 0.100	130	397	18.5	209	1.23	15.6	78.3	2350
Taiwan 16	220	1.06	1220	1580	2430	79.8	1.79	< 0.100	126	456	8.19	236	1.33	15.7	63.1	2760
Taiwan 17	251	1.32	1240	1780	2570	95.8	2.25	< 0.100	143	330	14.9	233	1.24	13.7	89.4	2110
Taiwan 18	220	1.02	1240	1560	2400	80.8	1.42	< 0.100	148	370	19.6	209	1.23	18.8	68	4480
New Zealand 1	244	1.68	1160	1690	2470	92.8	4.13	< 0.100	145	510	12.8	213	3.2	16.8	121	2350
New Zealand 2	177	2.22	829	1440	1490	67.2	4.1	< 0.100	140	591	6.21	185	3.07	17.4	104	5570
New Zealand 3	240	1.42	1140	1730	2510	89.1	3.54	< 0.100	126	490	25.9	216	2.73	14.1	120	2200
New Zealand 4	183	2.33	820	1460	1410	89.7	4.81	< 0.100	141	782	4.63	186	2.7	17.9	113	2750
New Zealand 5	179	2.69	955	1660	1500	86	7.55	< 0.100	177	1510	7.21	204	3.52	27.9	130	4650
New Zealand 6	205	3.03	892	1560	1600	92.9	6.45	< 0.100	146	949	5.65	191	2.65	16.4	151	2160
New Zealand 7	231	2.86	1080	1630	2140	147	5.97	< 0.100	157	772	9.5	197	2.33	16.1	120	2450
New Zealand 8	212	2.78	910	1550	2040	111	4.42	< 0.100	141	963	14.2	187	2.81	20.9	121	2780
New Zealand 9	159	3.28	939	1530	1360	445	5.57	< 0.100	165	767	11.4	185	4.89	52.7	143	9630
New Zealand 10	167	2.27	745	1290	1250	89.3	4.13	< 0.100	199	529	9.22	174	2.61	22.8	76.9	2150
New Zealand 11	199	3.02	887	1540	1700	78.8	6.62	< 0.100	141	523	7.56	184	2.71	18.2	101	2840
New Zealand 12	217	3.26	926	1560	1860	260	7.19	< 0.100	147	933	15.2	188	3.55	38	165	3760
New Zealand 13	201	2.53	1080	1400	2130	84.6	5.52	< 0.100	203	612	7.53	184	3.02	26	78.9	1890
New Zealand 14	263	3.36	1170	1860	2720	105	5.07	< 0.100	138	451	12.8	209	2.35	11.5	146	1950
New Zealand 15	234	3.59	1060	1760	2230	79.4	6.67	< 0.100	145	737	10.6	201	2.79	14.3	102	2750
New Zealand 16	219	3.7	879	1540	1710	110	6.26	< 0.100	153	670	8.24	180	2.62	22.3	131	2710
New Zealand 17	177	3.31	742	1630	1280	89.2	4.25	< 0.100	146	619	8.63	182	2.77	18.5	110	3200
New Zealand 18	229	2.21	988	1640	2310	97.5	4.39	< 0.100	165	488	24.3	200	2.84	16.4	156	4580
New Zealand 19	217	1.96	1030	1580	1990	412	5.13	< 0.100	172	666	23.7	200	3.7	17.8	114	5510
New Zealand 20	195	3.4	893	1660	1480	94.6	6.14	< 0.100	169	868	8.06	192	3.06	19.1	137	5950
New Zealand 21	246	3.24	1130	1730	2520	101	5.99	< 0.100	172	681	9.22	205	2.74	17.8	188	2150
New Zealand 22	183	2.54	1060	1190	2110	449	6.28	< 0.100	219	920	19	166	3.56	22.4	187	6180

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
New Zealand 23	198	3.3	806	1520	1550	97.2	5.76	< 0.100	142	891	5.32	182	2.25	16.9	126	3180
New Zealand 24	234	3.41	985	1560	2240	107	5.28	< 0.100	145	528	8.81	186	2.4	13	145	2490
New Zealand 25	156	2.29	883	1080	1650	65.8	4.78	< 0.100	215	1220	5.65	142	3.22	27.8	78.8	2550
New Zealand 26	192	3.32	890	1590	1340	180	6.45	< 0.100	168	1460	12	181	4.12	24.5	134	5890
New Zealand 27	217	2.91	880	1460	2000	95.1	4.47	< 0.100	120	493	9.41	165	2.09	11.7	118	1690
New Zealand 28	290	3.08	1400	1940	3180	112	6.22	< 0.100	178	662	16.5	225	3.37	14.6	129	2730
Cone Bay Fish 1	142	0.47	630	813	2500	48.1	5.34	< 0.100	155	54.1	1.75	135	0.895	5.74	31.6	666
Cone Bay Fish 2	165	0.342	780	944	2750	52.9	5.1	< 0.100	141	87.6	3.66	147	0.879	6.4	29.6	638
Cone Bay Fish 3	137	0.35	756	758	2210	53	7.38	< 0.100	221	246	4.36	159	1.03	11.7	33.8	1160
Cone Bay Fish 4	169	0.139	840	926	2590	57.7	5.82	< 0.100	168	111	10.1	159	1.09	9.17	32.2	794
Cone Bay Fish 5	144	0.178	647	807	2400	56.6	6.17	< 0.100	151	73.3	2.69	163	1.33	8.06	32.8	1630
Cone Bay Fish 6	167	0.165	805	901	2580	524	11.5	< 0.100	184	105	16.3	174	1.57	8.71	60.4	4480
Cone Bay Fish 7	141	0.229	614	753	2170	57.8	6.99	< 0.100	158	31	5.37	145	0.925	7.71	53.2	889
Cone Bay Fish 8	180	0.286	865	1030	2500	86.8	8.74	< 0.100	181	143	11.8	186	1.24	7.9	73.7	1170
Cone Bay Fish 9	178	0.247	844	992	2520	82.3	9.2	< 0.100	175	113	5.41	181	1.73	21.4	86.2	1110
Cone Bay Fish 10	165	0.223	787	888	2450	56	7.18	< 0.100	192	127	11.6	167	1.08	9.66	36.9	832
Cone Bay Fish 11	137	0.209	625	763	2270	87.9	8.5	< 0.100	166	64.3	6.09	150	1.06	6.01	32.6	1410
Cone Bay Fish 12	166	0.265	898	963	2500	64.6	9.51	< 0.100	202	286	3.84	180	1.24	11.6	39.3	1340
Cone Bay Fish 13	196	0.264	938	1120	2860	82.8	6.57	< 0.100	150	134	6.66	193	1.23	7.76	67.3	1100
Cone Bay Fish 14	152	0.222	774	824	2260	67.6	7.27	< 0.100	196	88.3	5.91	157	1.03	9.26	32.8	1190
Cone Bay Fish 15	171	0.251	882	1000	2600	48.7	6.79	< 0.100	168	102	17.7	175	1.12	7.2	32.1	904
Cone Bay Fish 16	11.7	0.187	161	58.8	201	10.4	1.82	< 0.100	313	260	3.44	79.5	0.581	25.6	7.51	2360
Cone Bay Fish 17	171	0.246	777	919	2540	61.6	5.4	< 0.100	161	75.5	3.62	174	1.03	9.44	51.3	1070
Cone Bay Fish 18	197	0.222	1040	1100	2830	255	6.86	< 0.100	173	85.2	7.83	185	1.06	6.93	57.6	2180
Cone Bay Fish 19	158	0.259	780	883	2580	54.7	6.39	< 0.100	168	127	5.27	164	0.983	5.97	29.6	812
Cone Bay Fish 20	161	0.215	823	964	2430	52.6	9.8	< 0.100	170	101	5.96	172	1.09	7.89	29.1	905
Cone Bay Fish 21	163	0.246	805	900	2500	48.6	8.17	< 0.100	178	189	10.7	154	1.07	7.36	30.2	799
Cone Bay Fish 22	143	0.182	805	731	2070	201	7.17	< 0.100	241	76.9	3.79	143	0.817	14.8	36.5	1670
Cone Bay Fish 23	140	0.254	717	758	2380	50.2	7.5	< 0.100	180	60.3	8.32	143	0.889	9.84	34.3	1360
Cone Bay Fish 24	166	0.243	859	930	2680	52.8	7.06	< 0.100	165	50.7	3.1	167	0.952	10.1	33.6	1210
Cone Bay Fish 25	146	0.207	724	850	2380	217	8.26	< 0.100	157	70.7	8.01	164	1.09	9.01	36.7	1830
Cone Bay Fish 26	115	< 0.100	686	577	1650	491	11.5	< 0.100	268	133	4.29	132	1.13	17.6	60.1	4920
Cone Bay Fish 27	86.5	< 0.100	557	491	1250	109	11	< 0.100	233	74.2	4.94	104	1.01	15.8	34.1	2100
Cone Bay Fish 28	156	0.191	833	918	2120	102	12.5	< 0.100	184	72.2	6.7	158	1.29	9.31	54.4	1620
Cone Bay Fish 29	151	0.2	833	839	2210	44.8	5.93	< 0.100	217	75.4	7.29	153	1.06	16.2	29.6	952
Cone Bay Fish 30	139	0.189	727	732	2080	43.6	6.28	< 0.100	212	85.6	8.54	152	1.12	16.4	33.8	1040
Study 2B Unknown sample trace back																
Unknown Taiwan Fish 1	188	1.57	879	1320	1370	97.6	19.6	< 0.100	214	194	8.99	270	3.98	16.6	40	1900
Unknown Taiwan Fish 2	180	0.905	934	1260	2120	62.4	4.77	< 0.100	100	150	4.79	202	5.44	11.5	39.7	1230
Unknown Taiwan Fish 3	186	0.985	986	1320	1840	80.6	2.74	< 0.100	104	193	13.1	218	2.74	7.58	45.2	1160
Unknown Taiwan Fish 4	172	1.36	868	1200	1840	84	6.36	< 0.100	85	155	8.04	196	2.18	10.3	60.6	1370
Unknown Taiwan Fish 5	164	0.899	832	1090	1820	75.9	3.16	< 0.100	107	110	5.32	193	2.33	9.22	50	1020
Unknown Taiwan Fish 6	173	1.14	884	1190	2000	80.2	4.08	< 0.100	96.5	93.3	12.4	178	2.16	9.84	56.2	1540
Unknown Taiwan Fish 7	137	0.601	831	863	1570	53.4	1.8	< 0.100	226	298	5.06	187	1.52	17.1	33.5	808
Unknown Taiwan Fish 8	183	1.37	961	1250	2380	77.8	3.02	< 0.100	99.1	165	15.2	215	1.71	8.44	67.7	1210
Unknown Australian Fish 1	178	0.495	946	1060	2270	75	4.17	< 0.100	159	131	8.16	183	1.04	9.26	56.6	1400
Unknown Australian Fish 2	178	0.493	850	1060	2270	73.7	3.25	< 0.100	118	63.8	10.4	189	0.992	15.6	68	1100
Unknown Australian Fish 3	131	0.506	724	763	1730	60	3.63	< 0.100	188	93.2	4.98	143	0.973	12.5	42.8	1550

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	Mg2795	Si2516	P1774	S1807	K7664	Ca4226	7 Li	9 Be	11 B	27 Al	45 Sc	49 Ti	51 V	53 Cr	55 Mn	57 Fe
Unknown Australian Fish 4	172	0.654	943	1070	2350	53.5	3.7	< 0.100	134	202	13.8	179	1.14	10.6	42.3	1310
Unknown Australian Fish 5	116	0.459	637	685	1630	48.7	3.37	< 0.100	190	221	4.52	138	0.872	13	30.1	1220
Unknown Australian Fish 6	164	0.393	886	1050	2120	57.6	2.41	< 0.100	129	3260	5.52	163	0.99	9.69	47	902
Unknown Australian Fish 7	167	0.47	937	1030	2290	58.6	3	< 0.100	132	68.6	4.31	166	0.954	11.2	42.5	1840
Unknown Australian Fish 8	150	0.471	835	869	2050	51	3.17	< 0.100	166	112	3.74	166	0.83	10.3	33.6	1470

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
Study 1A Country of Origin															
Carpentaria 1	0.467	33.4	142	3060	2.02	1.41	2540	361	914	310	0.832	35.3	0.464	2.87	< 0.100	0.265
Carpentaria 2	0.921	28.3	174	3850	2.1	1.5	2040	355	885	472	1.15	71.4	1.07	3.59	< 0.100	0.503
Carpentaria 3	0.402	11.9	120	2790	2.51	1.69	3100	423	892	285	0.554	24.6	0.701	1.4	< 0.100	0.184
Carpentaria 4	0.199	5.56	143	2770	2.16	1.92	3410	451	835	316	0.196	6.81	0.403	1.83	< 0.100	< 0.100
Carpentaria 5	0.313	7.16	130	2790	2.03	1.59	2910	390	746	369	0.243	8	0.526	2.3	< 0.100	< 0.100
Carpentaria 6	0.317	8.29	148	2830	2.13	1.53	2440	360	633	447	0.282	11.9	0.534	2.51	< 0.100	< 0.100
Carpentaria 7	0.553	10.3	162	4650	1.84	1.47	3020	353	716	631	0.406	15.4	0.822	3.64	< 0.100	0.14
Carpentaria 8	0.223	6.54	116	2840	2.48	1.63	4380	417	817	377	0.262	9.05	0.523	2.14	< 0.100	< 0.100
Carpentaria 9	0.384	5	110	2750	2.62	1.71	4610	439	755	365	0.255	9.34	0.639	2.13	< 0.100	< 0.100
Carpentaria 10	0.621	13.9	151	3570	1.86	1.33	1760	329	562	637	0.468	17.3	0.636	3.69	< 0.100	< 0.100
Carpentaria 11	0.316	8.21	134	2800	2.1	1.66	2290	359	622	491	0.372	14.2	0.525	3.06	< 0.100	< 0.100
Carpentaria 12	0.347	7.61	109	2500	2.69	1.53	2650	388	720	446	0.575	12	0.637	2.54	< 0.100	< 0.100
USA 1	0.293	8.61	118	3310	3.47	1.3	3890	297	1280	210	0.209	1.53	0.491	1.23	< 0.100	< 0.100
USA 2	0.194	7.13	103	3060	2.48	1.29	3820	283	1210	207	0.143	1.14	0.433	1.29	< 0.100	0.259
USA 3	0.339	6.85	110	3330	2.66	1.23	3800	290	1210	196	0.242	1.47	0.551	1.38	< 0.100	< 0.100
USA 4	0.167	4.59	112	3260	2.76	1.37	4600	313	1330	199	0.161	0.98	0.42	0.91	< 0.100	< 0.100
USA 5	0.207	3.73	110	3290	3.24	1.55	4950	331	1270	189	0.176	1.88	0.298	0.621	< 0.100	< 0.100
USA 6	0.148	4.36	104	3090	2.92	1.38	4500	297	1320	195	< 0.100	0.97	0.343	0.724	< 0.100	< 0.100
USA 7	< 0.100	3.33	113	2810	2.89	1.17	4570	272	1220	167	< 0.100	0.71	0.343	0.59	< 0.100	< 0.100
USA 8	0.459	3.06	141	3230	3.05	1.46	4850	306	1250	162	< 0.100	0.396	< 0.100	0.771	< 0.100	< 0.100
USA 9	0.137	3.35	118	3010	2.89	1.38	4760	284	1310	160	< 0.100	0.581	0.29	0.697	< 0.100	< 0.100
USA 10	0.232	5.02	126	2990	2.32	1.26	4090	290	1220	198	< 0.100	0.717	0.263	0.976	0.184	< 0.100
USA 11	0.24	2.77	120	2920	3.06	1.47	4820	331	1310	175	0.156	0.735	0.265	0.588	< 0.100	< 0.100
USA 12	0.338	5.22	118	2930	2.66	1.37	4940	323	1280	184	< 0.100	1.03	0.406	0.757	< 0.100	< 0.100
USA 13	0.134	12.6	130	3430	1.59	1.02	3310	258	1040	200	0.233	1.21	0.453	0.991	< 0.100	< 0.100
USA 14	0.195	5.7	103	2610	3.07	1.33	4620	315	1130	165	0.166	0.51	0.273	0.72	< 0.100	< 0.100
USA 15	0.181	3.97	107	2640	2.33	1.23	4230	289	1180	172	< 0.100	0.677	< 0.100	0.744	< 0.100	< 0.100
USA 16	0.282	2.79	114	2810	2.57	1.33	4900	306	1170	191	< 0.100	0.56	0.34	1.16	< 0.100	< 0.100
USA 17	0.293	4.61	126	3440	2.33	1.32	4360	308	1080	195	< 0.100	0.811	0.418	0.81	< 0.100	< 0.100
USA 18	0.228	4.25	130	3170	2.97	1.49	4740	316	1280	194	< 0.100	0.688	0.463	0.837	< 0.100	< 0.100
Taiwan 1	0.96	5.54	165	3250	3.55	1.17	468	284	2570	278	< 0.100	19.4	< 0.100	1.2	< 0.100	0.231
Taiwan 2	3.31	8.41	438	5510	3.01	1.12	228	263	2020	307	0.151	0.944	< 0.100	2.39	< 0.100	< 0.100
Taiwan 3	3.57	6.19	232	3080	2.46	1.06	186	258	1970	281	< 0.100	0.86	< 0.100	1.32	< 0.100	< 0.100
Taiwan 4	2.16	7.02	118	2640	2.4	0.817	232	232	2220	260	< 0.100	0.509	0.21	1.3	< 0.100	< 0.100
Taiwan 5	1.64	6.62	139	2310	3.17	1.08	199	308	3260	177	< 0.100	0.589	0.13	1.17	< 0.100	< 0.100
Taiwan 6	2.06	5.43	114	2350	3.2	1.25	229	288	3200	183	< 0.100	0.695	< 0.100	1.16	< 0.100	< 0.100
Study 1B Dorsal vs. Ventral Muscle															
Innisfail Queensland 14	0.909	12.3	217	4010	2.37	1.03	500	258	3470	695	0.378	1.33	0.634	1.83	0.129	< 0.100
Innisfail Queensland 15	0.5	3.24	121	2810	2.39	1.12	472	239	3890	260	0.157	0.768	0.331	1.92	< 0.100	< 0.100
Wingfield S. Australia 29	0.373	4.77	182	2650	2.24	0.844	373	177	3520	376	0.135	0.927	0.268	1.29	0.249	< 0.100
Wingfield S. Australia 30	0.327	3.8	113	2630	1.95	0.68	357	148	3820	237	< 0.100	0.415	0.186	2.18	< 0.100	< 0.100
Indonesia 47	0.657	3.51	82.9	2260	3.84	2.33	956	599	1020	297	< 0.100	0.566	< 0.100	0.693	< 0.100	< 0.100
Indonesia 48	0.515	1.96	72.5	1810	2.91	1.81	789	479	693	362	< 0.100	0.214	< 0.100	0.771	< 0.100	< 0.100
New Zealand 29	2.89	14.5	118	2430	2.61	0.793	510	228	1450	254	< 0.100	1.34	0.239	1.34	< 0.100	< 0.100
New Zealand 30	3	8.73	88	2130	2.19	0.941	466	266	1110	269	< 0.100	0.833	0.127	1.23	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
Study 2A National and International Provenance Data Base																
Innisfail Queensland 1	1.29	10.1	159	2680	2.48	1.2	613	248	3250	943	0.386	3.9	0.936	2.11	< 0.100	< 0.100
Innisfail Queensland 2	0.974	4.06	142	3250	2.63	1.19	557	243	4150	305	0.45	2.3	0.638	1.69	< 0.100	< 0.100
Innisfail Queensland 3	0.886	3.87	116	2620	2.31	1.05	567	249	3850	327	0.183	1.53	0.535	1.14	< 0.100	< 0.100
Innisfail Queensland 4	1.37	18.2	159	3430	2.78	1.27	468	262	4070	3620	0.822	1.53	0.618	1.65	< 0.100	< 0.100
Innisfail Queensland 5	0.753	8.79	138	3270	2.29	0.988	494	255	4080	265	0.344	1.32	0.347	1.45	< 0.100	< 0.100
Innisfail Queensland 6	0.772	4.3	124	2800	2.24	1.01	512	257	4110	278	0.152	1.06	0.265	1.42	< 0.100	< 0.100
Innisfail Queensland 7	1	4.83	119	2710	2.39	1.04	586	253	3430	699	0.265	1.38	0.408	1.74	< 0.100	< 0.100
Innisfail Queensland 8	0.708	3.22	125	2670	2.27	1.12	513	220	4230	228	0.183	0.867	0.252	1.55	< 0.100	< 0.100
Innisfail Queensland 9	0.676	3.7	115	2970	1.99	0.793	450	189	3650	261	0.297	0.861	0.191	1.18	< 0.100	< 0.100
Innisfail Queensland 10	0.99	4.08	126	2660	2.43	1.1	514	263	3820	489	0.205	0.755	0.418	1.77	< 0.100	< 0.100
Innisfail Queensland 11	0.945	6.3	138	2930	2.73	0.901	495	238	4370	1150	0.284	0.692	0.82	1.43	< 0.100	< 0.100
Innisfail Queensland 12	0.665	2.19	93.3	2290	1.67	0.825	406	190	3240	191	< 0.100	0.271	0.163	1.03	< 0.100	< 0.100
Innisfail Queensland 13	0.526	3.58	117	2580	1.97	0.91	436	205	3360	205	0.238	0.581	0.452	1.18	< 0.100	< 0.100
Wingfield S. Australia 1	1.04	19.9	137	2700	2.88	0.809	512	192	3690	4560	0.323	1.14	0.425	1.54	< 0.100	< 0.100
Wingfield S. Australia 2	0.265	2.48	96.7	2180	1.73	0.692	386	148	3550	166	< 0.100	0.552	0.143	0.735	< 0.100	< 0.100
Wingfield S. Australia 3	0.286	2.35	84.5	1860	1.61	0.529	317	124	3320	156	< 0.100	0.268	0.143	0.667	< 0.100	< 0.100
Wingfield S. Australia 4	0.304	2.48	161	2370	2.11	0.613	297	156	3730	236	< 0.100	0.613	0.126	1.25	< 0.100	< 0.100
Wingfield S. Australia 5	0.247	2.72	103	2620	1.66	0.722	309	143	3430	331	0.143	0.268	0.182	0.71	< 0.100	< 0.100
Wingfield S. Australia 6	0.26	2.95	124	2490	2.34	0.678	366	165	4710	183	< 0.100	0.632	< 0.100	1.08	< 0.100	< 0.100
Wingfield S. Australia 7	0.333	8.31	131	2550	2.42	0.716	440	185	4170	435	< 0.100	0.682	0.159	1.03	< 0.100	< 0.100
Wingfield S. Australia 8	0.282	3.12	110	2440	2.28	0.814	413	166	4280	248	0.127	0.557	0.192	1.26	< 0.100	< 0.100
Wingfield S. Australia 9	0.279	2.4	100	2300	2.11	0.834	399	166	4010	200	< 0.100	0.201	0.869	0.798	< 0.100	< 0.100
Wingfield S. Australia 10	1.03	18.3	168	2810	2.83	0.796	437	188	4580	4330	0.177	0.665	0.273	1.77	< 0.100	< 0.100
Wingfield S. Australia 11	0.304	3.51	129	2480	2.56	0.787	413	161	4760	200	< 0.100	0.568	< 0.100	1.33	< 0.100	< 0.100
Wingfield S. Australia 12	0.527	3.43	227	3590	2.75	0.929	456	208	5070	282	< 0.100	0.537	0.263	1.31	0.159	< 0.100
Wingfield S. Australia 13	0.354	3.26	176	2920	2.34	0.886	399	189	4500	209	< 0.100	0.611	< 0.100	1.37	< 0.100	< 0.100
Wingfield S. Australia 14	0.29	2.37	108	2130	1.85	0.746	321	141	3850	154	< 0.100	0.214	0.209	0.889	< 0.100	< 0.100
Wingfield S. Australia 15	0.363	2.48	124	2490	2.23	0.876	361	166	4560	191	< 0.100	0.478	< 0.100	0.778	< 0.100	< 0.100
Wingfield S. Australia 16	0.375	3.43	118	2480	2.33	0.881	431	194	3820	310	< 0.100	0.612	< 0.100	1.01	< 0.100	< 0.100
Wingfield S. Australia 17	0.371	4.18	103	2330	2.11	0.878	377	160	3870	237	< 0.100	0.539	0.318	1.01	< 0.100	< 0.100
Wingfield S. Australia 18	0.294	2.62	96.4	2470	1.91	0.684	354	159	3590	195	< 0.100	0.158	< 0.100	0.789	< 0.100	< 0.100
Wingfield S. Australia 19	0.68	11.6	147	2650	2.55	0.76	431	178	4300	2870	0.182	0.495	< 0.100	1.51	< 0.100	< 0.100
Wingfield S. Australia 20	0.329	4.11	126	2550	2.35	0.726	458	156	4510	200	< 0.100	0.41	0.259	1.29	< 0.100	< 0.100
Wingfield S. Australia 21	0.365	5.85	113	2400	2.45	0.715	449	155	5030	827	< 0.100	0.388	0.343	1	< 0.100	< 0.100
Wingfield S. Australia 22	0.288	3.86	124	2520	2.39	0.715	349	161	4620	208	< 0.100	0.544	0.234	1.21	< 0.100	< 0.100
Wingfield S. Australia 23	0.653	12.6	128	2620	2.62	0.946	341	176	4150	2980	0.167	0.73	0.185	1.63	< 0.100	< 0.100
Wingfield S. Australia 24	0.326	3.93	124	2470	2.04	0.644	302	149	3500	634	< 0.100	0.479	0.146	0.919	< 0.100	< 0.100
Wingfield S. Australia 25	0.474	7.19	159	2340	2.61	0.798	494	191	3500	1120	0.182	0.888	0.239	0.964	< 0.100	< 0.100
Wingfield S. Australia 26	0.355	3.36	147	3360	2.53	1.02	461	190	4430	280	< 0.100	0.378	< 0.100	1.15	< 0.100	< 0.100
Wingfield S. Australia 27	0.247	3.05	97	2360	1.88	0.764	386	155	3330	156	< 0.100	< 0.100	0.368	0.629	< 0.100	< 0.100
Wingfield S. Australia 28	0.304	4.25	131	2910	2.41	0.656	393	158	4210	259	< 0.100	0.871	0.226	1.13	< 0.100	< 0.100
Cowley Queensland 1	0.94	4.84	128	2220	3.94	0.746	285	174	4250	26.2	< 0.100	10.7	0.206	1.39	0.131	0.19
Cowley Queensland 2	0.972	8.12	127	2790	4.19	0.795	286	191	4510	46.5	0.176	3.39	< 0.100	1.28	< 0.100	0.138
Cowley Queensland 3	1.78	9.48	243	2340	4.11	0.659	424	204	2970	191	0.22	2.46	< 0.100	3.32	< 0.100	0.141
Cowley Queensland 4	0.636	3.82	142	2190	3.79	0.691	67.2	171	4700	20.4	< 0.100	1.54	< 0.100	0.541	< 0.100	< 0.100
Cowley Queensland 5	0.577	3.47	140	2290	3.59	0.593	52	175	4630	21.7	< 0.100	0.887	< 0.100	0.394	< 0.100	< 0.100
Cowley Queensland 6	0.559	3.87	143	1870	3.58	0.756	57.5	182	4450	34.5	< 0.100	0.927	0.162	0.647	< 0.100	< 0.100
Cowley Queensland 7	1.47	3.49	133	2330	3.8	0.733	224	201	3980	38.1	0.202	0.86	< 0.100	1.17	< 0.100	< 0.100
Cowley Queensland 8	1.56	4.28	98.9	2020	3.76	0.707	230	200	3640	34.5	< 0.100	0.823	0.274	1.12	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
Cowley Queensland 9	1.85	6.57	120	2230	3.39	0.887	295	214	2950	109	< 0.100	0.719	0.181	1.6	< 0.100	< 0.100
Cowley Queensland 10	0.708	3.7	152	1970	3.35	0.468	213	137	3700	32.4	< 0.100	0.69	< 0.100	0.858	< 0.100	< 0.100
Cowley Queensland 11	0.755	2.99	168	2160	3.32	0.543	177	133	3650	35.5	< 0.100	1.57	< 0.100	0.937	< 0.100	< 0.100
Cowley Queensland 12	0.779	3.22	176	1990	3.2	0.533	221	142	3510	40	0.199	0.732	< 0.100	0.794	< 0.100	< 0.100
Cowley Queensland 13	0.778	3.83	144	2260	3.16	0.454	153	122	3340	40	0.127	1.39	< 0.100	1.01	< 0.100	< 0.100
Cowley Queensland 14	0.778	3.37	150	2350	3.9	0.541	139	134	3420	48.8	0.351	1.09	0.351	1.04	< 0.100	< 0.100
Cowley Queensland 15	1.21	11.1	138	1870	3.76	0.6	373	154	2560	216	0.17	0.706	< 0.100	1.75	0.227	< 0.100
Good Fortune 1	2.7	5.1	309	2980	4.24	0.94	410	210	848	249	0.128	0.823	< 0.100	0.9	< 0.100	< 0.100
Good Fortune 2	3.47	9.24	464	3760	4.55	0.875	444	211	806	212	0.22	0.696	< 0.100	1.42	< 0.100	< 0.100
Good Fortune 3	2.48	6.88	163	3000	4.36	0.889	512	218	841	237	< 0.100	0.788	0.128	0.808	< 0.100	< 0.100
Good Fortune 4	2.19	4.54	128	3210	4.43	0.903	434	204	934	190	0.191	0.55	< 0.100	0.533	< 0.100	< 0.100
Good Fortune 5	1.66	4.09	146	2630	4.33	0.948	408	212	941	211	< 0.100	0.74	0.262	0.645	0.148	< 0.100
Good Fortune 6	1.79	4.66	135	2850	4.89	0.822	461	224	924	291	0.232	0.622	< 0.100	0.602	0.21	< 0.100
Good Fortune 7	3.37	11.4	114	2430	4.84	0.883	508	243	922	239	0.154	0.463	< 0.100	0.678	< 0.100	< 0.100
Good Fortune 8	1.54	6.81	140	2730	4.11	0.659	364	190	972	372	0.208	0.277	< 0.100	0.964	< 0.100	< 0.100
Good Fortune 9	2.09	6.82	172	5250	3.99	0.833	647	212	691	205	0.184	0.702	0.191	1.32	0.172	< 0.100
Good Fortune 10	4.5	10.8	138	2830	4.51	0.918	442	207	943	328	0.826	0.596	< 0.100	1.05	< 0.100	< 0.100
Good Fortune 11	1.39	7.71	147	3240	4.34	0.922	461	238	1060	329	< 0.100	0.617	< 0.100	1.19	< 0.100	< 0.100
Good Fortune 12	2.29	14	134	3490	4.54	1.11	489	227	887	212	0.182	1.24	< 0.100	0.94	< 0.100	< 0.100
Good Fortune 13	1.08	5.32	111	2280	4.1	0.804	466	206	900	221	< 0.100	0.455	< 0.100	1.06	< 0.100	< 0.100
Good Fortune 14	4.45	10.7	193	3670	4	0.736	402	220	843	278	0.264	0.781	< 0.100	0.857	< 0.100	< 0.100
Good Fortune 15	1.65	4.65	119	2470	4.23	0.99	593	217	810	192	0.149	0.511	0.144	0.736	< 0.100	< 0.100
Indonesia 1	0.505	2.61	117	2380	3.12	1.38	570	372	767	338	< 0.100	0.343	< 0.100	0.957	< 0.100	< 0.100
Indonesia 2	0.548	2.33	97.3	2340	3.09	1.39	532	369	805	347	< 0.100	2.33	< 0.100	1.22	< 0.100	< 0.100
Indonesia 3	0.642	3.52	112	2740	2.86	1.25	539	395	625	524	0.176	1.11	< 0.100	1.51	< 0.100	< 0.100
Indonesia 4	0.571	3.28	118	2430	2.99	1.11	133	261	1830	529	< 0.100	0.545	< 0.100	0.994	< 0.100	< 0.100
Indonesia 5	0.446	2.51	87.4	2230	3.15	1.13	97.6	255	1950	543	< 0.100	0.355	< 0.100	1.18	< 0.100	< 0.100
Indonesia 6	0.649	3.17	87.6	2020	2.92	1.07	151	244	1530	714	< 0.100	0.379	< 0.100	1.46	< 0.100	< 0.100
Indonesia 7	0.605	2.84	94.8	2420	3.67	2.11	1510	520	976	387	< 0.100	0.333	< 0.100	1.01	0.181	< 0.100
Indonesia 8	0.633	2.81	89.5	2110	3.23	1.69	1130	392	934	337	< 0.100	0.176	< 0.100	0.865	< 0.100	< 0.100
Indonesia 9	0.506	3.24	80.7	2060	3.07	1.75	1240	496	912	353	< 0.100	0.359	< 0.100	1.06	< 0.100	< 0.100
Indonesia 10	0.646	2.65	86.4	2090	3.4	1.71	1760	457	788	328	< 0.100	0.312	< 0.100	0.837	< 0.100	< 0.100
Indonesia 11	0.808	3.54	83	2380	3.48	1.7	1710	466	723	534	< 0.100	0.328	< 0.100	1.24	< 0.100	< 0.100
Indonesia 12	0.888	6.68	96.4	2820	2.93	1.61	1700	456	645	679	< 0.100	0.296	< 0.100	1.67	< 0.100	< 0.100
Indonesia 13	0.986	3.09	115	2430	3.33	1.25	769	341	799	498	< 0.100	0.451	< 0.100	1.09	< 0.100	< 0.100
Indonesia 14	1.24	3.63	174	2730	2.91	1.29	638	295	658	740	0.258	0.726	< 0.100	1.37	< 0.100	< 0.100
Indonesia 15	1.18	3.9	124	3170	2.72	1.15	688	310	833	785	0.21	0.505	< 0.100	1.35	< 0.100	< 0.100
Indonesia 16	0.82	2.27	85.8	2340	3.52	1.68	988	455	912	274	< 0.100	0.252	< 0.100	0.525	< 0.100	< 0.100
Indonesia 17	0.868	3.37	86.8	2950	3.75	1.81	954	469	758	423	< 0.100	0.34	< 0.100	0.806	< 0.100	< 0.100
Indonesia 18	0.819	2.46	85.4	2830	3.43	1.91	1000	459	843	331	< 0.100	0.313	< 0.100	0.648	< 0.100	< 0.100
Indonesia 19	0.449	2.02	74.4	2060	3.23	1.26	631	363	862	424	< 0.100	0.444	< 0.100	0.805	< 0.100	< 0.100
Indonesia 20	0.559	1.86	88.9	2180	3.05	1.44	603	318	897	470	< 0.100	0.206	< 0.100	0.862	< 0.100	< 0.100
Indonesia 21	0.872	3.12	102	2710	2.34	1.04	482	312	705	790	< 0.100	0.571	< 0.100	1.14	< 0.100	< 0.100
Indonesia 22	0.689	2.68	116	2260	3.65	1.34	358	377	787	383	< 0.100	0.281	< 0.100	1.11	< 0.100	< 0.100
Indonesia 23	0.612	2.87	80.5	2150	3.55	1.23	343	306	776	527	< 0.100	0.324	< 0.100	1.16	< 0.100	< 0.100
Indonesia 24	0.809	3.66	122	2920	3.06	1.33	385	337	643	753	< 0.100	0.698	< 0.100	1.49	< 0.100	< 0.100
Indonesia 25	0.392	2.51	94.5	2480	3.71	1.73	1220	442	836	334	< 0.100	0.457	< 0.100	0.85	< 0.100	< 0.100
Indonesia 26	0.47	3.13	75.2	2250	3.79	1.6	1100	439	834	458	< 0.100	0.523	< 0.100	0.925	< 0.100	< 0.100
Indonesia 27	0.434	2.42	76.5	2200	3.75	1.63	1020	436	867	515	< 0.100	0.374	< 0.100	1.03	< 0.100	< 0.100
Indonesia 28	0.66	2.95	86.9	2210	3.84	1.54	1020	405	964	318	< 0.100	0.616	< 0.100	0.759	< 0.100	< 0.100
Indonesia 29	0.79	3.24	108	2490	2.8	1.42	851	391	648	648	< 0.100	0.273	< 0.100	1.06	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
Indonesia 30	0.687	3.22	96.8	2420	3.21	1.7	1120	424	873	555	< 0.100	0.406	< 0.100	1.3	< 0.100	< 0.100
Indonesia 31	0.758	2.1	121	2510	3.73	1.56	784	459	851	295	< 0.100	0.691	< 0.100	0.763	< 0.100	< 0.100
Indonesia 32	0.523	1.94	83.1	2180	3.5	1.84	875	490	897	288	< 0.100	0.314	< 0.100	0.843	< 0.100	< 0.100
Indonesia 33	0.699	1.83	84	2100	3.22	1.61	839	479	764	360	< 0.100	0.823	< 0.100	0.682	< 0.100	< 0.100
Indonesia 34	0.567	2.49	75.2	1990	3.6	1.96	213	521	1050	482	< 0.100	0.336	< 0.100	0.802	< 0.100	< 0.100
Indonesia 35	0.632	2.87	72	2030	2.81	1.82	214	522	909	718	< 0.100	0.254	< 0.100	1.32	< 0.100	< 0.100
Indonesia 36	0.836	3.41	95.9	3380	3.82	2.02	406	548	939	736	< 0.100	0.916	< 0.100	1.28	< 0.100	< 0.100
Indonesia 37	0.534	2.09	116	2370	3.61	1.52	281	372	1070	306	< 0.100	0.419	< 0.100	0.815	< 0.100	< 0.100
Indonesia 38	0.923	3.87	187	3190	4.03	1.42	354	389	1040	296	0.266	0.367	< 0.100	1.01	0.137	< 0.100
Indonesia 39	0.611	2.49	86.4	1920	3.77	1.36	300	376	1050	278	< 0.100	0.354	< 0.100	0.556	< 0.100	< 0.100
Indonesia 40	0.518	2.93	85	2400	3.49	1.34	869	363	942	406	< 0.100	0.307	< 0.100	0.978	< 0.100	< 0.100
Indonesia 41	0.53	2.79	127	2790	3.87	1.42	938	367	957	389	< 0.100	0.316	< 0.100	1.23	0.145	< 0.100
Indonesia 42	0.64	3.07	78	1950	3.98	1.53	853	356	1040	400	< 0.100	0.338	< 0.100	1.21	< 0.100	< 0.100
Indonesia 43	0.774	4.82	90	2200	3.22	1.48	156	368	1350	724	0.127	0.491	< 0.100	1.4	0.155	< 0.100
Indonesia 44	0.842	4.15	80	2120	3.24	1.4	151	347	1260	781	< 0.100	0.494	< 0.100	1.27	< 0.100	< 0.100
Indonesia 45	0.795	3.93	85.8	2140	2.43	1.24	167	337	919	871	< 0.100	0.437	< 0.100	1.41	< 0.100	< 0.100
Indonesia 46	0.684	3.73	98.1	2610	5.01	2.17	1110	693	1230	348	< 0.100	0.545	< 0.100	0.959	< 0.100	< 0.100
Taiwan 7	2.04	4.88	483	3800	3.65	1.11	356	303	2570	166	< 0.100	1.08	< 0.100	2.15	< 0.100	< 0.100
Taiwan 8	0.964	10.3	132	3270	3.38	1.26	469	296	2660	226	< 0.100	0.972	0.346	2.75	< 0.100	< 0.100
Taiwan 9	1.28	5.75	130	2360	4.15	1.22	422	309	3110	176	< 0.100	0.867	< 0.100	1.13	< 0.100	< 0.100
Taiwan 10	1.2	4.62	108	2740	3.39	1.09	430	328	2980	182	0.127	0.504	< 0.100	0.925	< 0.100	< 0.100
Taiwan 11	2.54	5.62	87	2260	3.22	0.662	317	208	3120	131	< 0.100	0.589	< 0.100	1.14	< 0.100	< 0.100
Taiwan 12	2.44	3.81	89	2150	3.37	0.782	356	245	3540	78.3	< 0.100	0.53	< 0.100	0.96	0.154	< 0.100
Taiwan 13	2.25	4.78	115	2460	3.33	0.869	363	235	2970	110	< 0.100	0.596	0.14	0.99	< 0.100	< 0.100
Taiwan 14	2.22	5.43	114	3170	2.58	1.02	318	232	2560	207	< 0.100	0.601	< 0.100	1.07	< 0.100	< 0.100
Taiwan 15	1.32	5.49	90.4	2620	3.43	0.978	281	295	3680	138	< 0.100	0.834	< 0.100	1.05	< 0.100	< 0.100
Taiwan 16	1.61	3.84	123	2650	3.8	0.877	266	291	3490	122	< 0.100	1.37	0.239	0.875	< 0.100	< 0.100
Taiwan 17	1.47	3.72	70.1	2590	3.22	1.17	237	292	4040	171	< 0.100	0.638	< 0.100	0.947	< 0.100	< 0.100
Taiwan 18	2.69	6.09	160	3770	3.41	1.18	348	324	3720	115	< 0.100	0.606	< 0.100	1.52	< 0.100	< 0.100
New Zealand 1	2.59	7.28	76.6	2000	3.09	0.932	717	239	1990	218	< 0.100	0.802	0.181	1.07	< 0.100	< 0.100
New Zealand 2	3.96	5.63	207	2880	2.29	1.01	385	283	1180	254	< 0.100	1.05	< 0.100	1.59	< 0.100	< 0.100
New Zealand 3	2.84	5.82	87.9	2130	3.27	1.08	687	289	2010	162	< 0.100	0.833	< 0.100	1.59	< 0.100	< 0.100
New Zealand 4	4.86	9.44	105	2060	2.23	0.994	392	244	1170	332	< 0.100	0.447	< 0.100	1.59	0.272	< 0.100
New Zealand 5	10.1	9.45	245	5690	2.63	1.02	445	270	951	348	0.187	1.52	0.129	2.57	< 0.100	< 0.100
New Zealand 6	4.17	6.72	98.8	2700	2.37	0.886	604	233	840	304	< 0.100	1.2	< 0.100	1.41	0.349	< 0.100
New Zealand 7	4.87	4.95	104	2540	2.93	1.06	819	217	918	352	< 0.100	0.416	< 0.100	0.933	< 0.100	< 0.100
New Zealand 8	1.83	6.98	90.4	2860	2.65	0.956	429	242	1430	287	< 0.100	1.12	< 0.100	1.87	< 0.100	< 0.100
New Zealand 9	6.27	23.9	333	5210	2.73	1.11	337	298	941	1010	< 0.100	0.995	< 0.100	2.65	< 0.100	< 0.100
New Zealand 10	1.55	4.52	83.3	2340	2.13	1.16	603	300	847	231	< 0.100	1.3	< 0.100	1.36	< 0.100	< 0.100
New Zealand 11	4.73	4.62	138	3350	2.35	1.04	475	250	708	241	< 0.100	0.606	< 0.100	1.15	< 0.100	< 0.100
New Zealand 12	4	20.9	83.4	2460	2.7	0.974	543	251	785	749	< 0.100	1.1	< 0.100	1.44	< 0.100	< 0.100
New Zealand 13	5.12	4.38	104	2320	3.15	1.1	1180	316	809	162	< 0.100	0.892	< 0.100	1.58	< 0.100	< 0.100
New Zealand 14	3.53	6.16	87.5	1910	2.98	0.962	838	218	1210	176	< 0.100	0.69	< 0.100	0.904	< 0.100	< 0.100
New Zealand 15	5.1	6.72	135	2710	2.81	1.03	707	252	983	237	< 0.100	0.955	< 0.100	0.961	< 0.100	< 0.100
New Zealand 16	4.1	5.54	110	2140	2.57	0.802	630	252	809	308	< 0.100	1.51	< 0.100	0.981	< 0.100	< 0.100
New Zealand 17	3.17	4.65	151	3070	1.96	1.1	265	287	830	324	< 0.100	0.474	< 0.100	1.25	< 0.100	< 0.100
New Zealand 18	2.2	4.01	96.9	2440	3.1	1.08	538	286	1620	297	< 0.100	0.471	< 0.100	1.22	< 0.100	< 0.100
New Zealand 19	3.05	9.82	97.8	2290	3	1.31	563	306	1350	943	< 0.100	0.482	< 0.100	1.8	0.313	< 0.100
New Zealand 20	8.32	4.94	301	4850	2.43	1.17	465	308	665	364	< 0.100	0.846	< 0.100	1.31	< 0.100	< 0.100
New Zealand 21	6.4	4.59	116	2730	2.92	0.936	851	252	1130	260	< 0.100	0.691	< 0.100	1.19	< 0.100	< 0.100
New Zealand 22	9.32	10.4	133	2250	3.86	1.13	1210	318	894	1440	< 0.100	0.65	< 0.100	1.4	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																		
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
New Zealand 23	3.38	4.79	151	3090	1.99	1.01	423	282	707	331	< 0.100	0.866	< 0.100	1.18	< 0.100	< 0.100
New Zealand 24	3.33	3.2	120	2690	2.92	1.01	582	244	1010	261	< 0.100	0.371	< 0.100	1.29	< 0.100	< 0.100
New Zealand 25	6.55	4.05	154	3070	2.9	1.24	1220	289	720	157	< 0.100	0.689	< 0.100	1.62	< 0.100	< 0.100
New Zealand 26	6.27	9.76	311	5060	2.23	1.18	381	300	575	588	0.146	1.02	< 0.100	1.6	< 0.100	< 0.100
New Zealand 27	3.29	3.19	75	1960	2.29	0.771	555	196	836	212	< 0.100	0.726	< 0.100	0.746	< 0.100	< 0.100
New Zealand 28	5.87	3.65	113	2470	4.12	1.29	1100	327	1360	201	< 0.100	0.416	< 0.100	1.21	< 0.100	< 0.100
Cone Bay Fish 1	0.503	7.67	59.6	1410	2.34	0.69	550	181	750	91.5	< 0.100	2.12	0.192	0.286	< 0.100	< 0.100
Cone Bay Fish 2	0.492	9.9	70.4	1400	1.97	0.597	416	146	743	90.7	< 0.100	0.448	< 0.100	0.502	< 0.100	< 0.100
Cone Bay Fish 3	0.783	19	119	3060	2.68	0.639	531	172	705	126	0.189	2.68	0.284	0.543	< 0.100	< 0.100
Cone Bay Fish 4	0.427	7.05	65.9	1210	2.67	0.522	349	147	800	129	< 0.100	0.914	< 0.100	0.284	< 0.100	< 0.100
Cone Bay Fish 5	0.683	5.4	91.7	1770	2.8	0.532	318	148	821	151	< 0.100	4.03	< 0.100	0.493	< 0.100	< 0.100
Cone Bay Fish 6	1.69	11.1	76.6	1860	3.32	0.531	316	139	882	2240	< 0.100	1.76	< 0.100	0.312	< 0.100	< 0.100
Cone Bay Fish 7	0.531	3.56	51.1	1440	2.58	0.589	332	149	745	95.6	< 0.100	< 0.100	< 0.100	0.384	< 0.100	< 0.100
Cone Bay Fish 8	0.722	10.8	90.3	2060	2.53	0.519	278	132	869	169	< 0.100	0.387	< 0.100	0.442	< 0.100	< 0.100
Cone Bay Fish 9	0.795	5.55	60.4	1700	2.86	0.464	267	114	991	164	< 0.100	0.342	< 0.100	1.41	< 0.100	< 0.100
Cone Bay Fish 10	0.457	5.49	58.8	1250	2.91	0.548	298	145	875	114	< 0.100	0.365	< 0.100	0.312	< 0.100	< 0.100
Cone Bay Fish 11	0.651	5.74	74.8	1870	2.49	0.572	257	151	712	265	< 0.100	0.702	< 0.100	0.291	< 0.100	< 0.100
Cone Bay Fish 12	0.897	13.6	108	2320	2.52	0.422	254	119	843	172	< 0.100	0.605	0.805	0.869	< 0.100	< 0.100
Cone Bay Fish 13	0.563	5.83	66.2	1540	2.52	0.496	295	117	983	130	< 0.100	0.195	< 0.100	0.377	< 0.100	< 0.100
Cone Bay Fish 14	0.665	5.22	65.8	1400	3.04	0.574	358	147	830	188	< 0.100	0.302	< 0.100	0.325	< 0.100	< 0.100
Cone Bay Fish 15	0.642	3.95	56.4	1230	2.48	0.541	294	134	927	115	< 0.100	0.933	< 0.100	0.385	< 0.100	< 0.100
Cone Bay Fish 16	0.36	6.32	69.5	571	0.644	0.261	656	46.4	62.2	36.6	< 0.100	1.05	< 0.100	0.276	< 0.100	< 0.100
Cone Bay Fish 17	0.452	5.72	66.2	1410	2.89	0.568	323	147	830	83.3	< 0.100	0.525	< 0.100	0.411	< 0.100	< 0.100
Cone Bay Fish 18	0.903	7.53	64.3	1390	2.83	0.487	301	131	892	840	0.565	7.83	1.2	0.199	< 0.100	0.126
Cone Bay Fish 19	0.658	8.82	71.7	1170	2.63	0.46	255	109	979	145	< 0.100	0.26	< 0.100	0.382	< 0.100	< 0.100
Cone Bay Fish 20	0.485	5.9	64.6	1300	2.56	0.467	250	121	877	132	< 0.100	0.448	< 0.100	0.465	< 0.100	< 0.100
Cone Bay Fish 21	0.52	5.96	64.8	1350	2.78	0.41	254	111	967	118	< 0.100	0.311	< 0.100	1.24	< 0.100	< 0.100
Cone Bay Fish 22	0.648	4.58	51.2	1170	3.58	0.632	536	179	652	595	< 0.100	0.799	0.14	0.511	< 0.100	< 0.100
Cone Bay Fish 23	1.5	5.84	88.8	1730	3.02	0.491	335	145	882	119	< 0.100	0.534	< 0.100	0.543	< 0.100	< 0.100
Cone Bay Fish 24	0.641	1.71	70.2	1470	2.91	0.539	306	132	953	118	< 0.100	< 0.100	< 0.100	0.408	< 0.100	< 0.100
Cone Bay Fish 25	0.85	7.28	64.7	1290	2.74	0.564	310	151	903	752	< 0.100	< 0.100	< 0.100	0.471	< 0.100	< 0.100
Cone Bay Fish 26	1.78	11.1	77.6	3160	4.24	0.62	508	170	616	2090	0.147	2.1	0.257	0.536	< 0.100	< 0.100
Cone Bay Fish 27	0.789	10.5	83.6	3020	3.16	0.496	412	131	539	502	< 0.100	0.724	0.396	0.644	< 0.100	< 0.100
Cone Bay Fish 28	0.741	13.2	78.7	1820	2.79	0.487	280	124	764	292	< 0.100	0.246	< 0.100	0.526	< 0.100	< 0.100
Cone Bay Fish 29	0.539	32.4	67.2	2000	2.99	0.675	426	175	721	80.6	< 0.100	0.139	< 0.100	1.03	< 0.100	< 0.100
Cone Bay Fish 30	0.612	57.2	79.3	2020	3.39	0.74	399	166	800	86.1	0.61	0.179	< 0.100	1.28	< 0.100	< 0.100
Study 2B Unknown sample trace back																
Unknown Taiwan Fish 1	2.27	19.6	93.1	1410	3.32	0.646	205	147	1050	79.3	< 0.100	< 0.100	< 0.100	1.35	< 0.100	< 0.100
Unknown Taiwan Fish 2	2.21	16.7	90.1	1410	2.3	0.653	319	160	1460	75	< 0.100	0.179	< 0.100	1.14	< 0.100	< 0.100
Unknown Taiwan Fish 3	1.86	16.8	96.4	1100	2.09	0.511	281	128	1460	135	< 0.100	< 0.100	< 0.100	0.538	< 0.100	< 0.100
Unknown Taiwan Fish 4	1.43	19.6	106	1060	2.09	0.454	239	126	1620	212	< 0.100	0.296	< 0.100	0.726	< 0.100	< 0.100
Unknown Taiwan Fish 5	2.33	8.63	73.9	1080	2.09	0.505	299	146	1510	116	< 0.100	0.64	< 0.100	1.46	< 0.100	< 0.100
Unknown Taiwan Fish 6	2.08	15.9	117	1390	1.84	0.58	278	146	1430	116	< 0.100	< 0.100	< 0.100	1.01	< 0.100	< 0.100
Unknown Taiwan Fish 7	2.42	24	145	1020	2.71	0.855	846	225	1100	75.7	< 0.100	0.618	< 0.100	0.659	< 0.100	< 0.100
Unknown Taiwan Fish 8	2.3	19.1	125	1270	2.63	0.548	328	141	2110	105	< 0.100	0.234	< 0.100	0.622	< 0.100	< 0.100
Unknown Australian Fish 1	2.59	4.01	65.5	1380	2.88	0.542	370	147	1490	108	< 0.100	1.37	< 0.100	0.341	0.153	< 0.100
Unknown Australian Fish 2	2.14	15.7	84.6	1120	2.37	0.522	311	144	1430	89	< 0.100	< 0.100	< 0.100	1.45	< 0.100	< 0.100
Unknown Australian Fish 3	2.89	5.1	75.6	2500	2.95	0.72	464	190	1070	102	< 0.100	0.25	< 0.100	0.766	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	59 Co	60 Ni	65 Cu	66 Zn	71 Ga	74 Ge	75 As	77 Se	85 Rb	88 Sr	89 Y	90 Zr	93 Nb	98 Mo	101 Ru	108 Pd
Unknown Australian Fish 4	2.83	74.7	286	1370	2.51	0.522	312	126	1510	83.5	0.25	0.6	< 0.100	1.06	< 0.100	< 0.100
Unknown Australian Fish 5	2.31	16.3	109	1850	2.71	0.746	495	204	944	78.8	< 0.100	0.313	< 0.100	0.368	< 0.100	< 0.100
Unknown Australian Fish 6	1.83	6.5	52.4	1170	3.06	0.469	287	123	1320	83.9	0.392	< 0.100	< 0.100	0.436	< 0.100	< 0.100
Unknown Australian Fish 7	3.2	6.57	105	1680	2.56	0.577	360	143	1430	95.7	< 0.100	0.219	< 0.100	0.628	< 0.100	< 0.100
Unknown Australian Fish 8	2.71	8.64	97	1360	2.86	0.669	505	185	1170	75.9	< 0.100	< 0.100	< 0.100	0.219	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
Study 1A Country of Origin																
Carpentaria 1	0.256	0.35	0.289	10.8	2.22	0.187	19.9	34	0.727	1.48	< 0.100	2.48	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 2	0.255	0.603	0.306	10.6	2.49	< 0.100	20.3	54.3	0.529	1.6	< 0.100	2.56	< 0.100	< 0.100	0.182	< 0.100
Carpentaria 3	0.375	0.292	0.37	9.65	1.27	0.201	19.3	27.9	0.343	0.943	< 0.100	1.68	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 4	< 0.100	0.254	0.323	10.4	2.2	0.198	18.6	48.2	0.129	0.337	< 0.100	0.714	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 5	< 0.100	0.158	< 0.100	9.58	2.16	0.204	17	60.8	0.153	0.367	< 0.100	0.576	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 6	< 0.100	< 0.100	0.443	8.14	3.02	< 0.100	14.7	74.7	0.18	0.511	< 0.100	0.835	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 7	0.19	0.198	0.131	12.1	4.96	< 0.100	16.7	105	0.331	0.761	< 0.100	0.515	< 0.100	< 0.100	0.207	< 0.100
Carpentaria 8	< 0.100	< 0.100	< 0.100	9.45	2.69	0.187	17.7	63.8	0.148	0.239	< 0.100	0.229	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 9	< 0.100	< 0.100	0.187	8.31	2.81	0.269	15.9	59.6	< 0.100	0.271	< 0.100	0.331	< 0.100	< 0.100	< 0.100	< 0.100
Carpentaria 10	< 0.100	< 0.100	< 0.100	8.8	5.07	< 0.100	13.8	114	0.275	0.542	< 0.100	0.686	< 0.100	< 0.100	0.262	< 0.100
Carpentaria 11	0.413	< 0.100	< 0.100	7.97	4.07	< 0.100	14.1	83.3	0.193	0.436	< 0.100	0.491	< 0.100	< 0.100	0.153	< 0.100
Carpentaria 12	< 0.100	< 0.100	0.129	9.1	3.62	< 0.100	15.3	72.1	0.141	0.401	< 0.100	0.642	< 0.100	< 0.100	0.136	< 0.100
USA 1	< 0.100	0.334	0.168	3.51	0.543	< 0.100	32.7	13.4	0.299	4.7	< 0.100	5.05	< 0.100	< 0.100	< 0.100	< 0.100
USA 2	0.655	0.328	0.169	4.84	0.607	< 0.100	32.1	28.1	0.197	2.31	< 0.100	4.41	< 0.100	< 0.100	< 0.100	< 0.100
USA 3	0.232	0.451	< 0.100	4.16	0.453	< 0.100	30.8	14.8	0.641	0.639	< 0.100	0.855	< 0.100	< 0.100	< 0.100	< 0.100
USA 4	< 0.100	0.439	< 0.100	2.15	0.5	0.179	33.1	12.6	0.149	0.469	< 0.100	1.18	< 0.100	< 0.100	< 0.100	< 0.100
USA 5	< 0.100	0.349	< 0.100	2.16	0.313	< 0.100	31.4	12.7	0.158	0.804	< 0.100	1.43	< 0.100	< 0.100	< 0.100	< 0.100
USA 6	< 0.100	0.362	0.161	3.71	0.334	< 0.100	32.5	12	0.142	0.403	< 0.100	0.743	< 0.100	< 0.100	< 0.100	< 0.100
USA 7	< 0.100	0.286	< 0.100	3.43	0.273	< 0.100	31.4	10.4	< 0.100	0.251	< 0.100	0.464	< 0.100	< 0.100	0.125	< 0.100
USA 8	< 0.100	0.296	< 0.100	1.75	0.261	< 0.100	31.1	8.73	< 0.100	0.15	< 0.100	0.224	< 0.100	< 0.100	< 0.100	< 0.100
USA 9	< 0.100	0.428	< 0.100	1.78	0.189	< 0.100	32.7	6.31	< 0.100	0.223	< 0.100	0.176	< 0.100	< 0.100	< 0.100	< 0.100
USA 10	< 0.100	0.425	< 0.100	3.68	0.36	< 0.100	36.8	18.2	< 0.100	0.62	< 0.100	1.12	< 0.100	< 0.100	< 0.100	< 0.100
USA 11	< 0.100	0.387	< 0.100	1.72	0.189	< 0.100	37.3	15.7	< 0.100	0.21	< 0.100	0.265	< 0.100	< 0.100	< 0.100	< 0.100
USA 12	< 0.100	0.568	< 0.100	2.33	0.457	< 0.100	37.1	14.1	< 0.100	0.468	< 0.100	0.618	< 0.100	< 0.100	< 0.100	< 0.100
USA 13	0.139	0.647	< 0.100	2.79	0.405	< 0.100	25.4	29.3	0.212	0.733	< 0.100	1.21	< 0.100	< 0.100	< 0.100	< 0.100
USA 14	< 0.100	0.495	< 0.100	1.63	0.307	< 0.100	26.6	9.87	< 0.100	0.256	< 0.100	0.543	< 0.100	< 0.100	< 0.100	< 0.100
USA 15	< 0.100	0.482	< 0.100	1.54	0.217	0.134	28	8.71	< 0.100	0.175	< 0.100	0.276	< 0.100	< 0.100	< 0.100	< 0.100
USA 16	< 0.100	0.291	< 0.100	1.77	0.214	< 0.100	25.2	6.16	< 0.100	< 0.100	< 0.100	0.174	< 0.100	< 0.100	< 0.100	< 0.100
USA 17	< 0.100	0.298	< 0.100	3.02	0.676	< 0.100	23.9	14.9	< 0.100	0.635	< 0.100	1.36	< 0.100	< 0.100	< 0.100	< 0.100
USA 18	0.171	0.319	< 0.100	2.48	0.251	< 0.100	27.7	8.65	< 0.100	0.213	< 0.100	0.23	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 1	0.321	0.276	< 0.100	0.353	< 0.100	< 0.100	18.3	14.2	< 0.100	0.154	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 2	< 0.100	0.462	< 0.100	0.702	0.237	0.138	14	18.6	0.153	0.297	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 3	< 0.100	0.311	0.212	0.594	0.206	< 0.100	17.7	17	0.46	0.593	< 0.100	0.338	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 4	< 0.100	0.363	< 0.100	0.299	0.191	0.162	21.3	13.7	0.284	0.477	< 0.100	0.179	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 5	< 0.100	0.27	< 0.100	0.445	0.129	0.206	22	12	0.127	0.131	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 6	0.172	0.477	< 0.100	0.795	0.286	< 0.100	20.8	15.5	< 0.100	0.634	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Study 1B Dorsal vs. Ventral Muscle																
Innisfail Queensland 14	0.279	0.179	< 0.100	1.47	0.238	< 0.100	28.8	62.1	0.263	0.311	< 0.100	0.164	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 15	0.365	0.177	< 0.100	1.05	0.244	< 0.100	31.7	27.8	0.211	0.186	< 0.100	0.166	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 29	< 0.100	0.694	< 0.100	5.84	0.157	< 0.100	19.6	18.3	< 0.100	0.132	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 30	< 0.100	0.238	< 0.100	1.87	0.129	< 0.100	20.7	16.8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 47	< 0.100	0.44	< 0.100	0.342	0.184	0.343	23.5	12.2	0.167	0.21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 48	< 0.100	0.44	< 0.100	0.134	0.149	0.424	17.3	11.9	0.172	0.197	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 29	< 0.100	0.256	< 0.100	0.728	0.364	0.236	15.4	17.8	1.73	3.02	0.341	1.21	0.147	< 0.100	0.132	< 0.100
New Zealand 30	< 0.100	0.39	< 0.100	0.455	0.246	< 0.100	12.4	15.6	1.28	2.08	0.252	1.12	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
Study 2A National and International Provenance Data Base																
Innisfail Queensland 1	0.601	0.297	< 0.100	2.27	0.381	< 0.100	28.9	93.7	0.17	0.856	< 0.100	0.386	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 2	0.224	0.211	< 0.100	1.23	0.248	< 0.100	36.8	40.9	< 0.100	0.33	< 0.100	0.329	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 3	0.371	0.221	< 0.100	0.984	0.18	< 0.100	33.9	52.6	0.177	0.289	< 0.100	0.251	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 4	0.187	0.216	< 0.100	1.45	0.276	< 0.100	31.9	364	< 0.100	0.384	< 0.100	0.346	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 5	0.31	0.131	< 0.100	1	0.253	< 0.100	32.3	21.2	0.173	0.218	< 0.100	0.225	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 6	0.28	0.15	< 0.100	1.09	0.453	< 0.100	32.2	24.9	0.173	0.168	< 0.100	0.202	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 7	0.172	0.336	< 0.100	0.85	0.218	< 0.100	27.5	49.3	0.187	0.253	< 0.100	0.231	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 8	0.202	< 0.100	< 0.100	0.764	0.211	< 0.100	32.8	16	< 0.100	0.157	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 9	0.197	0.331	< 0.100	1.04	0.23	< 0.100	28	19.7	0.201	0.173	< 0.100	0.206	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 10	0.19	0.178	< 0.100	0.854	0.183	< 0.100	28.9	40.1	0.165	0.262	< 0.100	0.197	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 11	0.249	0.163	< 0.100	0.772	< 0.100	< 0.100	32.5	111	0.216	0.22	< 0.100	0.185	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 12	< 0.100	< 0.100	< 0.100	0.571	< 0.100	< 0.100	23.9	17.5	0.179	0.145	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Innisfail Queensland 13	0.258	0.164	< 0.100	1.06	0.148	< 0.100	26.9	26.5	0.208	0.176	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 1	0.159	0.5	< 0.100	1.15	0.258	< 0.100	19.4	139	< 0.100	0.128	< 0.100	0.148	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 2	0.169	0.138	< 0.100	0.842	0.145	< 0.100	18.3	17.5	0.154	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 3	0.155	0.133	< 0.100	1.21	< 0.100	< 0.100	18	15.9	0.166	< 0.100	< 0.100	0.152	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 4	< 0.100	0.197	< 0.100	1.06	0.142	< 0.100	18.9	26.9	0.131	0.17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 5	0.135	0.138	< 0.100	0.963	0.19	< 0.100	17.8	20.6	0.163	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 6	0.14	0.253	< 0.100	0.89	0.126	< 0.100	24	25.7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 7	< 0.100	0.232	< 0.100	0.874	0.151	< 0.100	22	29	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 8	0.149	0.172	< 0.100	0.703	0.177	< 0.100	22.7	29.3	0.186	< 0.100	< 0.100	0.197	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 9	< 0.100	< 0.100	< 0.100	0.73	< 0.100	< 0.100	20.7	26.5	0.171	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 10	< 0.100	0.52	< 0.100	2.51	0.169	< 0.100	23.7	149	< 0.100	0.157	< 0.100	0.224	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 11	< 0.100	0.256	< 0.100	0.878	< 0.100	< 0.100	23.6	22.9	< 0.100	0.128	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 12	< 0.100	0.238	< 0.100	1.97	0.145	< 0.100	25.9	25.5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 13	0.414	0.287	< 0.100	0.739	< 0.100	< 0.100	22.7	21.7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 14	0.132	0.136	< 0.100	1.6	< 0.100	< 0.100	18.6	21.1	0.173	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 15	< 0.100	< 0.100	< 0.100	12.3	0.203	< 0.100	23.1	20.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 16	< 0.100	0.346	< 0.100	0.87	0.131	< 0.100	19.9	19.1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 17	0.146	< 0.100	< 0.100	0.799	0.151	< 0.100	19.6	18.4	0.212	0.154	< 0.100	0.14	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 18	< 0.100	0.163	< 0.100	0.592	0.14	< 0.100	18.5	16.6	0.186	0.139	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 19	< 0.100	0.305	< 0.100	0.534	0.143	< 0.100	22.6	100	< 0.100	0.204	< 0.100	0.186	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 20	< 0.100	0.247	< 0.100	1.27	0.205	< 0.100	23.1	18.9	0.237	0.136	< 0.100	0.128	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 21	< 0.100	0.211	< 0.100	0.652	0.169	< 0.100	27	40.7	0.231	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 22	< 0.100	0.19	< 0.100	0.627	0.147	< 0.100	24.5	22.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 23	< 0.100	0.261	< 0.100	0.643	0.165	0.14	23	111	< 0.100	0.167	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 24	0.251	0.236	0.192	0.818	0.254	< 0.100	19.8	34.4	0.196	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 25	< 0.100	0.302	< 0.100	10.5	0.197	< 0.100	18.8	45.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 26	< 0.100	0.215	< 0.100	0.762	0.173	< 0.100	24.3	20.6	< 0.100	< 0.100	< 0.100	0.149	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 27	< 0.100	0.169	0.2	0.541	0.259	< 0.100	18.2	16.6	0.175	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 28	2.28	0.172	< 0.100	3.13	0.193	< 0.100	23.5	19	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 1	< 0.100	0.265	< 0.100	0.984	0.136	< 0.100	21.1	9.36	0.246	0.494	< 0.100	0.184	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 2	< 0.100	0.413	< 0.100	0.839	0.165	0.153	22.1	16.8	0.196	0.33	< 0.100	0.148	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 3	< 0.100	0.278	< 0.100	1.48	0.156	< 0.100	15.5	25.1	1.09	1.51	0.218	0.851	0.152	< 0.100	< 0.100	< 0.100
Cowley Queensland 4	< 0.100	0.314	< 0.100	0.385	< 0.100	< 0.100	33.9	6.79	< 0.100	0.225	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 5	< 0.100	0.405	< 0.100	0.357	< 0.100	< 0.100	37.6	5.88	0.184	0.219	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 6	< 0.100	0.37	< 0.100	0.444	< 0.100	< 0.100	37.9	8.84	0.208	0.382	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 7	< 0.100	0.221	< 0.100	0.255	0.152	< 0.100	17.2	10.4	0.352	0.569	< 0.100	0.252	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 8	< 0.100	0.169	< 0.100	0.295	< 0.100	< 0.100	15.4	10	0.163	0.305	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
Cowley Queensland 9	< 0.100	0.196	< 0.100	0.331	0.139	< 0.100	13.5	15.2	0.234	0.346	< 0.100	0.146	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 10	< 0.100	0.291	< 0.100	0.355	< 0.100	< 0.100	22.6	11.2	< 0.100	0.247	< 0.100	0.135	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 11	< 0.100	0.292	< 0.100	0.311	< 0.100	< 0.100	23.4	9.7	< 0.100	0.178	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 12	< 0.100	0.268	< 0.100	0.325	< 0.100	< 0.100	22.2	11.6	0.343	0.743	< 0.100	0.236	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 13	< 0.100	0.206	< 0.100	0.346	< 0.100	< 0.100	18.4	9.6	0.4	0.495	< 0.100	0.304	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 14	< 0.100	0.289	< 0.100	0.5	< 0.100	< 0.100	20.6	10.2	0.663	1.66	0.148	0.55	< 0.100	< 0.100	< 0.100	< 0.100
Cowley Queensland 15	< 0.100	0.483	< 0.100	0.421	0.165	< 0.100	15.8	27	0.263	0.377	< 0.100	0.153	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 1	< 0.100	0.551	< 0.100	0.279	< 0.100	0.176	15.2	7.25	0.184	0.261	< 0.100	0.132	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 2	< 0.100	0.749	< 0.100	0.387	0.132	< 0.100	14.4	8.29	0.223	0.353	< 0.100	0.137	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 3	< 0.100	0.528	< 0.100	0.458	< 0.100	< 0.100	15.1	6.93	0.137	0.241	< 0.100	0.126	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 4	< 0.100	0.482	< 0.100	0.371	< 0.100	< 0.100	17.3	3.47	2.22	4.23	< 0.100	0.138	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 5	< 0.100	0.492	< 0.100	0.304	0.125	0.145	17.5	4.85	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 6	< 0.100	0.45	< 0.100	0.333	< 0.100	< 0.100	16.9	5.6	1.15	2.1	0.222	0.939	0.139	< 0.100	< 0.100	< 0.100
Good Fortune 7	< 0.100	0.441	< 0.100	0.365	0.128	< 0.100	16.9	8.23	0.273	0.328	< 0.100	0.194	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 8	< 0.100	0.479	< 0.100	0.358	0.16	< 0.100	18.5	12.3	< 0.100	0.282	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 9	< 0.100	0.866	< 0.100	0.464	0.131	0.209	12.9	6.29	0.14	0.204	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 10	< 0.100	0.501	< 0.100	0.526	0.159	< 0.100	17.9	14.5	0.311	3.46	< 0.100	0.451	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 11	< 0.100	0.521	< 0.100	0.363	0.153	< 0.100	19.9	13.5	0.145	0.269	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 12	< 0.100	0.452	< 0.100	0.271	0.165	< 0.100	16.4	18.7	0.165	0.285	< 0.100	0.137	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 13	< 0.100	0.48	< 0.100	0.255	< 0.100	< 0.100	16.4	6.06	< 0.100	0.186	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 14	< 0.100	0.667	< 0.100	0.444	0.214	< 0.100	15.5	17.7	0.351	0.408	< 0.100	0.198	< 0.100	< 0.100	< 0.100	< 0.100
Good Fortune 15	< 0.100	0.577	< 0.100	0.309	< 0.100	0.176	14.8	5.08	0.18	0.271	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 1	< 0.100	0.453	< 0.100	< 0.100	0.353	< 0.100	24.2	13.8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 2	< 0.100	0.443	< 0.100	< 0.100	0.286	< 0.100	26.4	8.82	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 3	< 0.100	0.624	< 0.100	0.543	0.721	0.249	20.2	28.6	< 0.100	0.182	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 4	< 0.100	< 0.100	< 0.100	0.152	< 0.100	< 0.100	17.6	21.7	< 0.100	0.212	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.171	19.3	22.4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 6	< 0.100	0.288	< 0.100	< 0.100	< 0.100	< 0.100	14.5	29	< 0.100	0.132	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 7	< 0.100	0.605	< 0.100	< 0.100	0.173	0.21	21.5	9.77	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 8	< 0.100	0.481	< 0.100	0.132	0.34	0.164	20.2	9.55	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 9	< 0.100	0.42	< 0.100	< 0.100	0.168	< 0.100	19.5	10.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 10	< 0.100	1.16	< 0.100	< 0.100	0.169	0.208	26.7	12.1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 11	< 0.100	1.06	< 0.100	0.159	0.158	0.15	24.5	20.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 12	< 0.100	1.72	< 0.100	0.261	0.194	0.363	21.1	21.7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 13	< 0.100	0.589	< 0.100	0.23	0.326	0.934	23.1	12.3	< 0.100	0.253	< 0.100	0.139	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 14	< 0.100	0.378	< 0.100	0.179	0.297	1.13	19.8	18.5	0.256	0.488	< 0.100	0.21	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 15	< 0.100	0.377	< 0.100	0.22	0.308	0.741	42.5	21.8	0.227	0.369	< 0.100	0.249	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 16	< 0.100	0.696	< 0.100	< 0.100	0.235	0.259	26.6	6.64	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 17	< 0.100	0.693	< 0.100	0.157	0.34	0.248	22.7	13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 18	< 0.100	0.696	< 0.100	< 0.100	0.247	0.388	24.4	7.38	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 19	< 0.100	0.46	< 0.100	0.18	0.197	0.203	25.3	12.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 20	< 0.100	0.461	< 0.100	< 0.100	0.156	0.284	26.5	14.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 21	< 0.100	0.472	< 0.100	0.251	0.201	0.262	23.1	27.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 22	< 0.100	0.437	< 0.100	0.151	0.155	0.3	30.9	13.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 23	< 0.100	0.445	< 0.100	< 0.100	0.139	0.228	29.2	17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 24	< 0.100	0.759	< 0.100	0.158	0.188	< 0.100	23.9	24.3	< 0.100	< 0.100	0.197	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 25	< 0.100	0.925	< 0.100	0.236	0.203	0.332	48.2	8.59	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 26	< 0.100	0.655	< 0.100	6.93	0.203	0.287	45.4	17.7	< 0.100	0.158	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 27	< 0.100	0.725	< 0.100	0.22	0.161	0.208	51.4	18.5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 28	< 0.100	1.29	< 0.100	0.202	0.164	0.208	27.4	8	0.14	0.203	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 29	< 0.100	1.63	< 0.100	0.17	< 0.100	0.448	17.3	14.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
Indonesia 30	< 0.100	2.06	< 0.100	0.242	0.144	< 0.100	25.7	16.5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 31	< 0.100	1.18	< 0.100	0.149	0.195	0.414	25.4	11.7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 32	< 0.100	0.926	< 0.100	0.231	0.201	0.363	28	8.8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 33	< 0.100	1.32	< 0.100	0.214	0.251	0.429	24	12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 34	< 0.100	< 0.100	< 0.100	0.145	< 0.100	< 0.100	124	14.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 35	< 0.100	0.214	< 0.100	< 0.100	< 0.100	0.229	101	23	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 36	< 0.100	0.19	< 0.100	0.309	0.239	< 0.100	89.7	26.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 37	< 0.100	0.32	< 0.100	0.159	0.234	< 0.100	28.5	12	0.149	0.324	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 38	< 0.100	0.687	< 0.100	0.145	0.345	0.195	29.3	11.9	0.183	0.329	< 0.100	0.163	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 39	< 0.100	0.376	< 0.100	< 0.100	0.295	0.175	28.4	7.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 40	< 0.100	0.482	< 0.100	0.148	< 0.100	0.223	24.7	13.1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 41	< 0.100	0.654	< 0.100	0.162	0.131	< 0.100	23.1	11.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 42	< 0.100	0.556	< 0.100	0.169	0.233	0.168	27	12.1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 43	< 0.100	0.19	< 0.100	0.251	< 0.100	0.333	78.3	28.6	0.157	0.234	< 0.100	0.157	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 44	< 0.100	0.307	< 0.100	0.309	< 0.100	0.226	54.5	28.2	0.144	0.219	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 45	< 0.100	0.245	< 0.100	0.157	< 0.100	< 0.100	47.3	34.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Indonesia 46	< 0.100	0.52	< 0.100	0.422	0.21	0.512	28.6	10.5	0.187	0.193	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 7	< 0.100	0.289	< 0.100	0.475	< 0.100	0.203	18.2	8.15	0.132	0.136	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 8	< 0.100	0.411	< 0.100	0.918	0.182	< 0.100	19.1	12.7	0.323	0.501	< 0.100	0.208	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 9	< 0.100	0.33	< 0.100	0.568	0.184	< 0.100	22.4	12.5	0.801	0.723	0.176	0.592	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 10	< 0.100	0.27	< 0.100	0.369	< 0.100	< 0.100	19.9	9.62	0.414	0.401	< 0.100	0.31	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 11	< 0.100	0.195	< 0.100	0.728	0.126	0.132	30.4	8.25	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 12	< 0.100	0.256	< 0.100	0.463	0.178	0.173	35.6	13.3	< 0.100	0.149	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 13	< 0.100	0.231	< 0.100	0.349	< 0.100	< 0.100	29.2	7.02	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 14	< 0.100	0.279	< 0.100	0.427	0.243	< 0.100	24.5	11.5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 15	< 0.100	0.212	< 0.100	0.771	0.6	< 0.100	22.6	16.1	0.149	0.141	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 16	< 0.100	0.154	< 0.100	0.565	0.129	0.195	22	13.7	< 0.100	0.145	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 17	< 0.100	0.228	< 0.100	0.391	0.141	0.31	23.6	16.4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Taiwan 18	< 0.100	0.33	< 0.100	0.62	0.147	0.14	23.4	12.3	0.25	0.356	< 0.100	1.72	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 1	< 0.100	0.214	< 0.100	0.398	0.169	< 0.100	19.9	13.7	2.39	5.22	0.508	1.82	0.24	< 0.100	0.2	< 0.100
New Zealand 2	< 0.100	0.64	< 0.100	0.494	0.263	< 0.100	12.5	16.9	0.386	0.653	< 0.100	0.303	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 3	< 0.100	0.285	< 0.100	0.216	0.21	0.199	19.6	10.7	0.66	1.18	0.135	0.415	< 0.100	< 0.100	0.342	< 0.100
New Zealand 4	< 0.100	0.447	< 0.100	0.499	0.297	< 0.100	13	19.1	0.257	0.464	< 0.100	0.207	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 5	< 0.100	0.841	< 0.100	1.71	1.71	< 0.100	15.2	24.1	2.52	4.92	0.377	1.25	0.168	< 0.100	0.129	< 0.100
New Zealand 6	< 0.100	0.44	< 0.100	0.852	0.192	< 0.100	16.5	16.4	0.627	1.09	< 0.100	0.535	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 7	< 0.100	0.6	< 0.100	0.396	0.171	< 0.100	21.7	14.2	0.201	0.302	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 8	< 0.100	0.287	< 0.100	0.475	0.543	0.182	14.6	16.8	0.568	0.885	< 0.100	0.375	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 9	< 0.100	0.672	< 0.100	1.64	1.09	0.147	10	66.2	0.215	0.333	< 0.100	0.14	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 10	< 0.100	0.432	< 0.100	0.418	0.22	< 0.100	9.23	16.7	0.227	0.4	< 0.100	0.159	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 11	< 0.100	0.498	< 0.100	0.569	0.243	< 0.100	14.8	14.8	0.21	0.28	< 0.100	0.163	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 12	< 0.100	0.405	< 0.100	0.761	0.205	< 0.100	15.7	24.6	0.908	1.34	0.172	0.655	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 13	< 0.100	0.503	< 0.100	0.44	0.14	< 0.100	19.9	9.27	0.402	0.593	< 0.100	0.259	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 14	< 0.100	0.387	< 0.100	0.277	< 0.100	< 0.100	23.6	9.92	0.144	0.194	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 15	< 0.100	0.364	< 0.100	0.606	0.428	0.178	21.9	13.3	0.207	0.206	< 0.100	0.131	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 16	< 0.100	0.54	< 0.100	0.513	0.215	< 0.100	16.8	19.3	0.787	1.47	0.162	0.571	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 17	< 0.100	0.441	< 0.100	0.61	0.589	< 0.100	8.85	22.7	< 0.100	0.176	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 18	< 0.100	0.423	< 0.100	0.451	0.282	< 0.100	16.6	18.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 19	< 0.100	0.612	< 0.100	0.446	0.329	0.191	14.9	50	0.149	0.221	< 0.100	0.132	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 20	< 0.100	0.571	< 0.100	0.715	0.403	0.162	12.7	22.2	1.27	2.28	0.324	1.23	0.146	< 0.100	0.133	< 0.100
New Zealand 21	< 0.100	0.457	< 0.100	0.65	0.154	0.184	22.1	11.7	0.17	0.208	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 22	< 0.100	0.386	< 0.100	0.385	0.186	< 0.100	19.3	33.4	0.152	0.255	< 0.100	0.128	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
New Zealand 23	< 0.100	0.341	< 0.100	0.489	0.257	< 0.100	12.5	20	0.262	0.503	< 0.100	0.228	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 24	< 0.100	0.339	< 0.100	0.37	0.432	< 0.100	18.4	15.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 25	< 0.100	0.548	< 0.100	0.462	0.235	< 0.100	15.3	8.12	0.192	0.227	< 0.100	0.139	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 26	< 0.100	0.538	< 0.100	0.748	0.506	< 0.100	10.2	27.8	0.29	0.639	< 0.100	0.23	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 27	< 0.100	0.43	< 0.100	0.318	0.184	< 0.100	14.7	12.3	0.14	0.189	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
New Zealand 28	< 0.100	0.619	< 0.100	0.331	0.422	< 0.100	27.4	12.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 1	6.44	0.203	< 0.100	1.9	0.148	< 0.100	11.1	2.81	0.18	0.273	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 2	8.14	0.14	< 0.100	1.93	0.127	< 0.100	11.8	2.77	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 3	34.1	0.265	< 0.100	4.39	0.382	< 0.100	11.2	4.05	0.156	0.233	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 4	8.44	0.279	< 0.100	1.64	< 0.100	< 0.100	14.1	2.48	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 5	3.32	0.276	< 0.100	0.957	< 0.100	< 0.100	14.1	2.08	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 6	1.88	0.391	< 0.100	1.51	< 0.100	< 0.100	15	18.5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 7	0.512	0.142	< 0.100	0.436	< 0.100	< 0.100	10.9	2.04	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 8	1.31	0.258	< 0.100	1.88	0.372	< 0.100	12.1	4.37	< 0.100	0.13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 9	7.61	0.247	< 0.100	0.815	< 0.100	< 0.100	13.6	3.33	0.214	0.262	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 10	1.19	0.266	< 0.100	1.32	0.145	< 0.100	14.7	2.28	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 11	1.21	0.2	< 0.100	1.75	0.204	< 0.100	11.2	3.36	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 12	3.59	0.354	0.147	41.2	0.536	< 0.100	13.9	6.92	0.138	0.213	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 13	2.53	0.192	< 0.100	1.62	0.129	< 0.100	14.1	3.61	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 14	1.03	0.139	< 0.100	2.65	0.14	< 0.100	13.6	2.97	< 0.100	< 0.100	< 0.100	0.169	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 15	0.817	0.194	< 0.100	16.9	< 0.100	< 0.100	14.6	2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 16	1.77	0.436	< 0.100	0.943	0.221	< 0.100	0.905	2.24	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 17	1.12	0.196	< 0.100	1.15	< 0.100	< 0.100	13	3.11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 18	0.801	0.175	< 0.100	0.447	< 0.100	< 0.100	14.2	11.8	0.531	0.971	< 0.100	0.354	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 19	2.3	0.185	< 0.100	1.19	< 0.100	< 0.100	14.1	3.4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 20	0.377	0.183	< 0.100	0.707	< 0.100	< 0.100	12.6	2.18	< 0.100	< 0.100	< 0.100	0.708	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 21	0.514	0.157	< 0.100	1.14	< 0.100	< 0.100	14	2.82	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 22	< 0.100	0.219	< 0.100	0.29	0.151	< 0.100	10	4.57	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 23	0.874	0.171	< 0.100	0.974	< 0.100	< 0.100	13	1.85	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 24	0.158	0.176	< 0.100	< 0.100	< 0.100	< 0.100	13.9	1.31	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 25	2.17	0.134	< 0.100	5.26	< 0.100	< 0.100	13.1	7.07	< 0.100	0.155	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 26	0.416	0.405	< 0.100	0.573	0.17	< 0.100	9.13	18.2	< 0.100	0.232	< 0.100	0.184	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 27	3.69	0.156	< 0.100	2.08	< 0.100	< 0.100	8.04	7.73	< 0.100	0.163	< 0.100	0.172	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 28	0.369	0.232	< 0.100	1.36	< 0.100	< 0.100	10.9	3.82	< 0.100	< 0.100	< 0.100	0.273	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 29	2.23	0.216	< 0.100	2.21	0.156	< 0.100	11.1	2.58	< 0.100	0.133	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 30	0.711	0.211	< 0.100	1.23	0.127	< 0.100	12.4	2.33	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Study 2B Unknown sample trace back																
Unknown Taiwan Fish 1	4.99	0.558	< 0.100	12.2	0.306	< 0.100	11.5	6.48	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 2	5.85	0.449	< 0.100	14.1	0.291	< 0.100	14.2	6.75	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 3	4.13	0.286	< 0.100	5.24	0.183	< 0.100	13.3	12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 4	5.62	0.212	< 0.100	13.1	0.252	< 0.100	14.2	28.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 5	1.73	0.247	< 0.100	2.87	0.193	< 0.100	14	11.2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 6	1.31	0.139	< 0.100	5.61	0.285	< 0.100	12.7	17.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 7	10.6	0.38	< 0.100	5.24	0.423	< 0.100	10.5	8.26	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 8	8.1	0.291	< 0.100	5.84	0.231	< 0.100	18	14.3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 1	6.18	0.406	< 0.100	0.474	< 0.100	< 0.100	15.1	6.21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 2	2.71	0.58	< 0.100	0.755	< 0.100	< 0.100	14.2	5.74	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 3	3.05	0.283	< 0.100	1.07	< 0.100	< 0.100	10.7	7.77	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million																
analytes not marked have concentrations in parts per billion	109 Ag	111 Cd	115 In	120 Sn	121 Sb	126 Te	133 Cs	138 Ba	139 La	140 Ce	141 Pr	146 Nd	147 Sm	153 Eu	157 Gd	159 Tb
Unknown Australian Fish 4	16.5	0.476	< 0.100	8.79	0.272	< 0.100	15	11.7	0.142	0.176	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 5	2.57	0.579	< 0.100	1.34	0.14	< 0.100	9.44	5.06	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 6	0.856	0.359	< 0.100	21	< 0.100	< 0.100	13.7	38.9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 7	1.52	0.353	< 0.100	6.23	< 0.100	< 0.100	14.7	5.6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 8	1.75	0.204	< 0.100	2.52	< 0.100	< 0.100	12.6	5.07	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
Study 1A Country of Origin															
Carpentaria 1	< 0.100	0.69	< 0.100	< 0.100	< 0.100	< 0.100	0.219	0.151	2.95	36	< 0.100	4.41	1.09	0.288	< 0.100
Carpentaria 2	< 0.100	1.21	< 0.100	< 0.100	< 0.100	< 0.100	0.351	0.144	2.66	35.7	0.152	4.67	0.928	0.28	0.149
Carpentaria 3	< 0.100	0.649	< 0.100	< 0.100	< 0.100	< 0.100	0.184	< 0.100	1.01	35.1	< 0.100	2.89	0.859	0.231	< 0.100
Carpentaria 4	< 0.100	0.199	< 0.100	< 0.100	< 0.100	< 0.100	0.146	< 0.100	1.19	37	< 0.100	1.15	0.784	0.269	1.05
Carpentaria 5	< 0.100	0.269	< 0.100	< 0.100	< 0.100	< 0.100	0.146	0.144	2.47	36	< 0.100	1.06	0.735	0.31	1.13
Carpentaria 6	< 0.100	0.472	< 0.100	< 0.100	< 0.100	< 0.100	0.159	< 0.100	1.61	34	< 0.100	1.64	0.73	0.318	1.68
Carpentaria 7	< 0.100	0.302	< 0.100	< 0.100	< 0.100	< 0.100	0.198	0.174	2.59	36.9	< 0.100	5.56	0.937	0.498	2.63
Carpentaria 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.184	0.129	1.2	43.2	< 0.100	2.29	0.931	0.355	1.44
Carpentaria 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.151	< 0.100	0.952	38.3	< 0.100	1.49	0.871	0.551	1.48
Carpentaria 10	< 0.100	0.397	< 0.100	< 0.100	< 0.100	< 0.100	0.184	0.148	1.97	35.3	< 0.100	3.51	1.46	0.497	2.53
Carpentaria 11	< 0.100	0.306	< 0.100	< 0.100	< 0.100	< 0.100	0.158	< 0.100	1.14	32.9	< 0.100	2.69	0.812	0.39	2.13
Carpentaria 12	< 0.100	0.33	< 0.100	< 0.100	< 0.100	< 0.100	0.157	< 0.100	1.3	31.2	< 0.100	2.05	0.808	0.332	1.74
USA 1	< 0.100	2.81	< 0.100	< 0.100	< 0.100	< 0.100	0.135	0.132	1.12	73.3	< 0.100	2.05	< 0.100	0.178	< 0.100
USA 2	< 0.100	2.42	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.13	0.843	79.1	< 0.100	4.4	0.198	0.158	< 0.100
USA 3	< 0.100	0.468	< 0.100	< 0.100	< 0.100	< 0.100	0.135	< 0.100	0.736	77.3	< 0.100	3.32	0.178	0.155	< 0.100
USA 4	< 0.100	0.227	< 0.100	< 0.100	< 0.100	< 0.100	0.13	< 0.100	0.847	86.5	< 0.100	2.19	< 0.100	0.158	< 0.100
USA 5	< 0.100	0.263	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.679	83.6	< 0.100	1.32	< 0.100	< 0.100	< 0.100
USA 6	< 0.100	0.406	< 0.100	< 0.100	< 0.100	< 0.100	0.128	< 0.100	0.913	83.4	< 0.100	2.18	0.343	0.151	< 0.100
USA 7	< 0.100	0.195	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.623	87.8	< 0.100	1.67	< 0.100	0.132	< 0.100
USA 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.126	1.17	93.2	< 0.100	0.597	< 0.100	< 0.100	< 0.100
USA 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.125	0.13	0.77	94.4	< 0.100	0.174	< 0.100	0.149	< 0.100
USA 10	< 0.100	0.644	< 0.100	< 0.100	< 0.100	< 0.100	0.146	< 0.100	0.76	89.3	< 0.100	1.85	< 0.100	0.153	< 0.100
USA 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.136	< 0.100	0.404	84.1	< 0.100	0.607	< 0.100	< 0.100	< 0.100
USA 12	< 0.100	0.307	< 0.100	< 0.100	< 0.100	< 0.100	0.144	< 0.100	0.599	84.5	< 0.100	2.12	< 0.100	0.147	< 0.100
USA 13	< 0.100	0.33	< 0.100	< 0.100	< 0.100	< 0.100	0.152	0.129	0.944	80.5	< 0.100	3.12	0.169	0.162	< 0.100
USA 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.735	75.3	< 0.100	0.935	< 0.100	< 0.100	< 0.100
USA 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.155	< 0.100	3.22	76.3	< 0.100	0.382	0.149	0.129	< 0.100
USA 16	< 0.100	0.168	< 0.100	< 0.100	< 0.100	< 0.100	0.141	< 0.100	0.564	79.9	< 0.100	0.144	< 0.100	< 0.100	< 0.100
USA 17	< 0.100	0.882	< 0.100	< 0.100	< 0.100	< 0.100	0.139	< 0.100	0.376	77.4	< 0.100	0.743	0.212	< 0.100	< 0.100
USA 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.162	0.126	0.868	79.8	< 0.100	0.67	< 0.100	< 0.100	< 0.100
Taiwan 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.159	0.142	0.784	35.2	0.832	0.574	< 0.100	< 0.100	< 0.100
Taiwan 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.15	0.132	0.905	43.7	1.23	1.84	0.235	< 0.100	< 0.100
Taiwan 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.45	67.5	1.2	1.43	0.202	< 0.100	< 0.100
Taiwan 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.07	57.1	1.36	1.22	< 0.100	< 0.100	< 0.100
Taiwan 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.903	30.5	1.81	0.716	< 0.100	< 0.100	< 0.100
Taiwan 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.714	28.7	1.72	6.95	0.283	< 0.100	< 0.100
Study 1B Dorsal vs. Ventral Muscle															
Innisfail Queensland 14	< 0.100	0.146	< 0.100	< 0.100	< 0.100	< 0.100	0.166	0.293	0.631	78.5	0.822	0.723	< 0.100	0.277	< 0.100
Innisfail Queensland 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.131	0.187	0.65	83.8	1.04	0.462	< 0.100	0.214	< 0.100
Wingfield S. Australia 29	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.156	0.164	0.972	53.4	0.34	0.539	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 30	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.133	0.132	0.621	47.5	0.459	0.392	< 0.100	< 0.100	< 0.100
Indonesia 47	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.419	234	< 0.100	0.493	4.18	< 0.100	< 0.100
Indonesia 48	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.202	184	< 0.100	0.359	3.04	< 0.100	< 0.100
New Zealand 29	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.43	90.9	0.445	6.56	0.131	< 0.100	< 0.100
New Zealand 30	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	7.94	106	0.322	2.36	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
Study 2A National and International Provenance Data Base															
Innisfail Queensland 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.132	0.129	1.58	73.9	0.565	2.55	0.252	0.271	< 0.100
Innisfail Queensland 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.27	79.6	0.826	0.563	< 0.100	0.219	< 0.100
Innisfail Queensland 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.565	82.3	0.814	0.493	< 0.100	0.147	< 0.100
Innisfail Queensland 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.47	76.9	0.979	0.833	0.389	0.182	< 0.100
Innisfail Queensland 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.377	74.1	1.09	0.45	0.242	< 0.100	< 0.100
Innisfail Queensland 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.358	73.1	1.06	0.448	0.178	0.3	< 0.100
Innisfail Queensland 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.844	72.4	0.832	0.285	< 0.100	0.312	< 0.100
Innisfail Queensland 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.875	76.2	1.11	0.281	< 0.100	0.234	< 0.100
Innisfail Queensland 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.691	71.6	0.956	0.388	< 0.100	0.125	< 0.100
Innisfail Queensland 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	0.567	74.8	0.873	0.32	< 0.100	0.19	< 0.100
Innisfail Queensland 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.223	0.86	82.4	1.25	0.377	< 0.100	0.239	< 0.100
Innisfail Queensland 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	68.6	0.918	0.236	< 0.100	0.156	< 0.100
Innisfail Queensland 13	< 0.100	0.212	< 0.100	< 0.100	< 0.100	< 0.100	0.129	0.162	44.4	76.5	0.884	0.631	0.149	0.17	< 0.100
Wingfield S. Australia 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.153	0.212	1.2	56.5	0.378	1.38	< 0.100	0.195	< 0.100
Wingfield S. Australia 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.329	46.8	0.445	0.45	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.126	0.4	42	0.364	0.211	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.13	0.381	49.4	0.383	0.552	< 0.100	0.146	< 0.100
Wingfield S. Australia 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.13	47	0.396	0.509	< 0.100	0.168	< 0.100
Wingfield S. Australia 6	< 0.100	0.242	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.156	0.703	58.3	0.527	0.289	< 0.100	0.131	< 0.100
Wingfield S. Australia 7	< 0.100	0.137	< 0.100	< 0.100	< 0.100	< 0.100	0.169	0.214	1.64	59.9	0.382	0.301	< 0.100	0.176	< 0.100
Wingfield S. Australia 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.181	0.436	53.5	0.556	0.211	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.134	0.381	53	0.535	0.174	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 10	< 0.100	0.198	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.167	0.566	52.6	0.525	0.612	< 0.100	0.196	< 0.100
Wingfield S. Australia 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.139	0.93	51.9	0.555	0.298	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	0.858	60.6	0.563	0.282	< 0.100	0.166	< 0.100
Wingfield S. Australia 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	0.89	53.9	0.587	0.337	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.14	0.461	46.8	0.515	0.213	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.491	53.2	0.562	0.195	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 16	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.157	0.204	1.28	61.3	0.412	0.255	< 0.100	0.127	< 0.100
Wingfield S. Australia 17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.62	53.7	0.455	0.481	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	53.3	0.473	0.487	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 19	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.422	58.3	0.396	0.487	< 0.100	0.14	< 0.100
Wingfield S. Australia 20	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.137	0.145	0.496	54.3	0.588	0.364	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.221	0.889	54.2	0.576	0.156	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 22	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.143	0.694	53.8	0.627	0.304	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 23	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.129	0.142	1.08	57.2	0.523	0.347	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 24	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.454	52	0.466	0.957	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 25	< 0.100	0.153	< 0.100	< 0.100	< 0.100	< 0.100	0.137	0.167	0.945	42.8	0.308	0.648	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 26	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.13	0.755	48.9	0.482	0.287	< 0.100	0.168	< 0.100
Wingfield S. Australia 27	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.221	44.6	0.408	0.318	< 0.100	< 0.100	< 0.100
Wingfield S. Australia 28	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	1.07	49	0.427	0.397	< 0.100	< 0.100	< 0.100
Cowley Queensland 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.401	66.7	1.64	1.12	0.507	2.18	< 0.100
Cowley Queensland 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.391	66.4	1.83	1.29	0.257	0.599	< 0.100
Cowley Queensland 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.75	53.2	1.21	1.08	0.209	0.355	< 0.100
Cowley Queensland 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	0.343	155	0.603	0.897	0.914	0.187	< 0.100
Cowley Queensland 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.243	168	0.611	0.78	0.981	0.145	< 0.100
Cowley Queensland 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.653	170	0.543	5.24	1.07	< 0.100	< 0.100
Cowley Queensland 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.132	< 0.100	0.399	47.1	1.8	1.46	0.169	0.867	< 0.100
Cowley Queensland 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.454	43.6	1.84	1.01	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
Cowley Queensland 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.133	< 0.100	0.336	46.4	1.49	0.864	0.149	< 0.100	< 0.100
Cowley Queensland 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.207	47.1	0.84	3.99	< 0.100	< 0.100	< 0.100
Cowley Queensland 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.31	49.6	0.69	1.36	0.165	< 0.100	< 0.100
Cowley Queensland 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.128	< 0.100	0.25	51.3	0.759	2.86	0.138	0.165	< 0.100
Cowley Queensland 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.18	44.9	0.793	2.75	< 0.100	< 0.100	< 0.100
Cowley Queensland 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.293	50.8	0.786	4.05	< 0.100	0.384	< 0.100
Cowley Queensland 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	< 0.100	0.431	35.6	0.613	1.33	< 0.100	< 0.100	< 0.100
Good Fortune 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.322	51.1	0.259	0.348	< 0.100	< 0.100	< 0.100
Good Fortune 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.151	< 0.100	0.239	52.1	0.285	0.471	< 0.100	< 0.100	< 0.100
Good Fortune 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	< 0.100	0.328	48	0.267	1.58	< 0.100	< 0.100	< 0.100
Good Fortune 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.18	< 0.100	0.37	47.9	0.304	1.75	< 0.100	< 0.100	< 0.100
Good Fortune 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	< 0.100	0.134	53.1	0.278	0.294	< 0.100	< 0.100	< 0.100
Good Fortune 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.15	< 0.100	0.149	50.5	0.341	0.515	< 0.100	0.129	< 0.100
Good Fortune 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.226	53.1	0.224	0.823	< 0.100	< 0.100	< 0.100
Good Fortune 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	49.1	0.32	0.671	< 0.100	< 0.100	< 0.100
Good Fortune 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.148	< 0.100	0.594	41.4	0.202	0.454	< 0.100	< 0.100	< 0.100
Good Fortune 10	0.134	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.128	< 0.100	0.287	59	0.262	1.22	< 0.100	< 0.100	< 0.100
Good Fortune 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.266	58.7	0.336	0.738	< 0.100	< 0.100	< 0.100
Good Fortune 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.162	< 0.100	0.444	50.8	0.286	0.457	< 0.100	< 0.100	< 0.100
Good Fortune 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.175	< 0.100	0.228	47.2	0.283	0.379	< 0.100	< 0.100	< 0.100
Good Fortune 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.149	< 0.100	< 0.100	54.7	0.244	0.72	< 0.100	0.155	< 0.100
Good Fortune 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.152	0.213	< 0.100	0.164	42.5	0.246	0.533	< 0.100	< 0.100	< 0.100
Indonesia 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.134	< 0.100	0.345	231	0.135	0.385	0.39	< 0.100	< 0.100
Indonesia 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.19	< 0.100	0.225	220	< 0.100	0.373	0.483	< 0.100	< 0.100
Indonesia 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.125	< 0.100	0.631	230	0.129	2.31	0.577	< 0.100	< 0.100
Indonesia 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	< 0.100	0.381	73	0.357	0.495	1.57	< 0.100	< 0.100
Indonesia 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.268	73	0.391	0.486	1.51	< 0.100	0.176
Indonesia 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.457	71.7	0.354	3.81	1.41	< 0.100	0.166
Indonesia 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.141	0.156	0.245	201	0.167	0.243	2.28	< 0.100	< 0.100
Indonesia 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.28	180	< 0.100	16.7	2.07	< 0.100	< 0.100
Indonesia 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.249	175	0.168	0.491	1.98	< 0.100	< 0.100
Indonesia 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.265	200	< 0.100	0.314	1.95	< 0.100	< 0.100
Indonesia 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.368	201	0.146	1.71	2.12	< 0.100	0.155
Indonesia 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.607	193	0.183	0.829	2.08	< 0.100	0.15
Indonesia 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.391	145	0.138	1.51	3.52	< 0.100	0.128
Indonesia 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.131	< 0.100	0.339	138	0.165	4.96	4.05	< 0.100	0.188
Indonesia 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.338	158	0.171	2.95	3.91	< 0.100	0.224
Indonesia 16	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.274	214	0.156	0.168	1.18	< 0.100	< 0.100
Indonesia 17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.351	208	0.154	0.374	1.3	< 0.100	< 0.100
Indonesia 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.218	222	0.138	0.3	1.25	< 0.100	< 0.100
Indonesia 19	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.461	210	0.146	0.358	1.57	< 0.100	< 0.100
Indonesia 20	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.412	205	0.171	0.199	1.49	< 0.100	< 0.100
Indonesia 21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.146	< 0.100	0.653	211	0.193	0.575	1.72	< 0.100	0.23
Indonesia 22	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.355	127	< 0.100	0.435	0.774	< 0.100	< 0.100
Indonesia 23	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.138	< 0.100	0.428	114	0.136	0.571	0.858	< 0.100	0.148
Indonesia 24	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.155	< 0.100	0.525	114	0.15	0.548	0.9	< 0.100	0.137
Indonesia 25	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.137	< 0.100	0.398	670	0.14	0.608	4.03	< 0.100	< 0.100
Indonesia 26	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.351	658	0.14	1.82	4.05	< 0.100	< 0.100
Indonesia 27	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.402	657	< 0.100	1.18	4.18	< 0.100	0.127
Indonesia 28	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.354	220	0.169	0.658	3.99	< 0.100	< 0.100
Indonesia 29	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	< 0.100	0.528	216	0.156	2.98	3.77	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
Indonesia 30	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.126	< 0.100	0.434	221	0.213	0.709	4	< 0.100	0.166
Indonesia 31	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.21	268	0.131	1.19	1.98	< 0.100	< 0.100
Indonesia 32	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.254	257	< 0.100	0.462	1.94	< 0.100	< 0.100
Indonesia 33	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.256	263	< 0.100	0.765	1.81	< 0.100	< 0.100
Indonesia 34	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.428	171	0.209	0.444	1.96	< 0.100	< 0.100
Indonesia 35	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.616	170	0.194	0.423	1.98	< 0.100	0.142
Indonesia 36	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.127	< 0.100	0.684	185	0.234	4.51	2.27	< 0.100	0.183
Indonesia 37	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.126	< 0.100	0.275	257	0.218	0.264	0.915	< 0.100	< 0.100
Indonesia 38	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.355	235	0.182	6.34	0.978	< 0.100	< 0.100
Indonesia 39	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.288	245	0.224	0.386	0.875	< 0.100	< 0.100
Indonesia 40	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.125	< 0.100	0.539	123	0.149	0.359	1.6	< 0.100	< 0.100
Indonesia 41	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.161	0.135	0.56	130	0.146	0.278	1.61	< 0.100	< 0.100
Indonesia 42	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.139	0.819	117	0.129	0.307	1.59	< 0.100	< 0.100
Indonesia 43	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.151	0.215	1.18	106	0.308	0.986	1.05	< 0.100	0.206
Indonesia 44	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.738	106	0.214	1.46	1.06	< 0.100	0.231
Indonesia 45	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.133	< 0.100	0.866	107	0.22	0.593	1.07	< 0.100	0.21
Indonesia 46	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.408	259	0.152	0.473	4.28	< 0.100	< 0.100
Taiwan 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.195	0.135	0.974	36.5	1.01	0.778	0.197	< 0.100	< 0.100
Taiwan 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.143	< 0.100	1.58	39.2	0.84	144	0.153	< 0.100	< 0.100
Taiwan 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.153	< 0.100	0.447	38.9	1.11	0.757	< 0.100	< 0.100	< 0.100
Taiwan 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.299	41.4	1.11	3.14	< 0.100	< 0.100	< 0.100
Taiwan 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.794	47.7	1.49	0.649	< 0.100	< 0.100	< 0.100
Taiwan 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.478	53.6	1.68	0.797	< 0.100	< 0.100	< 0.100
Taiwan 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.705	55	1.57	1.01	< 0.100	< 0.100	< 0.100
Taiwan 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.326	55.9	1.46	1.05	< 0.100	< 0.100	< 0.100
Taiwan 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.382	27.4	2.04	1.8	0.2	< 0.100	< 0.100
Taiwan 16	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.21	28.2	1.77	0.695	0.183	< 0.100	< 0.100
Taiwan 17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.26	32.9	2.03	0.421	< 0.100	< 0.100	< 0.100
Taiwan 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.582	31.1	2.16	0.741	0.135	< 0.100	< 0.100
New Zealand 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.565	100	0.586	6.7	< 0.100	< 0.100	< 0.100
New Zealand 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.73	101	0.361	3.05	< 0.100	< 0.100	< 0.100
New Zealand 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.754	97.1	0.599	1.19	< 0.100	< 0.100	< 0.100
New Zealand 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	44.6	93.1	0.393	2.88	< 0.100	< 0.100	< 0.100
New Zealand 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	85.1	110	0.449	15.5	0.23	0.157	< 0.100
New Zealand 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	6.25	95.8	0.415	4.46	0.177	< 0.100	< 0.100
New Zealand 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	15.9	90	0.413	0.741	< 0.100	< 0.100	< 0.100
New Zealand 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	4.41	111	0.546	8.9	0.144	< 0.100	< 0.100
New Zealand 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	68.3	127	0.42	19	< 0.100	< 0.100	< 0.100
New Zealand 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.143	< 0.100	0.577	105	0.311	1.28	< 0.100	< 0.100	< 0.100
New Zealand 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	16.2	102	0.305	1.83	0.131	< 0.100	< 0.100
New Zealand 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	3.05	98	0.384	1.74	0.147	< 0.100	< 0.100
New Zealand 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.5	90.8	0.298	1.43	0.132	< 0.100	< 0.100
New Zealand 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.79	93.9	0.44	0.96	< 0.100	< 0.100	< 0.100
New Zealand 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.139	< 0.100	17.3	104	0.465	3.71	0.149	< 0.100	< 0.100
New Zealand 16	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.7	89.2	0.34	2.24	0.176	< 0.100	< 0.100
New Zealand 17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	29	123	0.314	16.8	< 0.100	< 0.100	< 0.100
New Zealand 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.71	112	0.451	2.26	< 0.100	< 0.100	< 0.100
New Zealand 19	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	3.11	113	0.413	3.1	< 0.100	< 0.100	< 0.100
New Zealand 20	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	33	103	0.301	3.56	0.148	< 0.100	< 0.100
New Zealand 21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.92	85.9	0.457	1.36	< 0.100	< 0.100	< 0.100
New Zealand 22	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.85	75.4	0.322	1.61	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
New Zealand 23	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	9.35	99.6	0.333	6.69	< 0.100	< 0.100	< 0.100
New Zealand 24	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	4.67	96.1	0.462	5.45	0.141	< 0.100	< 0.100
New Zealand 25	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	3.68	62.8	0.338	0.931	< 0.100	< 0.100	< 0.100
New Zealand 26	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	10.8	106	0.255	5.17	0.212	< 0.100	< 0.100
New Zealand 27	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	1.21	88.2	0.32	2.59	< 0.100	< 0.100	< 0.100
New Zealand 28	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	3.31	115	0.528	0.547	0.13	< 0.100	< 0.100
Cone Bay Fish 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.153	24.3	0.14	1.04	< 0.100	< 0.100	< 0.100
Cone Bay Fish 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	22	0.143	1.11	< 0.100	< 0.100	< 0.100
Cone Bay Fish 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.212	0.125	0.137	20.7	0.135	6.21	< 0.100	< 0.100	< 0.100
Cone Bay Fish 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	26.4	0.135	1.1	< 0.100	< 0.100	< 0.100
Cone Bay Fish 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.157	< 0.100	6.09	29	0.127	0.701	< 0.100	< 0.100	< 0.100
Cone Bay Fish 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	26.4	< 0.100	0.809	< 0.100	< 0.100	< 0.100
Cone Bay Fish 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	22.6	0.152	0.321	< 0.100	< 0.100	< 0.100
Cone Bay Fish 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	25.4	0.154	1.31	< 0.100	< 0.100	< 0.100
Cone Bay Fish 9	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.18	18.8	0.158	0.582	< 0.100	< 0.100	< 0.100
Cone Bay Fish 10	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.5	0.138	1.04	< 0.100	< 0.100	< 0.100
Cone Bay Fish 11	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	22	< 0.100	1.1	< 0.100	< 0.100	< 0.100
Cone Bay Fish 12	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.134	0.198	22.4	0.13	2.6	< 0.100	< 0.100	< 0.100
Cone Bay Fish 13	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.3	0.185	0.817	< 0.100	< 0.100	< 0.100
Cone Bay Fish 14	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	21.4	< 0.100	0.591	< 0.100	< 0.100	< 0.100
Cone Bay Fish 15	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.9	0.139	0.535	< 0.100	< 0.100	< 0.100
Cone Bay Fish 16	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.248	< 0.100	0.147	0.405	< 0.100	1.14	< 0.100	< 0.100	< 0.100
Cone Bay Fish 17	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.8	0.14	0.684	< 0.100	< 0.100	< 0.100
Cone Bay Fish 18	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.203	0.186	< 0.100	24.7	0.141	0.536	< 0.100	< 0.100	< 0.100
Cone Bay Fish 19	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	22	0.14	1.3	< 0.100	< 0.100	< 0.100
Cone Bay Fish 20	< 0.100	0.181	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	23.7	0.157	0.601	< 0.100	< 0.100	< 0.100
Cone Bay Fish 21	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.17	20.6	0.148	0.499	< 0.100	< 0.100	< 0.100
Cone Bay Fish 22	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	2.17	23.4	< 0.100	0.268	< 0.100	< 0.100	< 0.100
Cone Bay Fish 23	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.5	0.155	1.08	< 0.100	< 0.100	< 0.100
Cone Bay Fish 24	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	3.3	26.6	0.149	< 0.100	< 0.100	< 0.100	< 0.100
Cone Bay Fish 25	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	23.3	< 0.100	0.547	< 0.100	< 0.100	< 0.100
Cone Bay Fish 26	< 0.100	0.274	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	18.2	< 0.100	0.712	< 0.100	< 0.100	< 0.100
Cone Bay Fish 27	< 0.100	0.169	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.182	2.15	10.8	< 0.100	0.856	< 0.100	< 0.100	< 0.100
Cone Bay Fish 28	< 0.100	0.167	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	20.3	0.129	0.47	< 0.100	< 0.100	< 0.100
Cone Bay Fish 29	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	22.1	0.139	2.58	< 0.100	< 0.100	< 0.100
Cone Bay Fish 30	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	21.8	0.137	3.45	< 0.100	< 0.100	< 0.100
Study 2B Unknown sample trace back															
Unknown Taiwan Fish 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.181	39.2	0.357	1.66	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	41	0.443	1.38	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	29.4	0.729	1.47	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	28.9	0.779	1.37	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.157	25.5	0.731	0.577	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 6	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	25.5	0.72	1.64	< 0.100	< 0.100	< 0.100
Unknown Taiwan Fish 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	25	0.502	1.37	2.07	< 0.100	< 0.100
Unknown Taiwan Fish 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.352	25.2	0.856	1.58	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	27.1	0.411	0.747	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 2	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	27.2	0.403	0.715	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 3	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	24.8	0.342	1.23	< 0.100	< 0.100	< 0.100

Analytes marked with an asterisk have concentrations in parts per million															
analytes not marked have concentrations in parts per billion	163 Dy	165 Ho	166 Er	169 Tm	172 Yb	175 Lu	178 Hf	181 Ta	182 W	202 Hg	203 Tl	208 Pb	209 Bi	232 Th	238 U
Unknown Australian Fish 4	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.283	26.1	0.415	3.69	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 5	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.135	25.1	0.281	1.1	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 6	< 0.100	< 0.100	< 0.100	< 0.100	0.151	0.217	< 0.100	< 0.100	< 0.100	25.9	0.377	2.17	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 7	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	28.3	0.426	0.379	< 0.100	< 0.100	< 0.100
Unknown Australian Fish 8	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	27.4	0.355	0.678	< 0.100	< 0.100	< 0.100