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CSIRO Submission 12/444

Inquiry into the role of science for fisheries and aquaculture

House of Representatives Standing Committee on Agriculture, Resources, Fisheries and Forestry

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Acronyms Used

AAHS	FRDC Aquatic Animal Health Subprogram
ABARE	(*now ABARES*)
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AFMA	Australian Fisheries Management Authority
AFMF	Australian Fisheries Managers Forum
AQIS	Australian Quarantine and Inspection Service
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSIRO-AAHL	CSIRO Australian Animal Health Laboratory
DAFF	Department of Agriculture, Fisheries and Forestry
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry (*previously DEEDI*)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EAC	East Australian Current
EPBC	Environment Protection and Biodiversity Conservation (Act)
ERA	ecological risk assessment
FAO	The Food & Agriculture Organisation of the United Nations
FBI	federal budget initiative
FRDC	Fisheries Research & Development Corporation
HSE	health safety and environment
IMOS	Integrated Marine Observing System
NARP	National Adaptation Research Plans
NERP	National Environmental Research Program
PISC	Primary Industries Standing Committee
R&D	Research and Development
UN	United Nations

Executive Summary

Australia's fisheries and aquaculture industries are small by world standards but have a high regional, ecological, and political footprint. On global standards they are regarded as well managed. CSIRO has been involved in fisheries and aquaculture research for over 60 years. CSIRO science contributes directly into fisheries management through membership of assessment groups and management advisory committees. Internationally CSIRO is directly involved in regional fisheries management organizations, such as the Commission for the Conservation of Southern Bluefin Tuna. The methods and tools developed by CSIRO have been adopted globally. Likewise, our science has had profound impacts on the success and growth of aquaculture production nationally. The Australian model of collaboration across science, management, and industry is regarded as world's best practice.

This submission has been prepared by CSIRO scientists with extensive experience and international recognition in many facets of fisheries, aquaculture, climate change, and aquatic biosecurity. This submission focuses on the science that informs and supports fisheries and aquaculture and brings to the committee's attention conclusions based on past and current peer-reviewed research. A summary of CSIRO's main points in response to the Terms of Reference follows, with supporting references cited in the body of the submission.

1. **The relationship between scientific knowledge of fish species, ecosystems, biodiversity and fish stock sustainability**
   - The current status of Australia's fisheries has been due in part to many decades of directed scientific research, and management advice and support.
   - Australia is a leader in the implementation of ecosystem-based fisheries management underpinned by strong science. Methods and tools developed by CSIRO and its partners have been widely adopted internationally.
   - Scientific knowledge of fish species and fish stock sustainability is much greater than for biodiversity and ecosystems.
   - Recreational fisheries continue to be an important sector in Australia, socially, politically, economically, and environmentally, but methods to assess them are generally expensive and less well developed than methods applied to commercial fisheries.
   - There are important opportunities for science to inform Australia's broader policy objectives regionally given the importance of fisheries in our region.

2. **Fishery management and biosecurity**
   - Australia's participatory management in fisheries provides an effective means by which research has a direct input into management and policy.
   - The increased information demands required for ecosystem-based fisheries management is leading to the application of new technologies to provide cost effective monitoring strategies.
   - There is significant investment in aquatic animal health and biosecurity but the extensive nature of Australia's aquatic industries requires careful prioritisation of research activities.
   - Existing impacts of climate change on fisheries and aquaculture have been demonstrated and potential further impacts identified. Science can help address the challenges and opportunities faced by the fisheries and aquaculture industries and management systems.

3. **Research, development and applied science of aquaculture**

- Science has a demonstrated success in addressing current and future challenges for aquaculture. There is the opportunity to develop and apply knowledge and technology to enable the Australian aquaculture industry to achieve its full potential for sustainable growth.
- The aquaculture science and industry priorities are in environmental, economic, and social planning; production environment and energy use technology; domestication and selective breeding; health and welfare management; and sustainable aquafeeds technologies.
- Australia is free from many of the aquatic diseases which have had significant impacts on aquaculture overseas.
- CSIRO suggests there is now a need to integrate climate change and resource use research into spatial planning frameworks for aquaculture together with other uses of the marine environment.

4. **Governance arrangements relating to fisheries and aquaculture, including the implications for sustainability and industry development**

- Fisheries and aquaculture industries are two of many users of the aquatic environment. There is a role for new methods and further research to assess the interactions among multiple sectors and monitor cumulative impacts from multiple sectors.
- Continued investment is required in innovative model frameworks that enable evaluation of alternative management plans and arrangements for multiple uses of the marine environment, including fisheries and aquaculture.

5. **Current initiatives and responses to the above matters by state, territory and Australian governments**

- The recent implementation of the National Strategy for Fishing and Aquaculture research, development and extension should deliver improved collaboration and coordination of research activities targeted directly at priorities for fisheries and aquaculture development and management.
- CSIRO supports the recent initiatives for consistent reporting on stock status across jurisdictions and a national harvest strategy framework.

Introduction

CSIRO and the rationale for fisheries and aquaculture research

CSIRO has been involved in fisheries and aquaculture research for over 60 years and has conducted research relevant to this inquiry, including fish, crustacean and molluscan biology, fishery monitoring, quantitative stock assessment, risk assessments, biodiversity conservation and ecosystem modelling, domestication and selective breeding, environmental management including climate change impacts, aquafeed technology, and aquaculture health monitoring and prevention.

Seafood is a major contributor to global food security with the aquaculture sector continuing to be the fastest-growing animal food producing sector in the world. Aquaculture currently accounts for nearly half (46%) of the world's food fish consumption, compared with 33.8% in 2000 (FAO 2011). Capture fisheries and aquaculture produced 140 million tonnes of produce in 2009, of which capture fisheries contributed 90 million tonnes (FAO 2011). Global fisheries provide 2.9 billion people with 20% of their protein and provide employment for 46 million people directly and 180 million including secondary activities.

Australia's commercial fisheries and aquaculture industries are relatively small by world standards yet have disproportionately large ecological, social, and political footprints. For example, Australian marine fisheries account for 0.2% of global marine fisheries landed tonnage but 2% of marine fisheries landed value (FRDC 2010). A large proportion of the wild fishery catch in Australia is high-value species such as abalone, rock lobster, tuna, and prawns that are mostly exported. On the other hand, aquaculture production from Atlantic salmon, oysters, and prawns are predominantly for national consumption.

Australia is adjacent to one of the world's largest fishing nations (Indonesia) and to the world's two largest tuna fisheries, in which it has shared interests – politically as well as through access to migrating seafood resources. Indonesia overtook the USA in 2007 as the third ranked country for fisheries production (FAO 2011). The Indonesian annual capture fishery catch is five million tonnes and 3.3 million people rely directly on fishing activities for part or all of their income (FAO 2004). Fish is a mainstay for food security for Pacific island countries and territories (Bell et al 2009). Fish provides 50-90% of animal protein in rural areas and 40-80% animal protein in many urban areas of the Pacific (Bell et al 2009). These fisheries share species and ecosystems with Australia.

Demand for seafood is likely to increase with increasing populations both domestically and in our region, placing additional pressure on sustainable production of seafood. Global landings from capture fisheries are static or declining slightly while production from aquaculture continues to rise (FAO 2011). This global pattern generally is mirrored in Australia (ABARES 2011) but the annual growth rate of Australian aquaculture (4%) lags behind annual global growth rates (7%).

Australian marine industries were worth in excess of $44 billion per annum in 2010, having increased from $38 billion in 2008 (AIMS 2010). Increasing marine uses can lead to tensions between sectors and generate competing priorities for the same areas. Recreational fishing is a growing industry in Australia with up to four million people participating per annum and catches of many species exceeding commercial catches (Henry and Lyle 2001). The growth in this sector is increasing conflict with other users, including commercial fishers. No arrangements currently exist to provide a forum for identifying integrated strategic marine management or for setting spatial management priorities across multiple sectors.

Australia's fisheries jurisdictions have adopted ecosystem-based fishery management as a policy goal. This is consistent with the growing international demand for environmentally friendly produced products. Spatial management and participatory or co-management are also key features of the fishery management system. Our fisheries are well managed by global standards. For example, it has been estimated that 15% of our fisheries are overfished, with an improving trend, compared to 30% globally (FAO 2010, Smith and Webb 2011, Woodhams et al 2011).

Challenges for the growth of Australian aquaculture include: development of a national decision support system to develop the full potential for the sustainable growth of Australia's on-shore and off-shore aquaculture industries; progressively improving production efficiency in existing footprints (e.g. use of alternative energy); maintaining healthy disease free stocks and efficiently managing health and welfare issues; production of cost effective, sustainable, and efficient feeds; understanding product quality, value adding, and marketing; and appropriate investment to establish new industries (species, farming regions).

Australia's wild-capture fisheries, aquaculture, recreational fisheries, and traditional fisheries are free from many diseases that occur overseas, providing us with a competitive advantage in both production and trade. The number of aquatic animal species and the absolute number of aquatic animals being farmed in Australia is increasing annually. New diseases caused by emerging infectious agents (e.g. Atlantic salmon rickettsia-like organism (Corbeil et al 2005), abalone herpesvirus (Corbeil et al 2010), oyster oedema disease (Crockford and Jones 2011), ostreid herpesvirus (Frances et al 2011)) continue to threaten the sustainability of enterprises and the call on health services to support this expanding industry is growing.

Fishery and aquaculture science

Fisheries are relatively expensive to study and assess due to the nature of the environment in which they operate. There are twin challenges currently facing fisheries science in Australia within this context. First, public sector funding for research is flat but costs of research are increasing with ongoing needs for monitoring and research to reduce uncertainty about future resource dynamics (e.g., because of natural variability combined with increasing pressures on marine ecosystems from climate and other anthropogenic sources) and demand for scientific proof to meet society's high environmental standards.

Second, the fairly rapid shift in fisheries management from a focus on single target species assessments to a focus on ecosystem-based management places increasing demands on research. The information demands for the broader approach are much higher, despite development of tiered assessment approaches that start with lower cost approaches and only increase research cost when a material risk with that approach is shown. Australia is seen as being at the forefront in this area of research (Gallagher et al 2012; Scandol et al 2009) but the information demands are still formidable and outside the scope of previous research.

Current challenges are likely to be compounded by long-term changes in the ocean environment which limit the value of past experience and historical patterns. Science has a role in addressing these challenges through advances in ocean observation systems, data-poor species and fisheries, bio-economic research, 'whole of system' modelling frameworks, and, social research into governance systems, and better understanding of human behaviour.

A critical challenge for aquaculture science is to develop and apply the required knowledge and technology with sufficient speed and scale to enable the Australian industry to achieve its full potential. Key areas for research include: integrating climate change and resource use research into an aquaculture spatial planning frameworks that encompasses environmental and social values; species selection; production systems; market demand and other uses of adjacent environments; increasing the speed of transition from reliance on wild broodstock to the use of domesticated selectively bred stocks, including the application of genetic tools developed for livestock breeding and human health; and developing cost effective aquaculture feeds that minimise or eliminate the use of wild harvest fishmeal and fish oil.

Indigenous capture fisheries still require investment. Many are remote but very important to the social, economic, and health fabric of indigenous societies. Research in this area requires unique skills and strong links with local communities.

Australia's internationally recognized expertise in fisheries research and management provides opportunities to contribute regionally (e.g., Coral Triangle, South Pacific, Indian Ocean, Antarctic) and globally (FAO, UN) to improving food security, sustainable development, and ecosystem-based management. Opportunities exist to inform Australia's broader policy objectives regionally and globally.

CSIRO's response to the Terms of Reference

1 The relationship between scientific knowledge of fish species, ecosystems, biodiversity and fish stock sustainability

Key points

- The current status of Australia's fisheries has been due in part to many decades of directed scientific research, and management advice and support.
- Australia is a leader in the implementation of ecosystem-based fisheries management underpinned by strong science. Methods and tools developed by CSIRO and its partners have been adopted widely internationally.
- Scientific knowledge of fish species and fish stock sustainability is much greater than for biodiversity and ecosystems.
- Recreational fisheries are an important sector in Australia, socially, politically, economically, and environmentally, but methods to assess them are generally expensive and limited.
- There are important opportunities for science to inform Australia's broader policy objectives regionally given the importance of fisheries in our region.

Fisheries management agencies have a long history of drawing on scientific advice and input. The focus for most of this time has been on the productivity and dynamics of populations of commercially exploited species, where well founded theory and methods for providing robust information for the management and policy processes have been established.

A more recent shift towards ecosystem approaches to fisheries management has shifted the science focus towards, on the one hand, understanding the broader ecological impacts of fishing, and on the other to improving understanding of the role that biodiversity and ecosystem function might play in supporting fisheries production. The focus on ecological impacts of fishing in Australia has been driven in part by provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Recreational fisheries continue to be an important sector in Australia, socially, politically, economically, and environmentally, but methods to assess them are generally expensive and less well developed than those applied to commercial fisheries. The last national snapshot of recreational fishing was in 2000 (Henry and Lyle 2001). New cost effective methods are being developed (e.g., Griffiths et al 2010) but the recreational catch remains highly uncertain for many species, though in some cases it is known to be significant.

The EPBC Act Review in 2009 recommended that the EPBC Act be amended so that the fishery provisions under Parts 10, 13, and 13A are streamlined into a single strategic assessment framework for Commonwealth and State and Territory managed fisheries to deliver a single assessment and approval process. The review also recommended that the Australian Government:

(1) integrate the Commonwealth Fisheries Harvest Strategy Policy (HSP) framework with the threatened species listing process for marine fish; and
(2) ensure the HSP biological reference points reflect the biology of the species and its role in ecosystem function rather than standard default settings such as reduction of population.

Science will play a significant role in helping to deliver these recommendations efficiently and effectively. Scientific knowledge of fish species and fish stock sustainability is much greater than for biodiversity and ecosystems. Indeed, much of the information available for the latter has been obtained incidentally from fishery monitoring. Cost effective monitoring strategies and activities such as the Integrated Marine Observing System (IMOS) can enhance the information base for biodiversity and ecological function but will need on-going support to sustain consistent, structured, long term observations.

2 Fishery management and biosecurity

> Key points
>
> - Australia's participatory management in fisheries provide an effective means by which research has a direct input into management and policy.
> - The increased information demands required for ecosystem based fisheries management is leading to the application of new technologies to provide cost effective monitoring strategies.
> - There is significant investment in aquatic animal health and biosecurity but the extensive nature of Australia's aquatic industries requires careful prioritisation of research activities.
> - Existing impacts of climate change on fisheries and aquaculture have been demonstrated and potential further impacts identified. Science can help address the challenges and opportunities faced by the fisheries and aquaculture industries and management systems.

Calculation and monitoring of stock size, sustainable yield, bycatch, and related data collection

Australia has well established participatory management structures that involve industry, resource managers, and scientists explicitly in the process that provide direct, structured pathways to deliver research support into management and policy fora.

The science necessary to support the monitoring and assessment of fish stocks is relatively expensive and the investment in monitoring of stock status varies considerably across species and fisheries, largely reflecting the economic value of the resource or its conservation status. All Australian jurisdictions have well developed methods for monitoring and assessment of the most valuable target species but low value species tend not to be monitored or assessed as extensively (Smith et al 2009). Approaches for assessing these data-poor species and fisheries are advancing quite rapidly although methods for the very data-poor species (which form a very large part of Australia's fisheries) still require development.

Recent developments including the adoption and implementation of a Harvest Strategy Policy (e.g. Smith et al 2008) and an ecological risk assessment and management framework (e.g. Smith et al 2007) explicitly account for differences in data availability among fisheries and species. The Harvest Strategy Policy explicitly links the outcomes of monitoring and stock assessment with the management response to ensure sustainable fisheries. The risk assessment framework provides a method of assessing risks associated with fishing effects on bycatch species. CSIRO scientists were closely involved in the development and implementation of these approaches (Hobday et al 2011; Williams et al 2011).

New observation technologies are improving understanding of marine ecosystems in general and some harvested species in particular. These technologies include hydro-acoustic methods, video monitoring, swath mapping, and sensor platforms, exemplified in the Integrated Marine Observing System (IMOS). Fishers are one of the more active groups in the marine environment. Deploying sensors on fishing vessels to collect environmental information is an opportunity that is only just starting to be explored. New techniques from other science fields, such as genetics and software development, are also being developed to support more cost effective monitoring and processing of environmental data.

Australia has a strong and proven capability in modelling and assessment of fisheries that is being replicated around the world. CSIRO's broad capability covers conventional single species stock assessment models for data-rich species, risk-based assessment methods for data poor species, including bycatch (Hobday et al 2011), a suite of modelling approaches to support ecosystem-based assessment and management approaches (Smith et al 2007), and bio-economic modelling (Dichmont et al 2010).

Long term investment in monitoring programs provides sources of data that have been shown globally and in Australia to be valuable for a range of purposes, including marine spatial planning (DSEWPaC 2011).

Reduction in such programs would place at risk the scientific basis of Australia's claim of good management and potentially threaten high value markets that demand high environmental standards and demonstration of ecologically sustainable practices, such as through Marine Stewardship Council certification.

Effects of climate change, especially on species dispersion, stock levels, & fishing communities

Research by CSIRO and other agencies has demonstrated that climate change already is affecting the oceans around Australia (Poloczanksa et al 2007) and is projected to do so in future (Hobday and Lough 2011). Changes in biology, including the distribution of commercial fish species, have been documented (Last et al 2011) and are projected over the coming decade (Hobday 2010).

Sea surface temperatures are projected to be ~1°C warmer in the north and ~2°C warmer in the south-east within 100 years (Lough and Hobday 2011). The East Australian Current (EAC) is projected to strengthen by 20% over coming decades (Ridgway 2007). Changes in the Leeuwin Current off Western Australia are less certain and it may in fact weaken (Feng et al 2009). Changes in water chemistry, as the oceans absorb CO_2, are not well documented around Australia (Lough and Hobday 2011), although the pH of the global ocean has decreased by 0.1 unit already, which is a very significant change (Feely et al 2004; Sabine et al 2004) that will have significant consequences for marine ecosystems, especially organisms that form calcium-based skeletons and shells such as corals and molluscs (e.g. Hoegh-Guldberg et al 2007; Moy et al 2009).

Changes in species distributions around Australia have been reported, with 47 marine examples (Madin et al 2011). These changes primarily are related to increases in water temperature and changes in ocean currents (Booth et al 2011). Last et al (2011) reported that forty-five fish species representing 27 families (~30% of the inshore fish families in the region) show pole-ward distributional shifts over the last 30 years.

Impacts on marine species around Australia have been reported from a range of trophic levels. A 50% decline in the biomass of the spring phytoplankton bloom and growth rate (via chlorophyll a) between 1997-2007 has been reported from eastern Tasmania (Thompson et al 2009), where cold water zooplankton have become less common (Johnson et al 2011). These changes at the base of the food chain have been correlated with a change in small pelagic fish community composition (McLeod et al, in press). Growth of southern rock lobster, positively related to water temperature, has increased in southern Tasmania, but recruitment of juvenile lobsters is negatively related to temperature and has declined (Pecl et al 2010; Johnson et al 2011). Metabolic effects of increasing temperatures may lead to declining productivity in the north of species' ranges and range changes in the south (Neuheimer et al 2011).

The majority of Australia's fishery species are considered sustainably managed but future climate change may impact industry profitability (Hobday et al 2008; Pecl et al 2011; Norman-Lopez et al 2011). For example, pelagic fishes such as sharks, tuna, and billfish are projected to move further south on the east and west coasts of Australia (Hobday 2010). These changes may lead to shifts in overlap among different species) and changes in the distribution of fishing vessels amongst east coast ports, which have implications for fisheries bycatch management (Hartog et al 2011). Research to anticipate and support adaptation strategies for industry and resource managers is a growing need in response to climate change.

Australian fisheries impacts and adaptation research is guided by the Marine National Adaptation Research Plan (NARP) (Mapstone et al 2010), and the National Action Plan for Fisheries (DAFF 2010), both of which have a strong focus on ecosystem and industry adaptation. Adaptation options exist for a range of marine species and their fisheries (Pecl et al 2009; Hobday and Poloczanska 2010), such as maintaining freshwater flows to keep estuaries open and functioning for black bream fisheries in Victoria (Jenkins et al 2010). Options may be more limited, however, for southern species found on the continental shelf, as suitable habitat will not be present in future if the range of suitable ocean conditions shifts southward off the Australian continental margin. A southward shift in fishery activity already has been reported for Tasmanian southern rock lobster (Pecl et al 2009) but adaptation to climate change is considered possible by most participants given the spatial flexibility in the northern fleet. Translocation may be possible for some high value species as a mechanism to maintain production in the face of declining recruitment and has been trialled for southern rock lobster (Green et al 2010).

Pest and disease management and mitigation relevant to fisheries and aquaculture

Australia is free from many of the aquatic diseases which have had significant negative impacts overseas. The pilchard mortalities of 1995 (Hyatt et al 1997) and 1998 (Whittington et al 2008) in Southern Australian waters – arguably the most significant disease events in any wild fishery world-wide - were clear examples of threats posed by new and emerging diseases and prompted several national reviews into Australia's preparedness to respond to aquatic animal disease emergencies (e.g. Higgins 1996).

The FRDC Aquatic Animal Health Subprogram (AAHS) was established in 2001 under a joint agreement between DAFF and FRDC and, in consultation with industry, a portfolio of projects was developed. The AAHS R&D plan was drafted in consultation with industry, governments, and research providers and is reviewed regularly, most recently in 2011. AAHS has managed in excess of 80 projects during its tenure.

The extensive nature of Australia's aquatic industries requires careful prioritisation of research activities. Fisheries and aquaculture production involves dozens of major and hundreds of minor aquatic species and few can be considered domesticated. Knowledge of aquatic animal diseases is relatively poor and some diseases observed in aquatic species may be caused by entirely undescribed pathogens. R&D would benefit from coordination across sectors including aquaculture, wild-capture (Bowater et al 2012), recreational, and ornamental (Go and Whittington 2006) fisheries that share the aquatic environment.

Many Australian diseases are related to similar conditions observed overseas but there have been disease outbreaks specific to Australia (e.g. pilchard herpesvirus, oyster oedema disease) and for which there has been no previous knowledge. It is likely that diseases of aquatic animals new and exotic to Australia will continue to occur, possibly more frequently with changing climate (Hobday 2010). Exotic disease preparedness involves not only maintaining resources for their diagnosis but also developing essential resources for R&D (e.g. vaccine development, development of disease-resistant broodstock) such as state-of-the-art bio-secure research aquarium facilities like the CSIRO-AAHL Fish Diseases Laboratory.

International[i] and Australian[ii] experience demonstrates that disease can cause significant harm to fisheries and aquaculture production, threatening resource sustainability and industry profitability[iii]. Increasing numbers of new diseases of aquatic animals overseas is of particular concern as these pose risks of exotic disease intrusions for Australia[iv]. These diseases have had devastating socio-economic impacts in affected countries[v]. It is essential that Australia is well-prepared for incursions of such exotic diseases.

Minimising risks to the natural environment and human health

Australia has invested strongly in risk based assessments for environmental management. Australian methods for ecological risk assessment (ERA) have been adopted widely within Australia to assess impacts of fishing and several methods have seen wide adoption internationally (Hobday et al 2011).

Fishing vessels are one of the many potential vectors of marine invasive species around Australia. The science and implementation strategies for management of domestic transfer of invasive species have been developed for some time but implementation has been slow over the last decade.

Cooperation among Australian governments on the above

Please see response to ToR 5 – *Current initiatives and responses to the above matters by state, territory and Australian governments.*

3 Research, development and applied science of aquaculture

Key points

- Science has a demonstrated success in addressing current and future challenges for aquaculture. There is the opportunity to develop and apply knowledge and technology to enable the Australian aquaculture industry to achieve its full potential for sustainable growth.
- The aquaculture science and industry priorities are in environmental, economic, and social planning; production environment and energy use technology; domestication and selective breeding; health and welfare management; and sustainable aquafeeds technologies.
- Australia is free from many of the aquatic diseases which have had significant impacts on aquaculture overseas.
- CSIRO suggests there is now a need to integrate climate change and resource use research into spatial planning frameworks for aquaculture together with other uses of the marine environment.

Transitioning from wild fisheries to aquaculture in individual species

A major role of CSIRO aquaculture science has focussed on selective breeding and domestication. Atlantic salmon is the most valuable of all of Australia's seafood sectors with a farm gate value of $370 million. The industry is based on a genetically healthy population of founder breeding stocks introduced from Canada in the mid-1960's (Innes and Elliott 2006). A selective breeding program for the Tasmanian stocks of Atlantic salmon was established in 2005.

There has been a progressive decline in the value of the southern bluefin tuna (SBT) "farming" industry over the past decade, in contrast to the growth of Atlantic salmon. The industry relies on the fattening of wild caught fish in sea cages. There are no domesticated SBT broodstock and the industry has yet to succeed in rearing any stocks to sexual maturation in captivity (SBT take 10 years to reach sexual maturity). Most of the "farmed" tuna is exported to Japan. The value of farmed SBT production fell by 16% ($29 million) to $158 million in 2008–09 (ABARE 2010) and then to $102.2 million in 2010 (ABARES 2011).

The Sydney rock oyster is native to Australia and its production in New South Wales and Queensland is a combination of wild harvest and farming using seedstock supplied from hatcheries. A selective breeding program was established for Sydney rock oysters in 1990 (Nell et al 2000). The Pacific oyster was introduced to Tasmania from Japan between 1947 and 1952. A selective breeding program for Pacific oysters is well established (Kube et al 2012) and this has contributed to the progressive growth in production and total value of the oyster farming industry, with a current farm gate value of $98 million.

Black tiger Prawns (*Penaeus monodon*) and banana prawns (*Penaeus merguiensis*) are two native prawn species now farmed in Australia. A domestication and selective breeding program was established for black tiger prawns in 2000 (Preston et al 2009) that has contributed to recent increases in production of farmed prawns, which have a current farm gate value of $78 million.

Farmed production of Australian native barramundi is mainly from pond-based systems in Queensland and the Northern Territory, with one sea cage operation in North Western Australia. Some domesticated stocks have been produced but selective breeding of this species is still in early stages of development. Growth of the industry to its current farm gate value of $27 million has been from progeny of wild broodstock.

Two native abalone species, greenlip abalone (*Haliotis laevigata*) and blacklip abalone (*H. rubra*), and their hybrid cross are being farmed in Australia. Scientific advances in abalone domestication and production contributed to the growth of production of farmed abalone to its farm gate value of $23 million in 2009.

All key Australian aquaculture sectors except the sea-cage growth of wild-caught southern bluefin tuna have increased production and value in the past decade. Linear projections of these trends indicate that the total value of the industry could exceed $1 billion by 2020.

Improving sustainability and lifecycle management practices and outcomes

Sustainable production of any aquaculture species is dependent on successful domestication. Reliance on wild broodstock to supply seedstock for aquaculture increases the pressure on wild stocks, elevates the risks of introducing disease to farmed populations, and, most importantly, precludes the enormous benefits of selective breeding. CSIRO and its industry partners have responded to this challenge by established long-term (decadal) R&D programs to optimise the cumulative benefits of domestication and selective breeding of Atlantic salmon, Pacific oysters, prawns and abalone. Other species, including barramundi, amenable to domestication are likely to be the next candidates for selective breeding. Recent achievements of these partnerships include: 60% increase in the harvest yields of black tiger prawns; 15% genetic response to selection for growth and disease resistance in farmed Atlantic salmon; 10% genetic gains in growth rates of abalone; and 8.5% improvement in the economic performance of Pacific oysters.

All Australian aquaculture industries operate within strict environmental regulations applied at national and state government levels. The industry, CSIRO, and other research providers have made globally significant advances over the past two decades in environmentally sustainable management of near-shore sea-cages (Crawford et al 2003) and on-shore coastal ponds (Burford et al 2003). CSIRO suggests there is a need to integrate climate change and resource use research into spatial planning frameworks that include environmental and social values, species selection, production systems, market demand, and other uses of environments surrounding areas of aquaculture potential. Such integrated R&D will be important to enable industry and policy makers to realise the full potential for sustainable growth of Australian aquaculture.

Twenty to thirty million metric tons of wild-harvest fish per year are used globally to produce fishmeal and fish oil for animal feeds. Aquaculture's use of global fishmeal and fish oil is 68% and 88% respectively. There is a global need to develop cost effective alternatives to wild-harvest fishmeal and fish oil. CSIRO recently has achieved significant advances towards this goal. These include the bioconversion of low value agricultural plant waste to a high value bioactive feed that doubles the growth rate of farmed prawns (Glencross et al 2012) and the development of crops that produce omega-3 oils in their seeds, to provide the health benefits of omega-3 oils without depleting limited wild fish stocks (Petrie et al 2011). CSIRO and its industry and research partners are committed to achieving the goal of developing cost effective aquaculture feeds that will minimise or eliminate the use of wild harvest fishmeal and fish oil.

Pest and disease management and mitigation

Selective breeding for improved resistance or tolerance to diseases is a central component of the selective breeding collaborative research programs that CSIRO has established with Australia's Atlantic salmon, oyster, abalone, and prawn farming industries. Some aquaculture species, such as salmon around Tasmania, are considered vulnerable to warming ocean waters (Hobday et al 2008) but a range of adaptation options exist for such industries, including disease management, site selection, and selective breeding (Battaglene et al 2008). Experiments have shown that metabolic efficiency, calcification rates, and growth rates of cultured molluscs, including the blue mussel and the Pacific oyster, will be impaired by a warming ocean, with economic consequences (Hobday et al 2008). Some aquaculture operations will face challenges in continuing to grow the same species in the same locations (Hobday and Poloczanska 2010) as in the past. Seasonal forecasting is improving and provides early warning of adverse conditions to some aquaculture businesses such as salmon and prawns (Hobday et al 2011). Research such as that being done by CSIRO can assist the industry to develop viable adaptations strategies.

4 Governance arrangements relating to fisheries and aquaculture, including implications for sustainability and industry development

Key points

- Fisheries and aquaculture industries are two of many users of the aquatic environment. There is a role for new methods and further research to assess the interactions among multiple sectors and monitor cumulative impacts from multiple sectors.
- Continued investment is required in innovative model frameworks that enable evaluation of alternative management plans and arrangements.

Effective fisheries management benefits from a combination of top down and bottom up governance structures. Australia is seen as a leader in developing effective forms of governance for fisheries, including introduction of limited entry licensing, cost-recovery frameworks, development of formal harvest strategies, adoption of incentive based approaches to harvest regulation, and, particularly, participatory approaches to management. Australia also has a global lead in research that underpins the ability to evaluate alternative forms of governance through innovative model frameworks such as Atlantis that enable "whole of fishery" evaluation of management plans and arrangements with quantitative prognostic assessments of future outcomes (Fulton et al 2011).

Governance arrangements for commercial wild caught fisheries generally are well established but challenges in overall governance include resource allocation issues between commercial, recreational, and indigenous sectors, as well as with other marine uses. Recent focus on fisheries impacts from coastal development (e.g. around Gladstone Harbour) also underscores the interactions of multiple uses of marine environments with fisheries and the need for integrated management across multiple uses. Research is required to develop robust tools to inform such integrated management planning.

The National Strategy for the Conservation of Australia's Biological Diversity (ANZECC 1996), updated as Australia's Biodiversity Conservation Strategy 2010-2030 (NRMMC 2010), provides a broad framework for the conservation of all biodiversity in Australia and notes that along with other resource based industries fisheries contributes to direct and indirect costs to the environment. The 1996 National Strategy called for improved methods for the appraisal and measurement of public expenditure relating to the major resource-based sectors including fisheries, as well as 'increased *data collection and coordinated research into the biological diversity and human use of the Australian Fishing Zone and estuarine and freshwater areas*'. It also included reference to the following priority areas for research:

(a) the impact of recreational fishing on fisheries, fish, and their habitats;
(b) the impact of commercial fishery practices on non-target and by-catch species and ecosystems, on the viability of populations, and on genetic diversity;
(c) the development of fishing techniques that are species specific, that have the least impact on non-target species, and that minimise waste of the resource, with particular emphasis on trawling and shellfish dredging;
(d) the development of rapid monitoring techniques, especially where native species are used;
(e) the identification of critical habitats for harvested native fishes, in particular spawning and nursery grounds;
(f) the development of 'state of the environment' reporting for freshwater, estuarine, and marine areas;
(g) determination of the impact of both aquaculture species and aquaculture management practices on the environment, including aquatic wildlife.

CSIRO is active in each of the above areas. National research capacity to keep pace with growing demand for more robust information for and assessments of management strategies to cater for multiple uses of marine resources is diminishing, however, as a result of flat or declining funding.

5 Current initiatives and responses to the above matters by governments

Key points

- Recent implementation of the National Strategy for Fishing and Aquaculture research, development and extension (RD&E) should deliver improved collaboration and coordination of research activities.
- CSIRO supports the recent initiatives for consistent reporting on stock status across jurisdictions and a National harvest strategy framework.

CSIRO science contributes directly into fisheries management through membership of Scientific Advisory Committees, Resource Assessment Groups, and Management Advisory Committees for various State and Commonwealth governed fisheries. These fora provide structured and effective mechanisms to deliver R&D outputs to management planning and policy formulating processes.

There are several cross-government initiatives to improve coordination in fisheries governance and research. The Australian Fisheries Management Forum (AFMF) is a well established forum to deal with cross jurisdictional issues and other issues of common interest. It has a research committee that also identifies common research needs. FRDC also takes a national leadership role in coordinating research to support fisheries and aquaculture and includes funding for industry development.

The recent Primary Industries Standing Committee (PISC) initiative, delivered through the National Fishing and Aquaculture RD&E Strategy, to better coordinate research across state and federal agencies shows promise of reducing overlap and making the best use of scientific capability. The establishment of National and Regional Hubs is a positive step in the process for improved research collaboration, efficiency and effectiveness of RD&E to support Australia's fishing and aquaculture industry

IMOS is helping to coordinate (and fund) national monitoring initiatives. IMOS's primary focus historically has been on oceanography but it is moving towards more biological monitoring of relevance to fishery management and this direction should be extended and continue. The National Environmental Research Program (NERP) Marine Biodiversity Hub works on the interface of the DSEWPaC and AFMA with the intention of developing an increased number of options that support sustainable development of diverse uses of the marine environment, including fisheries and aquaculture.

Two current national initiatives concerning stock management in which CSIRO is involved deserve special mention. The first is the project on National Fishery Status Reports which has agreed a consistent reporting framework for reporting on stock status and will soon deliver the first national report. The second is the development of a national harvest strategy framework, funded by the FRDC and supported by AFMF. The Commonwealth Harvest Strategy Policy was implemented 2007 for Commonwealth-managed fisheries and has improved stock management and reduced overfishing. A number of states now are adopting similar approaches. CSIRO was directly involved in informing the development of the policy and its implementation. The policy currently is being reviewed following 5 years of operation.

A current review of the Commonwealth Bycatch Policy will include identification of priorities for future bycatch research and consideration of the applicability of risk based approaches to bycatch management. It also will evaluate the efficacy and appropriateness of reference points and structured decision rules in meeting the policy objectives for some bycatch species. The research required to assess such issues is not yet determined but these are non-trivial questions that may find our current knowledge to be inadequate.

A preliminary spatial analysis of Australia's northern coastline identified 1.2 million hectares that are potentially suitable for pond based marine aquaculture (McLeod et al 2002). Indigenous Australians own a large percentage of the areas. Aquaculture could play a pivotal role in the future livelihoods in these coastal communities and research has an important role in supporting this development through developing planning instruments for industry and government that permit rigorous, quantitative evaluation of the potential for aquaculture production systems to provide economic and social benefits whilst conserving ecosystem health and biodiversity.

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[i] e.g. infectious salmon anaemia, see http://www.thefishsite.com/articles/763/the-impact-of-the-isa-virus-in-Chile

[ii] e.g. abalone herpesvirus

[iii] http://www.thefishsite.com/articles/896/aquatic-animal-diseases-and-their-economic-impact

[iv] e.g. viral diseases of prawns such as white spot disease, viral diseases of finfish such as infectious salmon anaemia, red sea bream iridovirus, koi herpesvirus, and viral diseases of molluscs such as ostreid herpesvirus

[v] http://www.daff.gov.au/animal-plant-health/aquatic/reporting/reportable-diseases and http://www.oie.int/en/international-standard-setting/aquatic-manual