FINAL REPORT

E-fish

An integrated data capture and sharing project

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E-fish: An integrated data capture and sharing project

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Abbreviations

AFMA	Australian Fisheries Management Authority
API	Application Programming Interface
CAAB	Codes for Australian Aquatic Biota
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPIRD WA	Department of Primary Industries and Regional Development Western Australia
E-LOG	Electronic Logbook
EM	Electronic Monitoring
FLUX	The Fisheries Language for Universal Exchange
FRDC	Fisheries Research and Development Corporation
GDSTWG	Global Dialogue on Seafood Traceability Working Group
JSON	JavaScript Object Notation
KDE	Key Data Elements
MAC	Management Advisory Committee
POC	Proof Of Concept
QLD DAF	Queensland Department of Agriculture and Fisheries
RFMO	Regional Fisheries Management Organisation
RAG	Resource Assessment Group
SOA	Service Oriented Architecture
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
VMS	Vessel Monitoring System
XML	Extensible Markup Language

Executive Summary

About this report

This report provides a summary of the design and execution of the FRDC e-fish project outlining recommendations for implementation of the findings. Technical details can be found in the accompanying ‘e-fish design principles’ and ‘e-fish data architecture’ documents (Attachments A and B, respectively).

Background

Extracting the full value of a fisheries agencies data holdings can be challenging when the platforms used to collect and store data are siloed. As the needs of fisheries data users have increased, so too have the platforms available to collect, store and analyse data. The tendency for new platforms to be developed in isolation has created a status quo where there is often limited connectivity between related data streams. Maximising data and system connectivity is likely to generate efficiencies in sharing integrated data both within, and external to, fisheries agencies. This report provides a summary of the e-fish project that was led by the Australian Fisheries Management Authority (AFMA) in consultation with Australia’s State and NT fisheries jurisdictions, to investigate a solution for integrating fisheries data across data collection platforms and securely sharing with data users.

E-fish objectives

The aim of the e-fish project was to address the challenges currently experienced by fisheries data users and provide recommendations for fisheries agencies to further the pursuit of the following six key objectives:

1. Better meet the demands of the Australian community and fisheries stakeholders to readily access and use fisheries data
2. Provide opportunities for the digital transformation of fisheries data
3. Increase the opportunities for stakeholders to utilise fisheries data through enhancing its availability and power
4. Increase the cost effectiveness and efficiency of fisheries data capture and management
5. Better meet the demands of traceability schemes to aid market access for Australian seafood businesses, and
6. Provide greater access and linkage of fishery data without compromising data confidentiality and privacy obligations.

Creating design principles

Extensive consultation was undertaken with multiple data user types (i.e. fisheries managers, data users, IT specialists, data managers and third-party users) in each of the Australian fisheries jurisdictions to explore user perspectives on current data systems, data sharing and usage, challenges and suggestions for improvement. The user perspectives, as well as insights from fisheries traceability scheme providers, were used to develop design principles for a technical solution in the form of a recommendation data architecture which describes the rules and structure of how data could be collected, stored and integrated across systems. Five key design principles were developed that a fisheries data architecture should seek to address. These were:

1. **Linked data:** data sets are inherently linked in way that allows ease of use.
2. **Modern data sharing:** data sets are shared through an easy to maintain and minimal touch solution such as application programming interfaces (APIs).
3. **Ensure data integrity:** data is accurate and validated with minimal errors. Data is stored according to elements maintained in an agency or industry wide taxonomy.
4. **Standardised data collection:** data is received in a uniform approach. Care is taken to not duplicate data where it is unnecessary to do so.
5. **System capability fit for purpose:** implemented systems directly support the various business outcomes of fisheries stakeholders.

From design principles to a fisheries data architecture

Technical specialists were engaged to provide a recommendation for a data architecture capable of meeting the requirements described within each of the design principles. The modular nature of the systems used in fisheries agencies combined with the design principles led to a recommendation of a Service-Oriented Architecture (SOA) coupled with Application Programming Interfaces (APIs) for data capture and sharing. The advantages of a SOA lie in the flexibility and communication between existing systems it allows. When combined with API data capture and sharing, multiple data streams can be integrated and easily shared both internally and externally.

Proof of concept

To ensure the recommended data architecture was well suited to the fisheries operating environment, Proof of Concept (PoC) testing was undertaken. The PoC, using real fisheries data, showed how information from multiple sources (i.e. electronic monitoring, electronic logbooks and client data) were able to be integrated, visualised and made available to an end user. The integrated data was then used to automate complex reporting and demonstrate how a SOA could be practically applied within a fisheries agency to automate existing manual processes creating efficiencies. The benefits of API data capture and sharing were demonstrated through examples of multi-user data sharing (e.g., sharing data in a FLUX format with a third-party user) where data security, integrity and enhanced data validation were achieved.

Recommendations

The primary recommendations of the e-fish project is for fisheries agencies to consider adopting APIs for data collection and sharing, and implement an underlying Service-Orientated Architecture (SOA) to enhance the availability and use of fisheries data.

In parallel to the primary recommendations, fisheries agencies should also consider how they may:

1. Remove legislative barriers that prevent the sharing of fisheries data.
2. Consider adopting forms-based data storage to maintain data integrity.

Conclusion

The e-fish project was successful in producing an in-depth analysis of the challenges currently experienced by fisheries agencies in data integration and sharing. The analysis undertaken in this project, highlighted that increasing the availability, integration, use and confidence in fisheries data is seen as essential by data users for effective data-driven decision making.

A scalable fit for purpose solution that is well suited to the fisheries operating environment was tested in this project. Investigation showed that a SOA design can support the functionality and flexibility needed by fisheries agencies. If implemented, the advantages of a SOA would be notable as it allows communication between existing systems and provides high level of data integration. In combining a SOA design with API data capture and sharing, the e-fish project further demonstrated how improvements could be made to the validation, integrity and interoperability of fisheries data. Widespread uptake of the e-fish recommendations would increase confidence in captured and shared data in Australian fisheries.

The results of this project will be widely distributed across fisheries agencies so that the systems designed here can be considered in future data architecture planning and investment as a step towards making the full value of fisheries data accessible to the Australian community and fisheries stakeholders.

Keywords

Fisheries, Data sharing, Data linking, Data integration, Service-oriented architecture (SOA), Application Programmable Interface (API).

1. Introduction

Fisheries data is used for a variety of reasons such as assessing the sustainability of fish stocks, ensuring compliance with fisheries regulations and allowing for evidence-based decision making in fisheries management. The demand for fisheries data to be digitally collected, integrated across platforms, and shared with multiple users is increasing.

Fisheries data collection programs are responsive to change. New programs and their supporting data capture platforms being continually developed to add to existing information on fishing activity. Recent investments in digital data collection programs (e.g., electronic monitoring) within the Australian fisheries context have involved the development of singular supporting platforms, designed to serve a specific function. When platforms are developed in isolation, they lack an overall integrated design that allows new and existing applications to work together effectively. As data users rarely use information from a singular data stream, this creates inefficiencies where labour intensive processes are undertaken to manually link multiple data sources resulting in a loss of productivity.

While single integrated box solutions that encompass all data collection streams may initially appear an attractive solution for solving the problem of limited connectivity, they lack the ability to adapt quickly to changing data needs or capitalise on the benefits of new platforms that become available. There is a need for fisheries agencies to investigate a technical solution that allows for future adaptation and provides flexibility in the choice of data collection platform. Maximising data and system connectivity is likely to generate efficiencies both within and external to fisheries agencies.

2. Objectives

The e-fish project aimed to address the challenges that are currently experienced by fisheries data users and provide recommendations for fisheries agencies to pursue the following six key objectives:

1. Better meet the demands of the Australian community and fisheries stakeholders to readily access and use fisheries data
2. Provide opportunities for the digital transformation of fisheries data
3. Increase the opportunities for businesses to utilise fisheries data through enhancing its availability and power
4. Increase the cost effectiveness and efficiency of fisheries data capture and management
5. Better meet the demands of traceability schemes to aid market access for Australian seafood businesses, and
6. Provide greater access and linkages of fishery data without compromising data confidentiality and privacy obligations.

To achieve the project's objectives, the following three key activities were undertaken:

1. Develop design principles for a data architecture that can facilitate the overall needs of fisheries agencies in collaboration and consultation with Australian fisheries jurisdictions,
2. Applying the design principles identified, identify and recommend a data architecture that supports linking and sharing of fisheries data, and
3. Demonstrate the practical application of the data architecture identified using real fisheries data through proof of concept testing.

3. Method

3.1. Resources

A steering committee was formed to oversee the project with representation from Nadia Engstrom (QLD DAF), Karen Evans (CSIRO), Kyaw Kyaw Soe Hlaing (FRDC), Nicole Stubing (FRDC), Trent Timmiss (AFMA), and Brent Wise (WA DPIRD). The function of the steering committee was to ensure the project remained aligned with the above objectives, as well as identify key relevant stakeholders to participate in the design and development of project outputs. Additionally, a business analyst was engaged to assist the project team with consultation and requirements gathering for the creation of key design principles for a fisheries data architecture. The data architecture and proof of concept testing were developed based on the requirements gathered during the project and with technical specialists from AFMA and Management Technology People (MTP) services.

3.2. Consultation

One-on-one interviews with stakeholders were undertaken to get a solid understanding of the typical data systems and collection methods employed across agencies. Questions asked during each interview were focused on data usage, pain-points and suggested improvements to current data processes (described further in Attachment A). Stakeholders were categorised into groups prior to being interviewed to ensure there was sufficient coverage across the different data user types in each fisheries jurisdiction as well as traceability scheme providers. The groups consisted of:

1. **Fisheries managers:** responsible for the management of a fishery with an understanding of how data is used within their agency to support decision making.
2. **Data users**: generally compliance and monitoring officers, fisheries officers and/or licensing officers who are regular day-to-day data users and have a good understanding of the current limitations around data use within their role.
3. **IT specialists**: who have detailed knowledge of their agency's IT architecture and cyber security.
4. **Data managers**: responsible for data control and/or analysing and auditing data, as well as data policy management, who can provide insight into how their organisation stores/shares their fishery data.
5. **Third party users**: who receive data from fisheries organisations or directly from industry to support dedicated research projects.
6. **Traceability scheme providers**: who, like third party users, receive data from fisheries organisations or directly from industry but use data solely to determine the sustainability of a fisheries product by allowing fish to be tracked throughout each step of the supply chain.

Interviews were targeted to ensure a distribution of perspectives across both user groups and fisheries management jurisdictions. During the interview each user was asked to share their perspective on current data systems, data sharing and usage, challenges and suggestions for improvement. A list of the stakeholders interviewed in this project can be found in Appendix A .

3.3.Stakeholder workshop

Following consultation, a set of draft design principles were developed and incorporated into a report detailing the approach and outcomes of consultation (Attachment A). The report was circulated to targeted individuals that were interviewed across the data user groups in each fisheries jurisdiction. These individuals were invited to attend a workshop in Canberra on 22 July 2019 (attendees listed in Appendix B). The workshop presented the draft design principles which were then refined through discussion with participants and endorsed by the project's steering committee (Final design principles in section 4.2).

3.4. Recommendation of data architecture

The following considerations where taken into account in forming a recommendation for a suitable data architecture design:

1. **The design principles:** how a recommended data architecture satisfies the design principles gathered through the consultation phase of the project.
2. **Data properties and storage:** the amount of data generally collected within an agency, whether it is structured or unstructured and if storage methods currently used are well suited to the data.
3. **Data collection streams and applications:** the types of data collection streams and applications in place across fisheries agencies and the connectivity between them.
4. **Frequency of changes:** whether there are constant changes within the data capture environment or if changes are relatively infrequent.
5. **Investment and maintenance:** whether there are continual development and investment in fisheries agencies or if there is opportunity for major system overhaul by one or several agencies. The existing processes for the selection/ development of systems were also considered to ensure there is opportunity for an agency to strategically target future development as well as incorporate new 'off the shelf' products that become available.
6. **Privacy and security:** the appropriate privacy and security measures required for any proposed architecture and if it meets broader government requirements.

3.5.Proof of Concept (PoC)

A PoC was developed to introduce fisheries management agencies to the recommended data architecture using select data collection streams held by AFMA. An end-to-end architectural build was outside the scope of this project so three specific examples (described in the sections 3.5.1 – 3.5.3 below) were chosen to demonstrate how the data architecture could be practically applied within a fisheries agency. Technical details including the specific data fields and processes used to create linkages for each of the examples can be found in Attachment B.

3.5.1. Example 1: Linking multiple data streams

Data on the retained and discarded catch annotated from the review of electronic monitoring (EM) footage and collected through fishing logbooks were selected to assess the recommended data architecture's linkage capability. Data annotated from the review of EM footage and fisher reported logbook data were specifically chosen to represent how a relatively new data collection stream can be integrated with an existing data stream. Presently within AFMA's current data architecture, a link between the two data streams is created manually during the EM video footage review process. For the PoC, the existing link was not used so it could be demonstrated how a SOA could link these streams automatically without manual intervention.

3.5.2. Example 2: Securely collect and share data with multiple users

The second PoC example aimed to demonstrate the flexibility in securely sharing data between multiple users while maintaining control over the format and level of granularity of the data being shared. Two data sharing scenarios using fishing logbook data were used to demonstrate data sharing flexibility. The first was sharing fine-scale data with a user that has full-access to a particular data stream(s). The second, was sharing data with a third-party user (e.g., to a traceability scheme provider or a Regional Fisheries Management Organisation (RFMO)) and providing the data in a format requested by the end user while ensuring the integrity of the data is maintained. For the second scenario, Fisheries Language for Universal eXchange (FLUX), a data standard developed by the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT), was selected to demonstrate how an agency could enter into an arrangement to provide data in an agreed standard without the need to modify how it collected or stored its data.

3.5.3. Example 3: Increased reporting capability

The final example demonstrated how the recommended architecture could be used to visualise data from multiple sources and automate complex reporting for end users. Two specific reports were selected, one generated from the results of the linking example described in 3.5.1 and a second aimed at streamlining an existing process. The second report was aimed at replicating metrics (i.e. interaction rates) calculated under the *Threat Abatement Plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations (2018)* to demonstrate if the recommended architecture has potential to automate the metrics that are currently manually calculated and reported by fisheries managers.

4. Results

4.1. Outcomes of consultation and requirements gathering

A total of 55 stakeholders were interviewed across each of the user groups (i.e. fisheries managers, data users, IT specialists, data managers, third-party users and traceability scheme providers) with coverage over all Australian fisheries agencies as well as three supporting agencies. A list of the stakeholders interviewed in this project can be found in Appendix A.

Traceability providers approached in this project were unavailable for direct comment however the Global Dialogue on Seafood Traceability Working Group (GDSTWG) provided Key Data Elements (KDEs) that were combined with the KDEs from the Australian Seafood Traceability statement. These were produced with the aim of gaining an understanding of the current and future data and system requirements that would allow both fisheries agencies and fishing businesses to participate in traceability schemes. The GDSTWG has a membership of over 100 seafood companies, government organisations and traceability providers, so using these outputs gave the project a holistic view of the traceability provider perspective.

The information gathered through user interviews and supplied by traceability providers was categorised into five key problem themes. The information captured in each of the themes was:

1. **Data integrity:** pain-points around the accuracy and validity of the captured data
2. **Data sharing:** pain-points around how data is shared within and across agencies
3. **Siloed data**: the challenges faced by all data users as a result of the siloed nature of data storage
4. **Data collection**: the challenges faced by the conflicting nature of the different data collection methods, and
5. **System capabilities and support**: the issues and challenges faced by IT specialists in supporting the business outcomes of fishery management agencies.

Two additional themes were identified through the project but were considered out of scope of the project as they are unable to be addressed by any proposed technological solution. These were:

6. **Data Awareness**: identified that data is not being used because users are not aware the data exists, and
7. **Culture**: identified data could be intentionally misreported.

4.2. Design principles

Based on the information in each of the five themes, a draft set of design principles were developed and then refined at a stakeholder workshop held in Canberra on 22 July 2019. The workshop facilitated an in-depth discussion on each of the draft principles to ensure they captured information in each of the problem themes and associated requirements for an ideal data architecture. Following the workshop, the design principals were finalised and endorsed by the project steering committee. The final design principles were:

1. **Linked data:** data sets are inherently linked and linked in way that allows ease of use
2. **Modern data sharing:** data sets should be exposed to external users through an easy to maintain and minimal touch solution such as application programming interfaces (APIs)
3. **Ensure data integrity:** data is clean and validated with minimal errors. Data is stored according to predefined elements maintained in an agency or industry wide taxonomy
4. **Standardised data collection:** data is received in a uniform approach. Care is taken to not duplicate data where it is unnecessary to do so, and
5. **System capability fit for purpose:** implemented systems directly support various business outcomes of fisheries stakeholders.

Appendix C provides context for each of the principles including data gathered through stakeholder interviews and workshop.

4.3.Service Oriented Architecture (SOA)

The design principles and the considerations described in section 3.4 were used to formulate a recommendation for a fisheries data architecture. In considering the options available, it was recognised that fisheries agencies tend to have modular systems (e.g., a system for licensing, a system for VMS, a system for data collected through fishing logbooks, etc.) and the key was to allow for communication between those systems, rather than replacing the existing systems. Further to this, systems within fisheries agencies are often at different stages in their development life cycles with budgetary considerations often preventing major multi-system overhauls. This meant any recommendation made would need to support a model where development and management of the data architecture can be flexible, while still supporting the design principles. Following analysis, it was recommended that a Service Oriented Architecture (SOA) would provide the functionality and flexibility that fisheries management agencies require.

A SOA is a style of architecture that allows systems to be connected as a network through message-based communication. In a SOA design, each system can respond to an action performed by another system in the network. Using a fisheries example, a system that decrements quota could be triggered in response to a landing report received from a fisher in a separate reporting system. Figure 1 below shows a high-level representation of a SOA design in a fisheries agency context. The findings and technical specifications of a SOA and how it relates to each of the endorsed design principles is provided in **Attachment 1**.

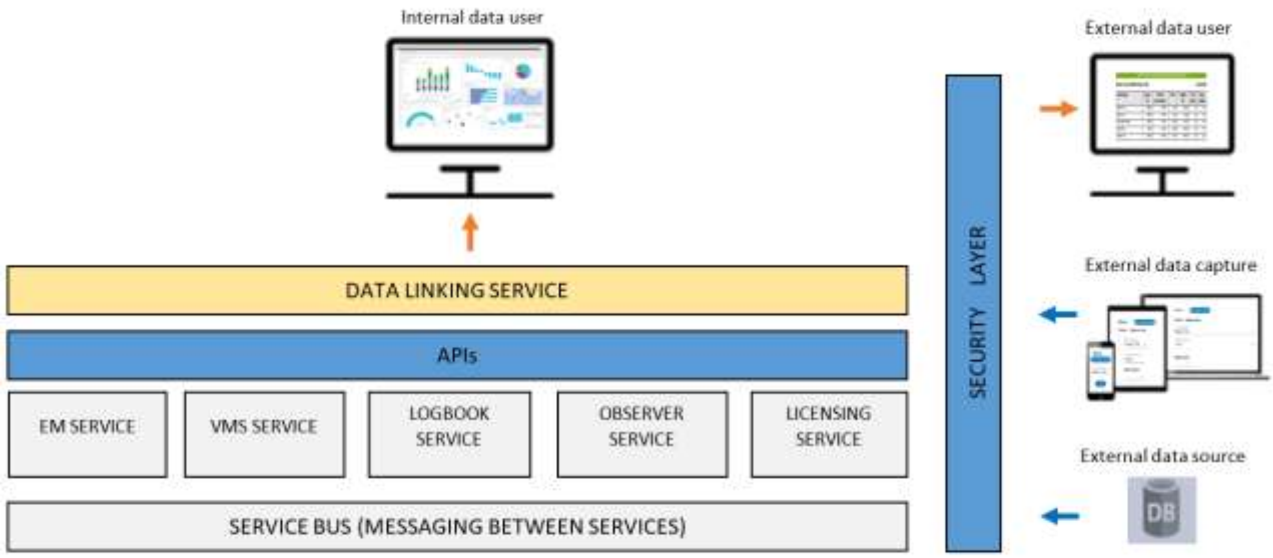


Figure 1 *Simplified diagram of a Service Oriented Architecture (SOA)*

4.4. Application Programmable Interface (API) data collection and sharing

The need for greater data integrity and modern data sharing led to a recommendation for the use of APIs as a standard for data exchange. An API is a software intermediary that allows two applications to talk to each other simplifying the exchange of information. For example in a fisheries context, an API could be used to enable two-way data exchange between e-log software developed and maintained by a third-party provider, and an application within a fisheries agency (Figure 2).

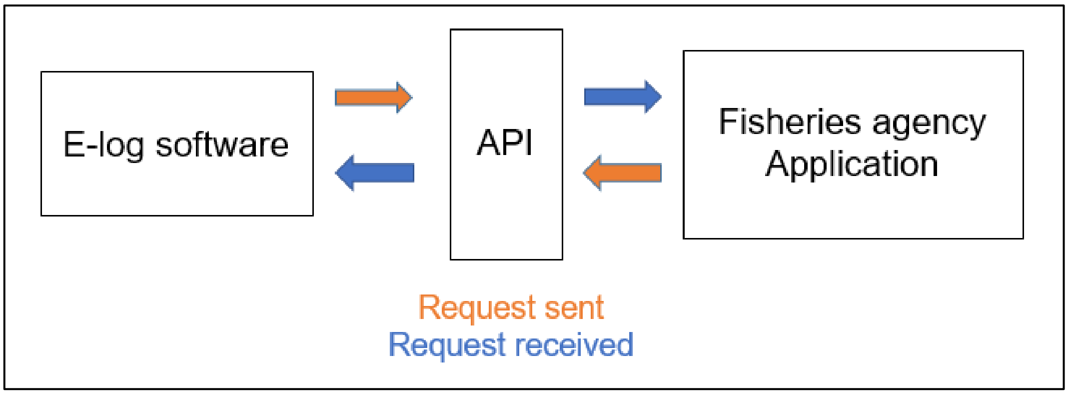


Figure 2 *Simplified diagram of how an API works as an intermediary for information exchange between third-party application that sits outside a fisheries agency (e.g. e-log software) and an application that sits within a fisheries agency.*

The API enables a fisher to report information through their e-log software with their responses validated against a predefined reference list of permitted values held within a fisheries agency's application. These reference lists could contain lists of species Codes for Australian Aquatic Biota (CAAB) codes, licensed vessels or simply define the format of how data should be entered (e.g. date/time format or units of measurement). A response would then be sent back to the fisher to either confirm that their submission has been accepted or to reject the submission and request that incorrect information be corrected. APIs can also be used by the fisher to recall previously submitted data or to request other information held by the management agency such as a list of their current quota holdings. The key advantage of this type of information exchange is that it not only allows for significant improvements to data integrity, but it can be used to automate the exchange of data in real time from multiple sources (e.g., to request live sea-surface temperature data by tapping in to APIs made available by the Bureau of Meteorology or exchanging catch and effort information with other fisheries management agencies or research providers who have APIs available).

4.5. Outcomes of the Proof of Concept (PoC)

4.5.1. Linking multiple data streams: Integrating catch records from two sources, Electronic Monitoring (EM) data and fishing logbook data

Currently within AFMA's system, a link exists between the data annotated from the review of EM footage and the data reported by fishers in their logbooks. The existing link is manually created during the EM review process where the reviewer determines if two records are related (generally, by matching the date and time of the two events as closely as possible). For the POC, the existing manual link was bypassed and an automatic linking workflow created to demonstrate how a similar decision making process could be embedded within the system. For simplicity, the matching criteria set in the PoC was restricted to exact matches where there were no discrepancies between EM and logbook records (e.g., spelling errors or slight differences in dates and times). If an automated linking service were to be fully implemented by a fisheries agency, the matching criteria would need to be broadened beyond exact matches by developing tools for near matches so that all records could be automatically linked by the system. When automated linking is combined with the increased data integrity that API data capture allows, a robust automated linking service within a SOA can be developed that is tailored to the data quality and collection methods of the individual data streams. The technical aspects of the resulting automated linking service have been described in Attachment B. The outcome of the comparison of the catch reported by a fisher in their logbook and catch observed to be caught through the review of EM footage is visualised in Figure 3. An indicator of the accuracy of reporting by the fisher (set as a 20% tolerance level for discrepancy between the two records) is also shown.

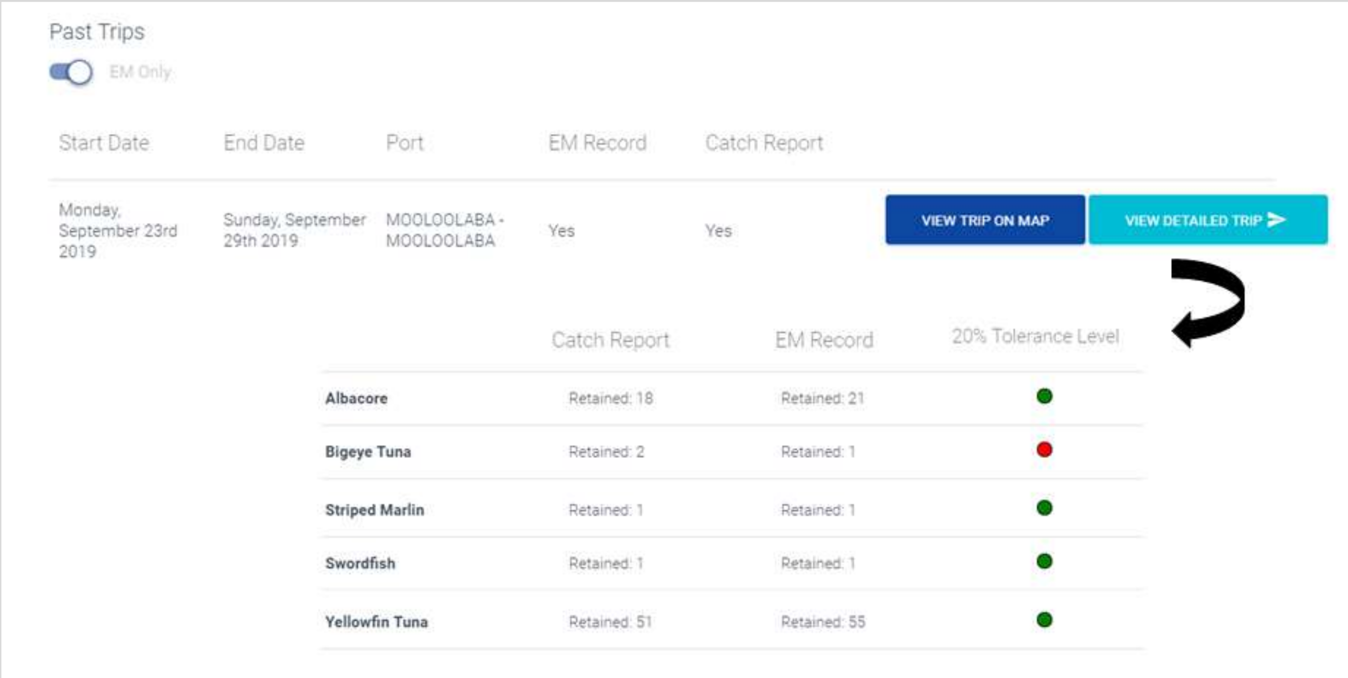


***Figure 3** Linked record view showing data annotated from electronic monitoring review and the corresponding fisher reported logbook record*

4.5.2. Securely collect and share data with multiple users

In the PoC, client details held within a customer relationship management (CRM) application were exposed to an end user through an API. For the PoC, fictional client details were used as the aim was to demonstrate fine-scale data sharing in principle only. Figure 4 shows the result of the fine-scale data sharing where the end user has full access to various client details (i.e. vessel name, nationality, call sign, license status etc.) and can also visualise recent fishing activity. The PoC was able to demonstrate how data sharing could be achieved while maintaining control over how data is aggregated prior to being shared with different user types through API data sharing.

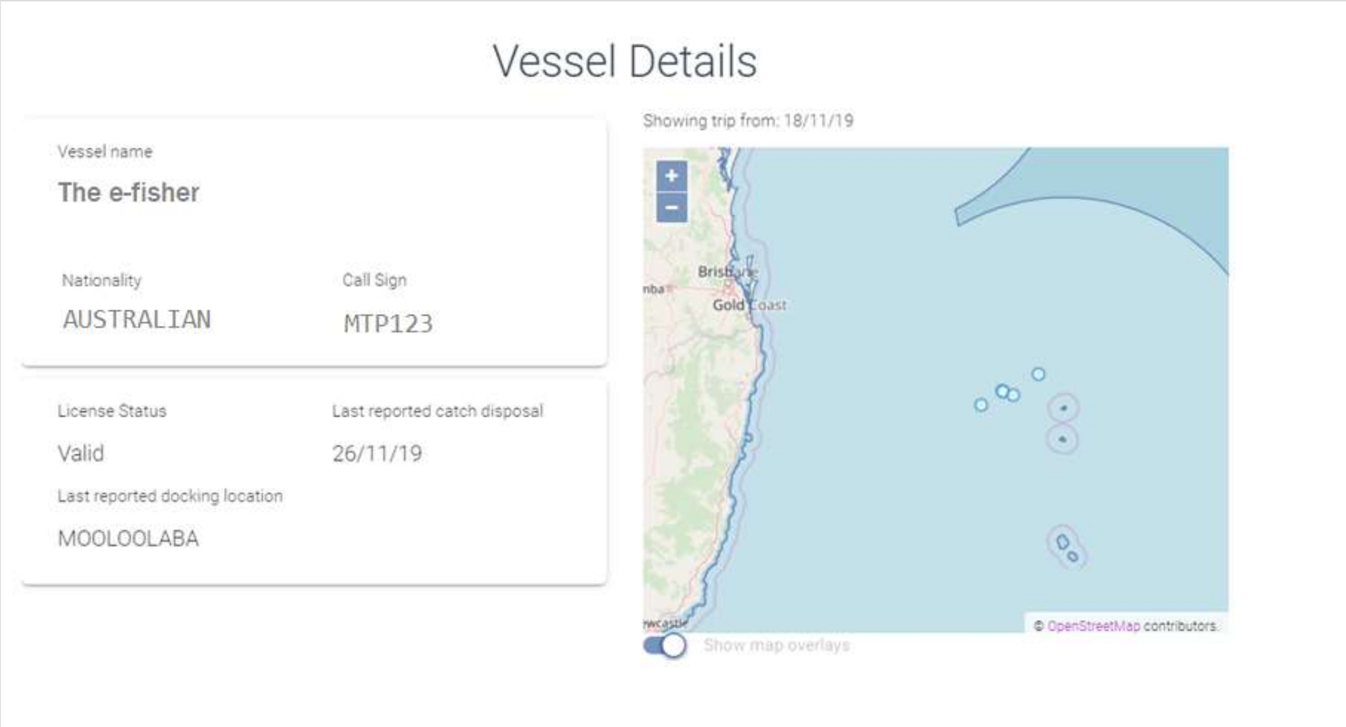


Figure 4 *Client details and fishing log data integrated into a single page view*

A second example demonstrating third-party data sharing, involved making higher level data available in a format requested by the end user (in this example, Fisheries Language for Universal eXchange or FLUX format). An API in conjunction with a function that converted electronic fishing log (e-log) data stored in a JSON format into a FLUX format in XML was created for this example. A third-party user (that was created for the purposes of the PoC) was given permission to access and retrieve a subset of the e-log data provided in a FLUX format. This demonstrated how APIs can allow for data to be shared with, or received from, a third-party user in a common standard, enabling a fisheries management agency to meet a requested data format regardless of the format they are storing their data in.

4.5.3. Increased reporting capability

Using the EM and logbook data linkage, a report was generated that compared an individual vessel's species reporting accuracy against the average species reporting accuracy across the fleet (Figure 5). Because the linkage was created within the SOA, the report can be refreshed to include new trips as they are completed. For the PoC, integrated reports were created by bringing together APIs developed for each individual data stream. This method is flexible enough that an agency could generate similar integrated reports through the use of custom web applications or existing/off the shelf reporting systems.

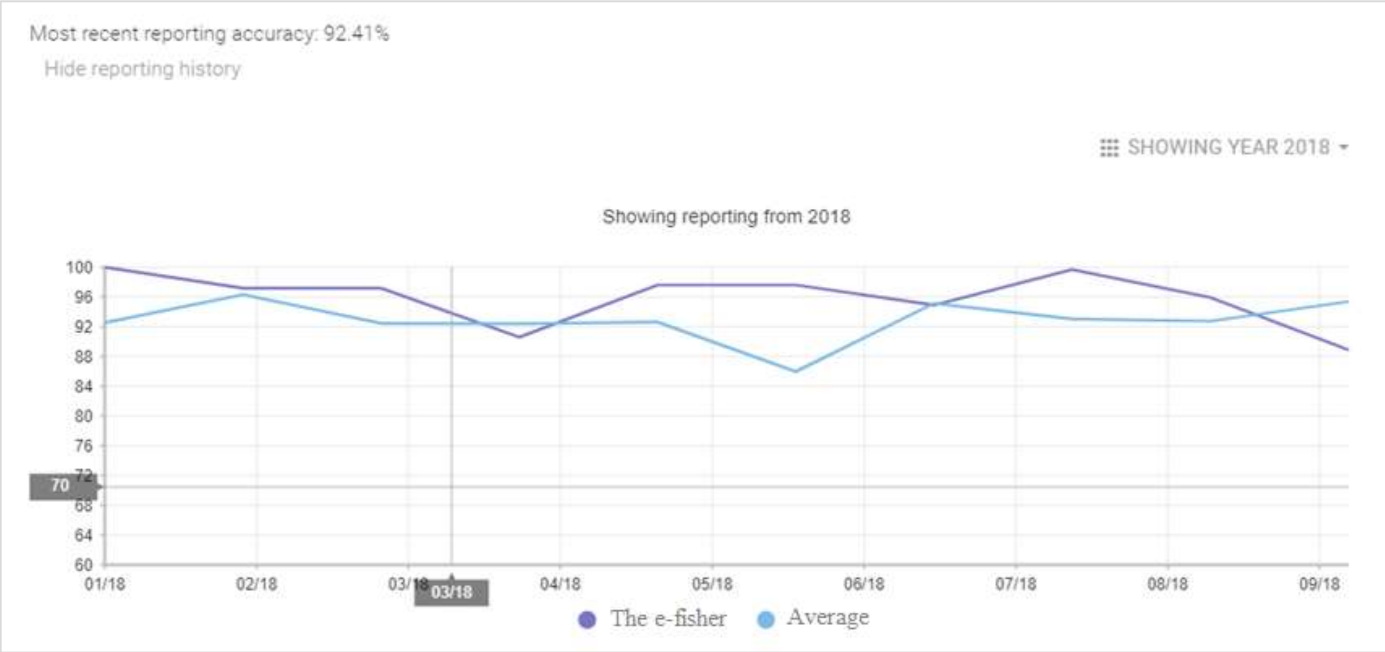
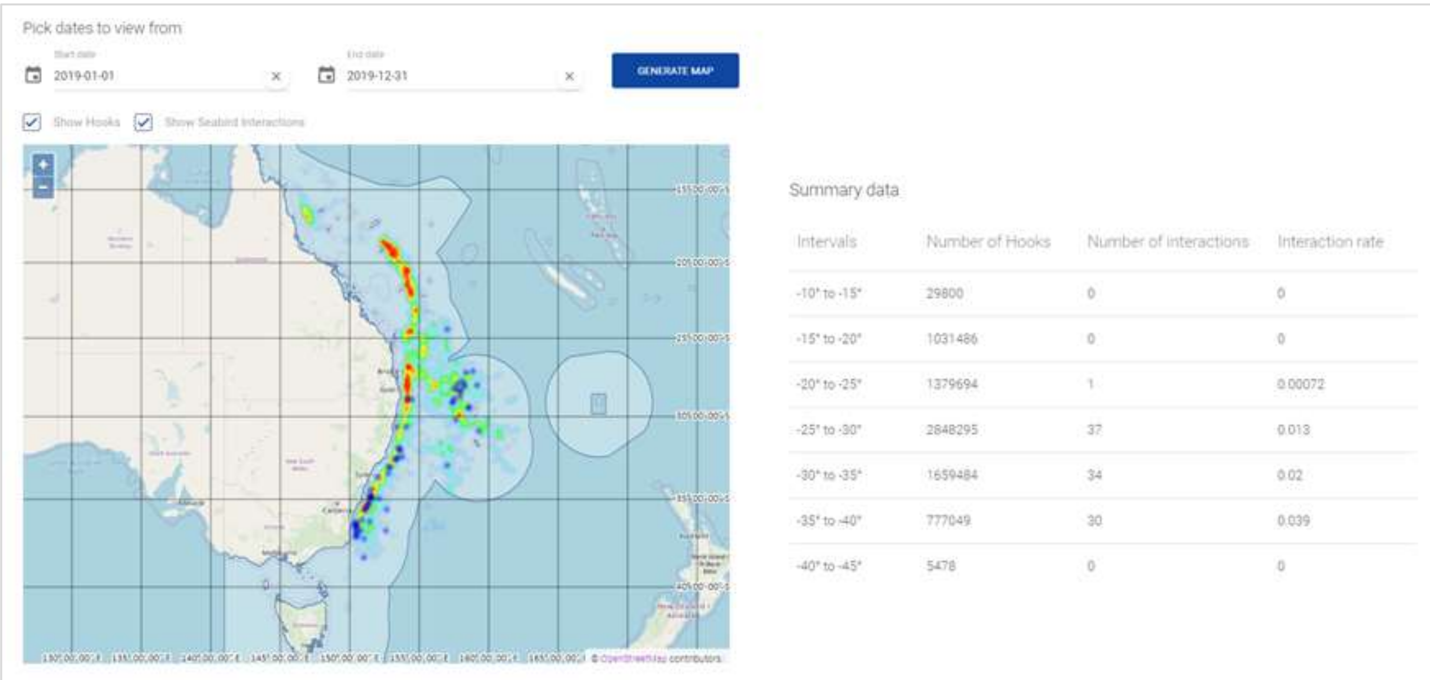


Figure 5 Vessel comparison to fleet average for accuracy in reporting determined through electronic monitoring review

A second report replicating metrics (i.e. interaction rates) calculated under the *Threat Abatement Plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations (2018)* is shown below in Figure 6. The resulting report is a significant improvement on the time-consuming manual process currently undertaken to collate the same information, demonstrating how a SOA could significantly streamline a fisheries agency's reporting capacity. The technical aspects of how the metrics were generated in these reports is described further in Attachment B.



Intervals	Number of Hooks	Number of interactions	Interaction rate
-10° to -15°	29800	0	0
-15° to -20°	1031486	0	0
-20° to -25°	1379694	1	0.00072
-25° to -30°	2848295	37	0.013
-30° to -35°	1659484	34	0.02
-35° to -40°	777049	30	0.039
-40° to -45°	5478	0	0

Figure 6 Heat map of effort (hooks) for a single fishery overlayed with seabird interactions. Interaction rates (number of seabirds per thousand hooks) calculate for each latitude band

5. Discussion

The e-fish project was able to clearly define the challenges faced by fisheries agencies in data integration and sharing, as well as recommend a data architecture that would be suited for a fisheries operating environment. The project outputs demonstrated how fisheries agencies can achieve better access, use and visualisation of data collected from fisheries.

The extensive consultation in this project provided an in-depth analysis of a number of problem themes currently experienced by fisheries management agencies. Interestingly, there was strong alignment on a number of issues between different data user groups across fisheries jurisdictions. While the individual perspectives of users varied, the resulting core requirements of a data architecture were common within each problem theme. As an example, challenges in data sharing were described differently by third party users and fisheries managers. Third party users described data sharing issues in the context of it being an onerous and inefficient process where data is manually requested and transmitted, often causing significant delays. Fisheries managers however raised concerns around data being shared and then stored in multiple locations, making it difficult to maintain data integrity and a single source of truth. Despite the two varying user perspectives, the commonality was the underlying principle that a modern data sharing solution is needed.

The use of APIs for data sharing recommended in this project provides a solution for the timeliness of data exchange by removing the reliance on database managers to manually export and share data. Using APIs, each agency can hold their own data and choose to make it available both within and external to their agency as needed. Uninterrupted access to data at its source may also reduce the occurrence of duplicate data sets being created and stored by end users. This could lead to a fundamental change in the way users view data availability, allowing users to shift from storing and maintaining data that has been shared with them at a single point in time to regularly accessing data directly from the data's owner at any time. This change would likely resolve issues associated with data integrity currently experienced by data users as well as reducing costs in data maintenance and storage and provide a single source of data truth.

The improvement in data validation during data capture that APIs allow can increase confidence in fisheries data as observed in the proof of concept. It is often the case that data is manipulated or 'cleaned' in some way before it is used for a specific purpose such as conducting a stock assessment. Current research funded by the FRDC is attempting to standardise and automate the methods used for validation and error checking, acknowledging the current processes undertaken by individual fisheries agencies and researchers vary considerably (Hall, K 2020, *In progress*[1]). If standard methods for validation are developed, there is

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[1] Hall, K, FRDC project 2017-085 (in progress), 2020, *Developing automated data cleansing and validation processes for fisheries catch and effort data.*

potential for these to be applied to data capture methods such as e-logs at the point of data entry. While validation of data entered within current e-log software exists, it is generally limited to specifying cut-off points or restricting values through drop down menus embedded in software developed and maintained by third party companies. API data capture allows for more robust data validations. For example, when a fisher records their vessel's name in their e-log software, this could be validated against a reference list of licensed vessels within a fishery that is stored within a fisheries agencies licensing system. As data is being validated against a live system, there is greater confidence in captured data reducing the need for manual checks or data cleaning after it has been received improving data integrity. This improvement to data integrity further allows captured data to be more easily relatable to other data streams which means pre-linked data can be more easily shared.

The PoC in this project was able to effectively demonstrate multi-user data sharing through the use of an API where both fine-scale data and higher level data can be shared while maintaining data integrity. If API data sharing is adopted across fisheries agencies, the flexibility it would allow provides an improved framework with respect to several challenges. One such challenge is legislative barriers preventing the sharing of data beyond certain levels of granularity. While adopting an API platform does not solve legislative barriers currently in place, it does provide a robust secure data sharing mechanism where there are multiple levels of control over who can access data and what data they receive. This means the level of data that is shared can be altered without major investment into new data sharing platforms if changes to legislation were to occur. In addition, it gives fisheries agencies the ability to achieve one of the project's objectives which was to better meet the demands of traceability schemes to aid market access for Australian seafood businesses by providing a platform where a fisher could authorise a traceability provider to have real time access to their data, to the granularity they wish to provided it.

A key finding of the PoC was that data can be collected in one format and shared in a different format requested by the end user. This showed that fisheries management agencies can integrate with other agencies following an agreed data exchange process without having to rework their entire data collection and storage process. Interoperability between IT systems in fisheries agencies is often considered a challenge in facilitating efficient exchange of data between two parties and API data sharing provides an opportunity to streamline data sharing arrangements.

Fisheries science and management is a flexible problem space where future data needs are often unknown. Despite the evolving nature of data requirements, this project discovered that fisheries management agencies are heavily reliant on forms-based data collection methods. While traditionally this information has been stored in relational databases (that is, a database structure that allows identification and access to data in relation to another piece of data in the database), as data collection methods change there can be a significant loss of metadata when databases are changed in parallel to accommodate new data structures. While moving to forms-based storage is not an essential part of the overall SOA architecture, it provides several advantages over traditional relational structures. Forms-based storage can best be described as a database that stores each record as its own standalone document. These documents define their own structure and information is preserved with metadata as to how the information was collected. The clear advantage of forms is reproducibility, where each user has visibility of metadata and can therefore make informed decisions on how to best make use of the information.

Stakeholder discussions throughout this project reiterated that fisheries data users infrequently use data streams in isolation, often collating several data sources within and sometimes across agencies. Manual linking of data from disparate data sources was described by users as a time-consuming and expensive process, often requiring a significant amount of work before value can be drawn from the data. Ad-hoc linking of data sources, rather than linkages embedded within a data architecture, have created unintended consequences where reproducibility of data sets can prove difficult. This is particularly the case when the process undertaken to integrate data streams is unknown by the end user. This also creates a situation where decision making based on data is difficult where the data’s integrity is unclear.

The PoC developed in this project were able to demonstrate how a dedicated data linking service, that is transparent in how the linkage has been applied, could be leveraged to link data from multiple sources within a SOA. Data users stated that a significant proportion of time is spent collating varying data sources before data can be used for its intended purpose. A dedicated linking service that combines commonly accessed data streams will create efficiencies for fisheries reporting. Reports that are frequently created can be streamlined or even automated removing the need for data users to manually calculate metrics each time a report is required. There is also the increased confidence when making decisions from the data knowing that metrics within a report have been calculated consistently irrespective of which data user has generated the report. From these linkages embedded within a data architecture, reporting dashboards with real-time information can be created to allow fisheries agencies to better focus their management and compliance activities.

The communication between applications that a SOA allows supports a model where a “tell us once” approach to information provision is achieved. The advantage of this model is that changes made in one system, flow through to other dependent systems as required. For example, if a fisher were to update an electronic logbook entry, a service could be enabled where the update flows through another system that is integrated with the e-log service (e.g. a report is updated or a message to a user is triggered). The modular nature of a SOA provides further efficiency by allowing individual systems to be progressively updated and replaced as they reach the end of their life cycle. This eliminates the need for costly one-off builds of systems that perform multiple functions for a fishery agency and allows new data capture systems to be added as needed.

A SOA design combined with API data capture and sharing, supports the functionality and flexibility that fisheries management agencies require meeting the overarching objectives the e-fish project set out to achieve.

6. Recommendations

The primary recommendation of the e-fish project is for fisheries agencies to adopt APIs for data collection and sharing with an underlying Service-Orientated Architecture (SOA) to enhance the availability and use of fisheries data. To support of these recommendations, the e-fish project has identified two key areas that, if addressed, would support the overall outcomes of the project:

(1) Remove legislative barriers that prevent sharing of fisheries data.

A recurring pain-point mentioned by fisheries data users was restrictive legislation often being the single greatest barrier preventing the sharing of fisheries data. While the e-fish project successfully found a technical solution that allows for easier data sharing, legislative barriers may still prevent data sharing for fisheries agencies. Where it is feasible to do so, legislative barriers should be removed so the full benefits of API data sharing can be realised.

(2) Consider adopting forms based data storage.

This project discovered that fisheries management agencies are heavily reliant on forms-based data collection methods but use relational databases for data storage. In a forms-based data storage method, documents define their own structure and information is preserved with metadata regarding how the information was collected. The clear benefit is reproducibility, where each user has visibility of metadata and can therefore make informed decisions on how to best make use of the information.

7. Conclusion

The e-fish project was successful in producing an in-depth analysis of the challenges currently experienced by fisheries agencies in data integration and sharing. The analysis undertaken in this project highlighted that increasing the availability, integration, use and confidence in fisheries data is seen as essential by data users for effective data-driven decision making.

A scalable fit for purpose solution that is well suited to the fisheries operating environment was tested in this project. Investigation showed that a SOA design can support the functionality and flexibility needed by fisheries agencies. The advantages of a SOA would be notable if implemented, with the communication between existing systems it allows, providing the level of data integration this project set out to explore.

Connectivity between systems would remove the need to capture the same piece of information across multiple data collections streams. As such, data will not be duplicated where it is unnecessary to do so and a “tell us once” approach to information provision can be achieved.

In combining a SOA design with API data capture and sharing, the e-fish project also demonstrated how improvements could be made to the validation, integrity and interoperability of fisheries data. APIs present a viable solution for data users to securely access data sets as required, without the need to recreate databases that are frequently used. This will result in a reduction of duplicate data sets that have undergone different data validation and cleaning processes. Widespread uptake of the e-fish recommendations would increase confidence in captured and shared data, while increasing productivity and efficiency within, and between, fisheries agencies.

The results of this project will be widely distributed across fisheries agencies so that the systems designed here can be considered in future data architecture planning and investment as a step towards making the full value of fisheries data accessible to the Australian community and fisheries stakeholders.

8. Extension and Adoption

Materials developed throughout this project (i.e. the e-fish design principles document and e-fish data architecture document) will be shared with stakeholders across fisheries jurisdictions for consideration in any future data architecture designs.

Further extension of the project’s findings will continue through internal AFMA presentations by the project team and externally through AFMA’s Research Advisory Group (RAG) and Management Advisory Committee (MAC) meetings and relevant inter-agency forums, such as the Australian Fisheries Management Forum.

Project materials developed

1. e-fish design principles document (Attachment A)
2. e-fish data architecture document **(**Attachment B)

Appendix A: Stakeholder interview list

Name	Date	Interview type	Organisation	Position/Branch	User Group
Stephen Mayfield & Angelo Tsolos	27/6/19	Phone call	PIRSA (Fisheries, SA)	Science Leader, Fisheries; Sub-Program Leader, Molluscan Fisheries (Stephen)	Data User (Stephen) Data Manager (Angelo)
Genevieve Phillips	9/7/19	Phone call	QLD	Fisheries Resource Officer	Data Manager
Sharna Rainer	25/6/19	Phone call	Fisheries, TAS	Senior Officer, Licensing and Operations	Data Manager
Véronique Vanderklift	30/5/19	Phone call	Fisheries, WA	Research Data Manager	Data Manager
Timothy Green	29/5/19	Email	Fisheries, WA	Manager Compliance Statistics & Systems	Data Manager
Mark Cliff	5/6/19	Phone call	Fisheries, WA	Principle Management Officer, Entitlement Monitoring	Data Manager
Joel Shirlow	31/5/19	Phone call	Fisheries, WA	Licensing, Regional Services	Data Manager
Stephanie Nicoloff & Aline Salas	30/5/19	Phone call	Fisheries, WA	Vessel Monitoring System Manger (job sharing)	Data Manager
Nadia Engstrom	24/5/19	Phone call	Agriculture and Fisheries, QLD	Fisheries Resource Officer	Data Manager
David Makin	17/7/19	Phone Call	NSW Fisheries	Fisheries Manager	Data User
Lucas Sumpter	10/7/19	Phone call	QLD	Compliance	Data User
Denise Garcia	27/6/19	Phone Call	Fisheries, TAS	Senior Officer Fisheries Monitoring	Data User
Sebastian Lambert	21/6/19	Phone call	PIRSA (Fisheries, South Australia)	Manager Intelligence & Strategic Support	Data User
Simon Conron	17/6/19	Phone call	Victorian Fisheries Authority	Senior Scientist	Data User
Ashley Mooney	15/5/19	In-person	AFMA, Canberra	Senior Intelligence Analyst, Fisheries Operations Branch	Data User
Shane Penny	6/6/19	Phone call	Fisheries, NT	Senior Research Scientist	Data User
Cheryl May	30/5/19	Phone call	Fisheries, WA	Prosecutions System Support Officer	Data User
Jeremy Thuell	22/5/19	Phone call	AFMA, Canberra	Intelligence Analyst, Fisheries Operations Branch	Data User
Karina Hall	21/5/19	Phone Call	NSW Fisheries	Stock Assessment Scientist	Data User
James Parkinson	24/6/19	Phone call	Fisheries, TAS	Manager, crustaceans fishery	Fisheries Manager
Blake Taylor	18/6/19	Phone call	Fisheries, NT	Aquatic Resource Manager	Fisheries Manager

Name	Date	Interview type	Organisation	Position/Branch	User Group
Toby Jeavons	17/6/19	Phone call	Victorian Fisheries Authority	Manager of Rock Lobster and Giant Crab Fishery	Fisheries Manager
Don Bromhead	23/5/19	Phone call	AFMA, Canberra	Manager of Tuna and International Fisheries	Fisheries Manager
Daniel Corrie	16/5/19	Phone call	AFMA, Lakes Entrance (NSW)	Manager of Coral Sea Fisheries	Fisheries Manager
Andrew Powell	15/5/19	In-person	AFMA, Canberra	Manager of Regulatory Improvement and External Services	Fisheries Manager
Dallas D'Silva	12/6/19	Phone call	Victorian Fisheries Authority	Director, Fisheries Policy, Management, Science and Lisensing	Fisheries Manager
Steven Matthews	12/6/19	Phone call	Fisheries, NT	Program Leader, Research and Field Operations	Fisheries Manager
Tim Nicolas	30/5/19	Phone call	Fisheries, WA	Manger of Aquatic Resource Management	Fisheries Manager
Natalie Rivero	16/5/19	In-person	AFMA, Canberra	Regulatory Improvement and External Services	Fisheries Manager
Callum Tyle	18/6/19	In-person	AFMA, Canberra	Data Architect	IT Specialist
John Garvey	18/5/19	In-person	AFMA, Canberra	Data Manager	IT Specialist
Nirmala Yeruva	15/5/19	In-person	AFMA, Canberra	Apps team manager	IT Specialist
David Newton	17/5/19	In-person	AFMA, Canberra	Senior Network Engineer	IT Specialist
Alex Kay & Malcom Evans	6/6/19	Phone call	Fisheries, WA	Manager ICT Strategy & Architecture (Alex), Enterprise Architect (Malcom)	IT Specialist
Trevor Guy	6/6/19	Phone call	Fisheries, NT	Business Analyst	IT Specialist
Karen Evans	17/6/19	Phone call	CSIRO, TAS	Principle Research Scientist	Third Party User
Patty Hobsbawn	6/6/19	Phone call	ABARES, Canberra	Fisheries Data Manager	Third Party User
Robert Curtotti	12/6/19	Phone call	ABARES, Canberra	Manager, Fisheries Economics	Third Party User
Paul Burch	23/5/19	Phone call	CSIRO, TAS	Research Scientist, Temperate Population Dynamics	Third Party User
Ian Knuckey	20/5/19	Phone call	Fishwell Consulting, VIC	Director	Third Party User
Western Australia group call	29/5/19	Group phone call	Fisheries, WA	Various	Various

Appendix B: Stakeholder workshop attendance list

Name	Organisation	Position/Branch
Trevor Guy	NT Fisheries	Business Analyst
Patty Hobsbawn	ABARES	Fisheries Data Manager
Brent Wise	DPIRD WA	Senior Principal Research Scientist
Karina Hall	NSW DPI	Fisheries Stock Assessment Scientist
Karen Evans	CSIRO	Senior Research Scientist
Sebastian Lambert	SARDI	Manager Intelligence & Strategic Support
Gretchen Grammer	SARDI	Senior Research Officer
Genevieve Phillips	DAF QLD	Senior Fisheries Resource Officer
Andrew Powell	AFMA	Senior Manager Fisheries Services
Callum Tyle	AFMA	Data Architect
Natalie Rivero	AFMA	Regulatory Improvement and External Services
John Garvey	AFMA	Data Manager
Don Bromhead	AFMA	Manager of Tuna and International Fisheries
Trent Timmiss	AFMA	Senior Manager of Tuna and International Fisheries
York Stanham	MTP Services	Business Analyst

Appendix C: e-fish design principles

***Box 1** Linked data*

Linked data

Data sets are inherently linked and linked in way that allows ease of use

Data is often stored in “silos” in many different formats and in numerous different locations. Internal and external data users are unsure where to find information and have low confidence in the reliability of information even if it is found.

Data available to internal users, data managers, and fishery managers is often duplicated and unable to be used until manually linked, often in spreadsheets. In some instances, the manual linking is limited to guess work based on dates, times, and GIS data rather than a common unique identifier.

Based on the findings of the stakeholder interviews, a number of key challenges have emerged. These were:

- Reliably linking data sets that aim to capture the same or related data is often done based on a qualitative assessment. For example, linking electronic monitoring and logbooks, or linking VMS data with reported daily fishing log activities.
- Manual linking of data from disparate data sources is a time-consuming and expensive process that often constitutes a significant amount of the work undertaken by fisheries managers and scientists.
- Manual linking of data often requires some massaging of data to produce a holistic picture. This massaging of data means the single point of truth is lost and also means agencies holding the original data are unable to reliably produce the same results and outputs as those produced by some data users.

Design Principle in Practice

Structure	People	Process	Technology
All data sources are linked in some way, for example the trip ID or through another appropriate method. This link can be used to connect associated data before it is exposed to end users. This structure will allow the creation of data analysis dashboards for all data users.	Data users will be able to access and use data from a range of data streams seamlessly. This will reduce the large overhead when collecting and analysing data for research, compliance, and management purposes.	An agency or industry wide data strategy will provide the framework for how each data set should be linked. Once the initial upfront work has been conducted the day to day maintenance of the framework should be minimal. Documentation around which elements or methods are used to link the data sets should be clear and explicit.	A recommendation for technology will be made however specific technology used to link data sets can vary and will therefore be decided by each individual agency. It must be noted that using an agency or industry wide approach to data storage and linking is likely to make linking easier.

***Box 2** Modern data sharing*

Modern data sharing

Data sets should be shared through an easy to maintain and minimal touch solution such as application programming interfaces (APIs)

Fishery management data is shared frequently across agencies, scientific bodies, compliance and intelligence bodies, and also within agencies. However, there is no standard method for data sharing and in many cases no self-service option.

Data is currently shared through the sending of spreadsheets (csv files) via emails, and copies of databases on DVD are mailed to the receiving party. The sharing of this data is often initiated through a request rather than a predefined agreement to send particular data at a particular frequency.

Based on the findings of the stakeholder interviews, a number of key challenges have emerged such as:

- The manual requesting and transmission of data often causes significant delays. There are often days between a request and receiving the data.
- Duplication of data to share with external agencies causes a loss of the one source of truth.
- Confidentiality and privacy obligations prohibits sharing of data across jurisdictions and to third parties.

Design Principle in Practice

Structure	People	Process	Technology
All data should be shared internally and externally via a uniform method. This method should utilise a modern sharing framework such as application programming interfaces (APIs). This will allow each agency to hold their own data but also make it available for consumption across the agency and across different agencies, by scientific bodies, and by industry.	A modern data sharing method will reduce the reliance on database managers to manually export and share the data. Making data instantly accessible is likely to reduce the delay associated with the current transfer methods. This is likely to hasten decision making and report production.	APIs will need to be built on top of existing solutions or heavily considered when building new solutions. Once these are developed in accordance with the business purpose, external and internal users will be able to interface with the API. These may be used to develop data analytics solutions or imported into Commercial off-the-shelf applications such as Microsoft Power BI for data analysis.	A modern standard such as REST API reporting should be made available across the agency reporting streams. These APIs should be exposed to relevant external agencies to consume. It is likely that the capability to internally consume API responses will also be required for reciprocated data transfers. Care must be taken to ensure API access is controlled and confidentiality and privacy obligations are met.

Box 3 Ensure data integrity

Ensure data integrity

Data is accurate and validated with minimal errors. Data is stored according to elements maintained in an agency or industry wide taxonomy

Data is often received in a way that suits the particular data collection stream (e.g. log books or VMS) without considering the wider use of data collection and use within a fisheries agency.

This often leads to duplication of data within siloed systems; often with different naming conventions, methods of collection, historically significance, validation, and accuracy.

Based on the findings of the stakeholder interviews, a number of key challenges have emerged such as:

- The diversity of data collection methods and validation across systems leads to significant resources dedicated to cleaning and processing of the collated data before any meaning can be drawn.
- Users are often not aware of the accuracy of the data. This, in combination with data cleaning leads to insufficient evidence to make decisions.
- Siloed data from different, unique collection methods does not allow agencies to establish one source of truth across all systems. This leads to difficulties and inaccuracies in determining stock assessments and collection of accurate compliance data.

Design Principle in Practice

Structure	People	Process	Technology
All data should be received in a uniform method and use a standard reporting taxonomy. Two such examples are the Standard Business Reporting (SBR) AU Taxonomy used across multiple Australian Government organisations, and the Fisheries Language for Universal Exchange (FLUX). Care must be taken to not over validate inputs because this may lead to users not using the system due to increase difficulty or unintentionally decrease the usefulness of the received data.	This process will require the establishment of a taxonomy and data collection working group. This process will require an agency wide approach to uniform data collection and validation.	All new data collection methods must conform to existing agency standards and predefined process. Each data element must be one that already exists in the taxonomy or added to the taxonomy through a thorough, predefined process such as that of the SBR AU Taxonomy.	A modern standard such as API reporting should be made available across the agency reporting streams. Fields within each API should be drawn from a predefined taxonomy. Data validation should be included as a key component of the API methods.

***Box 4** Standardised data collection*

Standardised data collection

Data is received in a uniform approach. Care is taken to not duplicate data where it is unnecessary to do so

Data is currently received through a variety of methods including paper-based landing report forms, paper-based observer records, electronic reporting of log books, video capturing and annotations, and VMS GIS data. These methods often differ in accuracy and how quickly the data reaches the agency.

A significant portion of this received data is used to verify and validate the primary data. This primary data includes the log books and landing reports; secondary data includes VMS, electronic monitoring, and fish receiver landing reports.

Based on the findings of the stakeholder interviews, a number of key challenges have emerged such as:

- Difficulties in collating and comparing primary and secondary data sources due to the different collection methods. Additionally, there is often a significant delay between each data source reaching the agency.
- Data users and fisheries managers often have difficulty comparing the primary and secondary data due to irregular collection and data storage formats.
- Data is often received and stored in silos despite being linked. This creates a significant overhead to link, clean, and process the data before any meaning can be drawn.

Design Principle in Practice

Structure	People	Process	Technology
All data should be received via a uniform method. Each collection method will be designed within the context of the overall data collection and use goals of the agency.	A move towards a standard data collection method will require significant buy in from agencies, and people responsible for inputting data. A standardised data collection only has value when all parties participate. This approach is likely to move all reporters to electronic reporting.	A standardised data collection method will need to be determined from the ground up. This will include analysing the business requirements across all domains within a fisheries agency. Once reporting methods are created (APIs and front-end software) then all future reporting will come through these pathways.	A modern standard such as API reporting should be made available across the agency reporting streams. Agencies will need to develop or outsource front-end UIs to accompany these APIs. Agencies will need to determine a suitable data storage method that collates data received across streams.

Box 5 System capability fit for purpose

System capability fit for purpose

Implemented systems directly support various business outcomes of fisheries stakeholders

The goal of a fishery management system is to support the management of fisheries. The business needs for fishery management agencies is often changing to adapt to new legislation, new fishing methods, and new scientific research methods. However, agency infrastructure and software systems are in a constant state of catch up.

Agency infrastructure and software systems have been created in a reactionary way; often in small bespoke parts using outdated technologies.

Based on the findings of the stakeholder interviews, a number of key challenges have emerged such as:

- Uplift of the system functionality to meet the evolving business needs is often slow; leading to quicker ad-hoc solutions that become the status quo.
- Ad-hoc solutions are often poorly integrated further exacerbating the siloed data problem.
- Current system designs do not facility the access and sharing of data in an easy and quick way; this is often done manually. Over time many systems have become unsustainable from a support and enhancement standpoint.
- The conglomeration of small bespoke applications causes significant overhead when updating and releasing new features. This often includes large downtime because modular releases can often not be performed.

Design Principle in Practice

Structure	People	Process	Technology
Systems are defined to meet current but also future business needs. Future business needs will often be unknown, so care must be taken to modularise applications such that new business needs can easily be met without the need for a full takedown of a system.	The design, maintenance, and uplift of the system must meet the changing business requirements. This means business must work closely with the development team. Frequent communication between product owners and business analysts will help ensure this.	Maintenance and design of systems is often more efficient and more accurate when a cross functional team is responsible for delivery. In practice this means a strong integration between business and IT such as is typically seen in agile development teams.	Current systems are built on old, clunky, and often over-powered systems. Lightweight, modular, systems such as cloud-based applications will better support rapid development that can better keep up with evolving business requirements.