Mapping and Assessment of Freshwater Ecosystem Services and Values - The Case of Waikato Region

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Abstract
In the Waikato Regional Policy Statement, objective 3.8 states that the council will take an ecosystem service approach to recognise and maintain or enhance fresh water ecosystem services to enable their ongoing contribution to regional wellbeing. Monitoring ecosystem services and socioeconomic and cultural values could enable better management of these resources and so increase the productivity and efficiency of resource use for community wellbeing. This is because the ecosystem service approach to natural resource management, in principle, considers all services to all sectors of a community.

To facilitate this approach, tools such as maps and a database of ecosystem services are useful at the level of detail at which policy and management decisions are made. This study characterises the freshwater ecosystems in the region by assessing a sample of water bodies (streams, rivers, lakes and wetlands), their services with economic benefits they provide. The results are being presented in web-maps and the underlying database of the ecosystems, their services and values.

The database system allows structured querying, searching and updating of the database as more information becomes available on these ecosystems. The ecological status and health of the ecosystems provide an indication of the services and values of these natural resources using the Millennium Ecosystem and Assessment (MEA) and the Common International Classification of Ecosystem Services (CICES) frameworks. This will help the regional council's capacity in monitoring the effectiveness of its natural resource management and policies.

Keywords: *Waikato region, Freshwater, Ecosystem services; Spatial planning, Natural capital*

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INTRODUCTION

The Waikato region is approximately 9,325km2 in land area, which accommodates approximately 10% of New Zealand's population and is a medium sized regional economy with significant primary production and energy generation (more than 20% of New Zealand's electricity). This economy relies heavily on its natural resources, including the natural assets of national significance like Lake Taupō and the Waikato River (MBIE, 2015). The region contained approximately 30% of New Zealand's wetlands, including the Whangamarino Wetland and Kopuatai Peat Dome (Swarbrick, 2015). The region consists of valleys and coastal lands separated by ranges. The rich landscapes encourage the diverse land use, but this also puts pressure on sustainable management of the natural resources in the region. This pressure warrants a better understanding of the way the national 'economic' growth agenda affects with the management of natural resources. This is a responsibility for the regional governments.

Objective 3.8 of the Waikato Regional Council (WRC) Policy Statement relates to Ecosystem Services (i.e. benefits people obtain from nature). Under this objective, the region seeks to 'recognise and maintain or enhance ecosystem services' to enable their ongoing contribution to regional wellbeing (Waikato Regional Council, 2016). In addition, an ecosystem-based approach to managing natural resources has the potential to contribute to the Government's business growth agenda objective of a more productive economy through a number of activities, such as the tourism growth partnership fund to grow tourism infrastructure, and resource management reforms to speed up decision-making (MBIE, 2015).

There are a few existing databases of ecosystem services being compiled by the Ecosystem Services Partnership (ESP)[2]. However, in New Zealand, this concept is relatively new and being understood even by the policy makers. Currently there is no database of these ecosystems with their associated services and values in one repository. This is a gap between the values the community expects from natural resources and the ecological monitoring data being collected by the WRC. For example, a tourist would benefit from knowing where ecosystems such as lakes, rivers, and wetlands are, as well as their uses, in terms of different types of fish, birds and plants they may see, the length of kayaking trails available, etc. Similarly, ecologists collecting data on the ecological status of water bodies would appreciate knowing not only the environmental benefits of the natural resources, but also the economic, social and cultural values of the resources – that is linking ecological status to socioeconomic and cultural values in terms of how (and how many) people benefit from the ecosystems.

Closing this gap is an important requirement to be able to monitor the effectiveness of the relevant regional policies. It will also provide information that will be useful when objectives and limits are being set to implement the National Policy Statement for Fresh water Management (NPS-FM). An ecosystem service approach to resource management can increase the productivity and efficiency of resource use for community wellbeing because it considers all services provided by ecosystems to all sectors of a community. This approach will also help the region to achieve well-informed natural resource management outcomes and avoid an issue-based approach to resource management where efforts are typically a corrective approach to particular problems. To facilitate this approach, tools such as ecosystem maps and database of their services are useful at the level of detail at which policy and management decisions are made. Hamilton et. al. (2008) and Ausseil, et al. (2013) have reported on priorities for an ecosystems approach in NZ and specifically, in the Waikato region.

This study, under the freshwater ecosystem service project, aims to build on earlier research work on this topic (Hart, Rutledge and Greenhalgh, 2012). The results (maps and database) will be useful for

[2]http://esp-mapping.net/Home/

well-informed natural resource management, especially for fresh water resources (rivers, streams, lakes, wetlands and ground water bores) in the region. The immediate justification for this project is that the challenge of regional planning is to spatially describe the landscapes in a manner that allows planning to protect and enhance the ecosystem services that support the wellbeing of the community by taking a holistic and integrated approach. Specifically, the NPS-FM (2014) requires the regional council to set appropriate objectives and targets for fresh water quality and quantity (MfE, 2014). The freshwater ecosystem service project is set up to provide socio-economic and cultural knowledge base on top of the biophysical and environmental monitoring knowledge/data base in order to be able to operationalise the concept of ecosystem services in decision making and policy development. Specifically, the process of freshwater management through plan development or change requires the region to decide if the 'current state' of freshwater bodies need to be maintained or improved. It also requires the council to think about the trade-offs of the proposed management regime and the likely economic and environmental impacts and opportunities. In addition, it is also required that a region, should show in a robust and comparable way, how much an economic activity depends on natural assets and how sensitive the economic activity is to changes in the natural assets it depends on. These are relevant applications of the concepts of ecosystem services in resource management.

The Objective and Methodology

The first objective of the project that informed this study is to identify the spatial distribution and characteristics of fresh water ecosystems in the region. In terms of methodology, the ecological status and health of the ecosystems were considered to estimate the services and values of these natural resources using the Millennium Ecosystem Assessment (MEA) and the Common International Classification of Ecosystem Services (CICES) frameworks with expert judgement. This study also came up with a tool to visually present the results using web maps, charts, photos and a database system that allows users (including the regional council, other territorial authorities, environmental organisations, and the public) explore the data. The public can explore the data to have a feel for where the ecosystems are, what sorts of services have been assessed to be potentially available at what amount and what the values of these services are. The regional council or territorial authorities or other agencies taking responsibility for maintaining and managing the ecosystem are able to appreciate the level of services and the value of the ecological status of the ecosystems.

In this study, we have not gone into the argument about the differences between the terms and concepts of benefits, services, ecological functions, and ecological structures and processes which underpin the links between natural capital and human well-being. We have rather focused on utilitarian perspective of the obvious benefits that human being directly or indirectly enjoys from ecosystems. These are things that can be valued either in monetary or social terms. The limitation may have implications for double counting, overestimation or underestimation in some instances. However an attempt was made in recognising the fourth category of ecosystem services, supporting services which some literature regards as intermediate services.

The starting point was a literature scoping review specifically to establish context and provide an overview of fresh water ecosystem services and identify dimensions of a database for ecosystem services assessment. From the literature the dimensions of the database were summarised into indicators of data to be collected for the assessment. The list of fresh water ecosystems in the region was considered before a sample was chosen for assessment.

The sample was based on a set of criteria established in the project – spatial representation, land use representation, ecosystems of significant size and ecosystems being already researched or monitored for ecological integrity. For example, the sources of these fresh water ecosystems include those associated with the WRC's monitoring sites, ecosystems mentioned in the Waikato Regional Council's

regional policy statement, and based on the recommendations of Hart, Rutledge and Greenhalgh (2012). The FENZ and NIWA database of fish values were also considered.

The literature review also led to the adoption of a database template (referred to as the 'blueprint' of data to be collected). This template was specifically developed for reporting and presenting ecosystem services as an effort to conform to the Common International Classification of Ecosystem Services (CICES v4.3) framework (Haines-Young and Potschin, 2013). Finally, the dimensions and parameters of the database were used to develop web-maps for the data collected to show spatial distributions of fresh water ecosystem services in the Waikato region. The dimensions were used as legends on the maps and also variables against which to search the database.

The rest of this paper presents a succinct summary of the study carried out in the freshwater ecosystem service project. A summary of the knowledge gleaned from literature is provided in Section 2; followed by Field works and data collection exercise (in Section 3) and the data collection reports are summarised in the results and project output section in section 4. This paper ends with a conclusion and ideas for further research (in Section 5).

LITERATURE REVIEW

Literature was reviewed to provide an understanding of the concepts of ecosystems and frameworks being used to assess them. The review shows that the idea behind ecosystem concepts is to recognise natural capital (a natural resource) as an ecosystem. The interactions and processes within and between an ecosystem's components performing their functions result in what are called ecosystem services. There are direct and indirect linkages between the services and human wellbeing. However, most of the resources (ecosystems) are often considered as public goods which are controlled by public entities because there is usually no market for them and they sometimes are not well represented in policies.

This is one of the ways the ecological economists have contributed to knowledge on the measure of wealth in an economy. Specifically, accounting for ecosystem services as natural capital is an advancement beyond a gross domestic product (GDP) approach to measuring the wealth of a nation. The ecosystem services paradigm helps to understand the value of nature. According to a leading economist (Joseph Stiglitz),

> *"Gross domestic product, the leading economic measurement, is outdated and misleading… It's like grading a corporation based on one day's cash flow and forgetting to depreciate assets and other costs."*

In some parts of the Waikato region, freshwater resources are finite and there are limits on their capacity and in most places are being degraded at an unsustainable rates. Hence, matching economic growth with environmental sustainability will help to better account for how we use natural resources in order to ensure economic growth does not deplete finite natural resources. This approach also helps to capture a holistic or diverse values of freshwater.

There is a growing understanding that ecosystem services can be explored to achieve biophysical, social, cultural and economic values that benefit humanity. Ecosystem services are generated from the stocks of natural capital; as the quality and condition of an ecosystem changes, the provision of the ecosystem services change. The services have been identified and categorised into provisioning, regulating, cultural and supporting which cuts across the provisioning, regulating and cultural categories. Efforts are being made to standardise the indicators for measuring these services, as well as how to present them to inform policy decisions. Fresh water bodies are examples of ecosystems. Specifically, fresh water ecosystems include, broadly, streams, rivers, lakes, wetlands and some

groundwater sources such as boreholes or aquifers. The remainder of this section presents the details of the knowledge gleaned from the literature.

Ecosystem services – concepts and assessment framework

An ecosystem is a functional unit of dynamic and complex interaction of plant, animal, and micro-organism communities and their non-living environment. These units (ecosystems), when their components do interact, provide some benefits for human wellbeing (MEA, 2005a, b). Ecosystem services are flows of biophysical features, quantities or qualities that directly or indirectly benefit humanity (Boyd and Banzhaf, 2007). Ecosystem services are not commonly considered in land use planning because the tools and information for decision makers have typically not yet been available. This includes information on who the beneficiaries of ecosystem services are, along with their perceptions of the value of ecosystem services.

The importance of understanding functional linkages between ecosystem components, including species, soils and the provision of specific ecosystem services has been indicated in the literature (McDowell, van der Weerden and Campbell, 2011; McDowell et al., 2015; Smith et al., 2015). However, in spite of the large number of publications on ecosystem services assessment frameworks, and the definition of the ecosystem services concepts (e.g. MEA 2005a,b; TEEB, 2010) there is still debate about the 'final' typology of ecosystem services and 'best practice' approaches for putting the concept into practice for the sake of ecosystem conservation and sustainable use.

The *assessment* of ecosystem services is mainly based around the concept that ecosystems perform certain functions (referred to as services), and these provide benefits to human wellbeing. According to Maynard, James and Davidson (2014), quantification and mapping of ecosystem services provides key information mainly to identify: areas that provide a high level of service requiring protection or management; areas that provide specific ecosystem functions or services; and changes in ecosystem service provision over time (i.e. a combination of natural capital status and land use). Spatial representation of the relative provision of ecosystem services across a landscape is critical for incorporating ecosystem services into processes for integrated urban and regional planning.

Previous studies have identified, classified and prioritised a wide range of ecosystem services from natural resources, and also to address some issues based on the requirements of the Resource Management Act 1991 (RMA). These requirements cover the state of resources, effects on climate change, provision for energy demand and the relationship of tangata whenua with the environment and health and wellbeing of the Waikato River catchment (Hart, Rutledge and Greenhalgh, 2012; Hart et al., 2013). Hart et al. (2013) identify some data needs in order to spatially map the identified and prioritised ecosystem services across the region.

Previous ecosystem service mapping approaches have used land use and land use zoning as proxies (Costanza et al., 1997). Based on its biodiversity values, the Waikato River catchment, which comprises Lake Taupō and its catchment, the Waikato River below the Lake Taupō outlet and Waipā River, has been identified as a water resource of national importance (White, Sharp and Reeves, 2004; Ministry for the Environment, 2004; Ministry of Tourism, 2004; Richmond, 2004).

Recent work reported in Hart, Rutledge and Greenhalgh (2012) introduced the concept of ecosystem services from a wider number of natural resources in the Waikato Region specifically by incorporating the concept into the Waikato Integrated Scenario Explorer (WISE) model. This is meant to allow the application of WISE to explore, assess and quantify the effects of developments and policies on particular ecosystem services across the region.

In this study, focus was on services that have been used and recognised internationally. These are services that contribute directly or indirectly to biodiversity and human wellbeing. It is, however, acknowledged that there are services that are being debated based on human perceptions or value judgments. The framework for assessing ecosystem services is still being developed. The most popular is Millennium Ecosystem Assessment (MAE) framework (MAE 2005a,b; Maynard, James and Davidson, 2010), which has been applied in this study.

Applications of ecosystems services approach

The ecosystem services approach to managing natural resources has been applied to achieve a number of purposes, such as trade-off analysis and project evaluation, disaster risk reduction (Ganter et al., 2015), planning and management (Henninger et al., 2015), co-investment and reward mechanisms for ecosystem services (Gatner et al., 2015), governance and institutions to manage ecosystems (Hamilton *et al.,* 2008; Maes et al., 2012; Winterbottom et al., 2015), agro-ecosystems (Smethurst, 2014) and tourism development (Burke et al., 2015).

In terms of trade-off analysis and project evaluation, it is acknowledged that the capacity of an ecosystem to concurrently provide multiple ecosystem services is inherently limited and trade-offs occur when one ecosystem service is enhanced at the expense of another. This is, however, outside the scope of this study. Nevertheless, it is important to note that this point implies that the values we arrived at in this study cannot necessarily be summed up to indicate the total value of ecosystems. Nor does it necessarily mean one service is more valuable than another, because of different dollar values per unit of a resource. However, where there is a need for trade-off analysis, the data collected in this study can help to achieve that in a further study.

The indicators can also inform disaster risk reduction because ecosystem types, quality, and conditions (e.g. wetlands) play important roles in terms of hazard mitigation and vulnerability reduction. The concept of ecosystem services can provide a useful instrument for more integrated and sustainable planning and management of natural resources as well as provide a powerful argument for investing more in restoration of degraded ecosystems.

In addition, co-investment and reward mechanisms for ecosystem services can be supported with the ecosystem service indicators and dollar values being translated into practical financing instruments and incentives for resource conservation and/or restoration. This is a key reason why it is useful to attempt an economic valuation on top of quantifying ecosystem services: to show benefits in monetary terms so as to justify an investment.

Where agriculture is a predominant source of living, farm intensification can interact with the ecological systems. In that case, the ecosystem services concept can: help to increase productivity per unit area by utilising inputs more efficiently; develop resilience against climatic variability; improve ecosystem functions/services to partially replace non-renewable inputs and minimise impacts on the environment; and contribute to the well-being of rural populations. Applications of these concepts have been reported for European countries (Maes et al*.,* 2015); Australia (Baral, 2013) and Africa (Willemen et al., 2013).

Indicators of ecosystem services

There is a wide range of indicators in the literature that are being used to assess ecosystem services (EU 2013, 2014; Haines-Young and Potschin, 2013; UKNAE, 2011), but standard guidelines on social-cultural and economic valuation are still being developed in the literature. The indicators overlap – one indicator can be used for more than one ecosystem, and consequently, for more than one service. Some services have more than one indicator. Some indicators cannot be used as a standalone to assess a service. Part of what leads to this complexity is for example the contributions of ground water to

some fresh water ecosystem services is not well known, i.e. ground water is connected to surface water and exerts indirect effects on the functioning of other ecosystems.

Most of the services are comprehensive and easily observed either during field visits and or well documented research (literature). However, some are proxies, which are subjective, and limited by lack of detailed information and scale inaccuracies. While these values will be an approximation, they can give an indication of trade-offs, and different values that can be derived from use of a resource. This can contribute to the decision-making process either on investment, raising funds for restoration projects, or exploration of ecosystem services.

In this study, the assessment of ecosystem services is mainly a reflection on the ecosystem's conditions and processes going on in an ecosystem that provide a benefit to the species that inhabit them either for survival or functioning, which in turn are of use to people in some form. The conditions and process do help to maintain biodiversity and the production of goods (e.g., food) and services (e.g., waste assimilation) that contribute to human welfare. These indicators can potentially be useful in enabling markets for ecosystem services. They can also justify regulations to support the establishment and scaling up of payments for ecosystem services.

The indicators are tools that can put an economy in a position to explore how scientists can contribute to the science-policy interface on issues affecting ecosystems and human welfare such as:

- To provide support for global or regional processes such as Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Intergovernmental Panel on Climate Change (IPCC), and the International Sustainable Development Agenda (ISDA) post-2015; and
- To advocate the application of valuation of ecosystem services in decision making processes, especially in development projects.

However, the indicators presented in this study are still valuable despite that most land use change decisions, population growth and increase in energy uses are based on incomplete information about the consequences for the involved ecosystems, their services and their effects on human wellbeing. One approach that the region might take is to sustainably manage, conserve and restore ecosystems so that they continue to provide the services that allow society to adapt to global changes.

For each of the Council's monitoring sites, associated freshwater ecosystems were observed and surveyed using the indicators of data to be collected. This involved describing their ecological values and services. For example: how an ecosystem has formed and developed over time; the ecological characteristics; how associated land use, land cover, land management practices, water storage, diversion/extraction, commercial eel harvesting, etc. have affected the ecological status of the ecosystem in terms of services and values (e.g. types of plant/animal communities living within the ecosystems, presence of invertebrate fauna, fish species, migratory fish, presence of mahinga kai, etc.).

Despite this body of literature on the concept of ecosystem services, the practical application in terms of assessment is still developing. Therefore, in this study, simple approaches have been taken both in data collection and processing, while efforts were made to contribute to the development of standardised measurements. For example the distinction between different valuation methods and frameworks was not considered. However relevant applications of these quantification methods are reported in the literature (Smith, Houtven and Pattanayak, 2002; Shultz, Pinazzo and Cifuentes, 1998; Schuijt, 2002; Costanza 2012; Dominati, 2014; Pinedo-Vasquez, 1992; Pattanayak and Kramer, 2001; Patterson, 1998).

In any case, a decision maker would want to know not just the overall picture, but also what the option means for specific stakeholders at multiple scales. Classifying the ecosystem services based on categories, divisions, groups, classes based on the popular MEA (2005a,b) framework was applied in this study. After quantifying the services, we then assigned dollar values based on published data. These values are usually based on benefit transfer3 rather than any of the more rigorous valuation methodologies in literature (which, despite their rigour, tend to remain controversial). In this study, we have adopted the simpler approach because of limitation in time and scope of this study.

FIELDWORKS AND DATA COLLECTION

After some understanding of the concepts of ecosystem services, data was collected on a sample of streams, rivers, lakes and wetlands. The steps are summarised in this section.

Sampling the Freshwater Ecosystems in the Region

Waikato Regional Council has a number of programmes through which the ecological conditions/status and trends in the region's natural resources are being monitored. These include the Regional Rivers Water Quality Monitoring Programme and the Regional Ecological Monitoring (REM) of streams. Under these programmes, there are a number of sites where Council scientists take samples for analysis for the purposes of monitoring environmental conditions. In the Waikato and Waipā catchments, Council scientists collect aquatic micro-invertebrate samples and basic habitat information at a range of sites:

- Approximately 95 sites on the state of the environment (SOE) network for invertebrate monitoring (each site is visited once every three years).
- There are approximately 15-20 reference condition ("pristine") sites being sampled annually.
- There are 10-20 long term/restoration/urban/peri-urban sites being sampled two out of every three years.
- Fish ecology monitoring is undertaken at around 100 of the above stream monitoring sites.
- For most of the above, the Council has a one-off water quality measurement collected when the site was visited between 2012 and 2014 summers.
- There are four "clean streams" monitoring sites. These are water bodies under the enhancement strategy of the Waikato Regional Council.
- There are about 100 river water quality monitoring sites. The monitoring team sample Regional Ecological Monitoring of Streams (REMS) at or near about seven of these sites (in the Waikato/Waipā catchments).
- From the FENZ dataset, there are approximately 169 lakes and 1,953 wetlands in the Waikato/Waipā catchment. About 10-15 lakes are monitored for water quality on a bi-monthly schedule.

Waikato Regional Council ecological monitoring (excluding water quality) is largely limited to wadeable streams, which are smaller waterways. Some of the wetlands have been surveyed in the past, and some are on-going (e.g. Whangamarino). Given limited resources for monitoring, the number of fresh water bodies and ecosystem services in the region were streamlined such that a manageable sample was selected. Having identified the Council monitoring sites as listed above and discussed with Council scientists, fresh water bodies (river/stream, lakes/ponds, wetlands, etc.) associated with or near those monitoring sites were identified so that a sizeable number of different fresh water bodies were sampled. Within the Waipā zone, efforts were made to ensure ecosystems that have planted forest upstream were represented. However, this was limited by the decision to ensure such ecosystems are within Council monitoring sites, thus providing access to previous biophysical monitoring data on final sites being studied.

Based on the review of the sampled sites, the sampled sites were adjusted to include:

- Lakes within vegetation (indigenous forest, manuka/kanuka, or exotic forest) including diverse lake type (volcanic, riverine or peat).
- Wadeable stream sites that have planted forest as a land use nearby.
- A river along the Waipā Catchment; the Waipā River being a main tributary in the Waikato River Catchment.
- Lakes that are within indigenous and planted forest catchments so that more land uses are represented

The list of the indicators and sampled sites (ecosystems) were reviewed and adjusted to allow for different land use and regional representation. Figure 1 shows the spatial distribution of the sampled sites with respect to all the sites that Council does monitor, i.e. all the ecosystems sampled are in Council's monitoring sites.

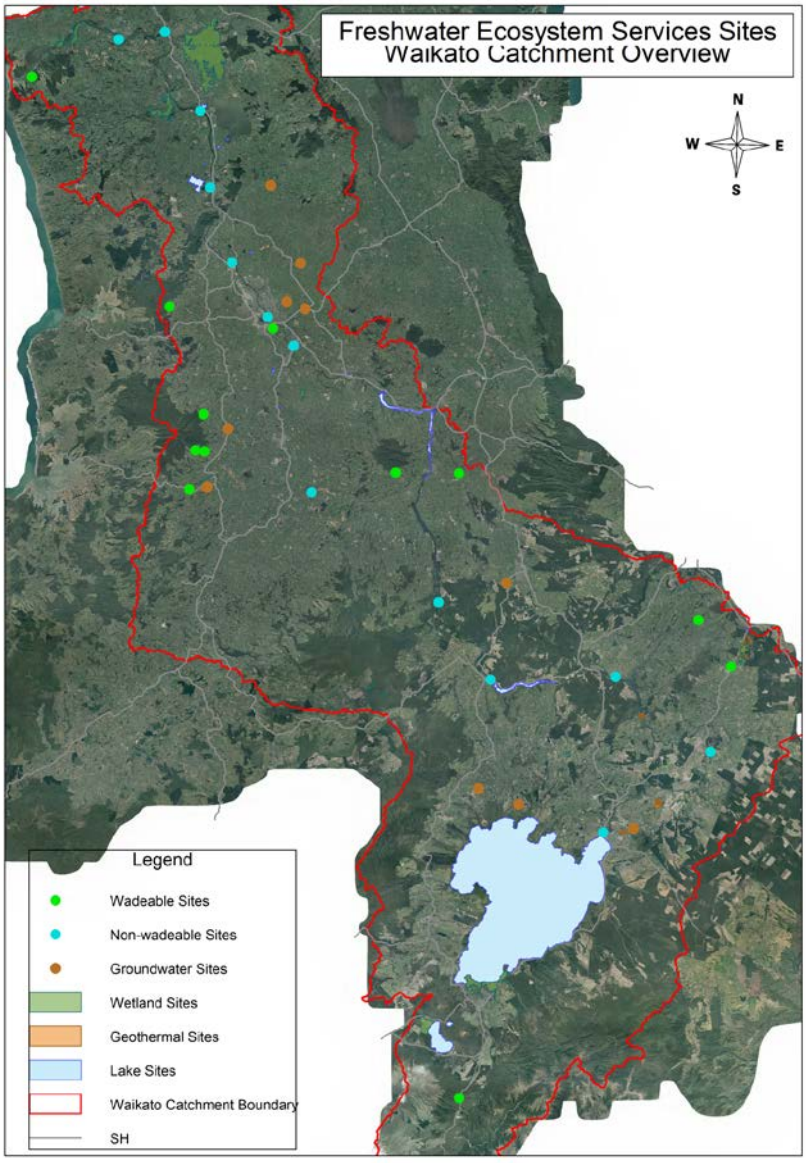

Figure 1: Sampled sites (ecosystems)

Data collection and ecosystem assessment

The Council's monitoring data sets on the sampled sites were used and the "blueprint" spreadsheet template for data collection was used to capture the data being mapped. The data sets include trends in hydrology, habitat, invertebrates, water quality, geothermal features, etc. Desktop data collection

was done to capture published data on the ecosystems. Some ecosystems were visited for personal observations of the conditions and presence of the ecosystem services. Where there is an absence of a service that we thought likely to be critical, we indicate no data in the records so as to identify gaps in data collection and to provide feedback for other areas of work that collect biophysical data.

In analysing the data, appropriate relationships between land use and provision of ecosystem services were applied to quantify ecosystem services by supplementing information with other local/regional information to estimate the level and or value of ecosystem services (including $-value) in populating the "blueprint" spreadsheet template. A note on each ecosystem service indicator were reported. This might include describing methodology, limitations, key assumptions, general field visits experience that is relevant to each site. It also includes brief remarks on each ecosystem.

Based on the Framework, ecosystem services are derived from the ecological conditions of the biological, chemical and physical states and characteristics of the ecosystem. The conditions are presented in Attachment E1 in the Appendix E. The conditions reflect the stock of potential services one could expect from these ecosystems. This is in line with published literature (Maynard, James and Davidson, 2014:6; TEEB, 2010; Watson and Albon, 2011) as a proxy where services are not directly quantified. Quantification of the services where possible was based on actual observation of services (field visits) and records of benefits as found in literature (desktop studies). The quantified services are presented in Attachment E2 in the Appendix E. The data represent the flow of ecosystem services in terms of the temporal units for each indicator. It is acknowledged that some data that were used as a proxy of ecosystem services were reviewed or refined in order to adjust for the uncertainties and similarity of ecosystem sites.

The blueprint of presenting an ecosystem services assessment as reported in Crossman *et al.* (2013) was applied to the data with some adjustment to accommodate the types of ecosystem in this study as well as maintaining the international standard of reporting being established in the field of ecosystem services assessment. Specific methods, references, the rationale for each estimate, the caveat about a particular indicator as well as future recommendations for updating the estimates are presented in the comment. Most of the estimates were also standardised to metric units to produce a common unit to facilitate comparisons where appropriate. To capture the scale of the extent of the services, the estimated services were extrapolated to the size of the ecosystem.

RESULTS AND PROJECT OUTPUT

In this study, targeted field surveys and observations of a sample of freshwater bodies (streams, rivers, lakes and wetlands) within the Waikato region was complemented with desktop data collection and the Council's monitoring databases. The data collected were analysed to assess the ecosystem services from the water bodies. The results in terms of a database are presented in the web map application (Figure 2) which is being hosted on the Council's website for public access. Thirty-eight out of the 75 ecosystems sampled have enough data to assess the services they provide (potential or observed). Of all various possible indicators, 204 of those indicators are presented in web maps and the underlying database.

The Economic Assumptions

It is always controversial to assign dollar values to some intangible benefits of a natural resource. In this study, we learned from literature, draw on expert knowledge, but remain conservative just to practice the concept of ecosystem services assessment. Therefore, we made some economic valuation assumptions based on literature. Details are reported in the comment column of the database. This is also presented as attributes on the map. The assumptions in terms of direct benefit of water (value) range from 4 cents/m^3 for the industrial water use, to $1.3/$m^3$ of water use in the

municipal and domestic water use. Agriculture and horticulture water use average at $0.12/m^3. The price of carbon at $7/tonne CO_2 equivalent, $6.5/m3 of sediment trapped, eel catch range between $7 and $21/kg, gray mullet at $3/kg, whitebait at $60/kg, fishing, visit/hunting range at $69 to $90, night visits to the freshwater destinations for recreational activities at $120 per night. In terms of the costs of keeping these water resources at their valuable state, there are certain costs such as the costs, to the territorial authorities, of improving water quality at about $50 per household per year, providing walkway access to streams at $24 person per year, maintaining biodiversity at $40 per household per year and costs of improving the ecological health of a water body at about $62 per household per year. These figures are not exact but have been extrapolated from past studies. These are direct benefits rather than total value which would capture the flow on impacts in the economy. These flow on impacts were not included explicitly in estimating both the quantities and corresponding values of the services in this first phase of the project. Monitoring data (biophysical, invertebrate and water quality records) were used together with field observation and desktop studies to assess the ecological conditions of sampled ecosystems. Based on literature review, some indicators of freshwater ecosystem services were identified and estimated. The data were standardised and harmonised across the ecosystems and services in terms of terminology and unit. Where no direct data were available, proxies of potential services were estimated.

Discussions and Policy Relevance

Starting with the tool to explore the results, the screenshot of the digital web-map with the underlying database is presented in Figure 2 as "***Freshwater Ecosystem Services in Waikato Region"***. The database behind the maps is a relational database that can be sorted or searched for any of the attributes like, type of ecosystem (streams, rivers, lakes, wetlands), categories of ecosystem services namely provisioning, regulating and maintenance, and cultural services. Exploring the results by looking at the various panels, the first panel on the top left named ***'The Sampled Freshwater Ecosystems"*** is the main window showing the map and the sampled ecosystems, each denoted by the postmark, ⚑.

Clicking on a postmark representing an ecosystem on the map will bring up a pop-up that shows the number of ecosystem services that have been assessed for the ecosystem. The pop-up can be flipped to see each of the ecosystem services (one after the other) for this particular ecosystem. The pop-up shows the details of each service including the quantity and value of a specific ecosystem service, photos, address, comments and sources of information about a particular ecosystem service. Specific methods, references, the rationale for each estimate, the caveat about a particular service as well as future recommendation for updating the estimates are presented in the comment. The panel on the top right, next to the map, named ***'Ecosystem Service Details'*** gives more details (based on a blueprint according to the international standards of reporting on ecosystem services assessment) about each ecosystem service across all the sampled ecosystems in the region. The currently displayed example, in Figure 1 shows the recreational service being in terms of number of recreational visits to the Waitapu Wetland assessed as about 160,000 visits per year and at a value of about $4m. The panel can also be flipped to see each of the ecosystem services (one after the other) across the sampled ecosystems in the region. In this study, 204 different types of services were assessed across the 38 ecosystems.

Back in the first panel, and considering the pop-up and the highlighted ecosystem that shows the example of the Waiotapu Wetland, the pop-up shows there are 4 ecosystem services assessed in this ecosystem. As mentioned earlier, this pop-up can be flipped to see other 3 services, one after the other. The panel directly below the map, named ***"Range and Distribution of Ecosystem Services and***

Values at Highlighted Ecosystem" shows a bar chart of the range and distribution of services being assessed at the highlighted ecosystem on the map***.*** For example the number of at risk species that are being habituated in the ecosystem are three, namely the prostrate kanuka (*Kunzea tenuicaulis*) and *Cyclosorus interuptus* and *Dicranopteris linearis;* the amount of carbon (C) sequestrated is 1,005 tonne $C0_2$-equivalent; the number of recreational visits to the ecosystem is 160,000 per year. Of the 4 assessed and presented services for this ecosystem, no monetary values have been estimated for the 3 at risk species being habituated and the 1 scientific study carried out using this ecosystem. Close to $300,000 and $4m per year were estimated for the C sequestrated and recreational visits services respectively. Not all the possible services have been quantified and reported here. This site is known for its geothermal activities which have other applications. As mentioned earlier, this is an ongoing work, as more data are available, this information will be updated. The ***"Estimate Services Total Estimate"*** panel in the right bottom corner shows the total value of the assessed ecosystem services in the highlighted ecosystem on the map, in this case, the Waiotapu Wetland. The total value of the services where we could ascribe a dollar value to, add up to over $4m. However, as indicated on the panel, the values of some services have not been estimated.

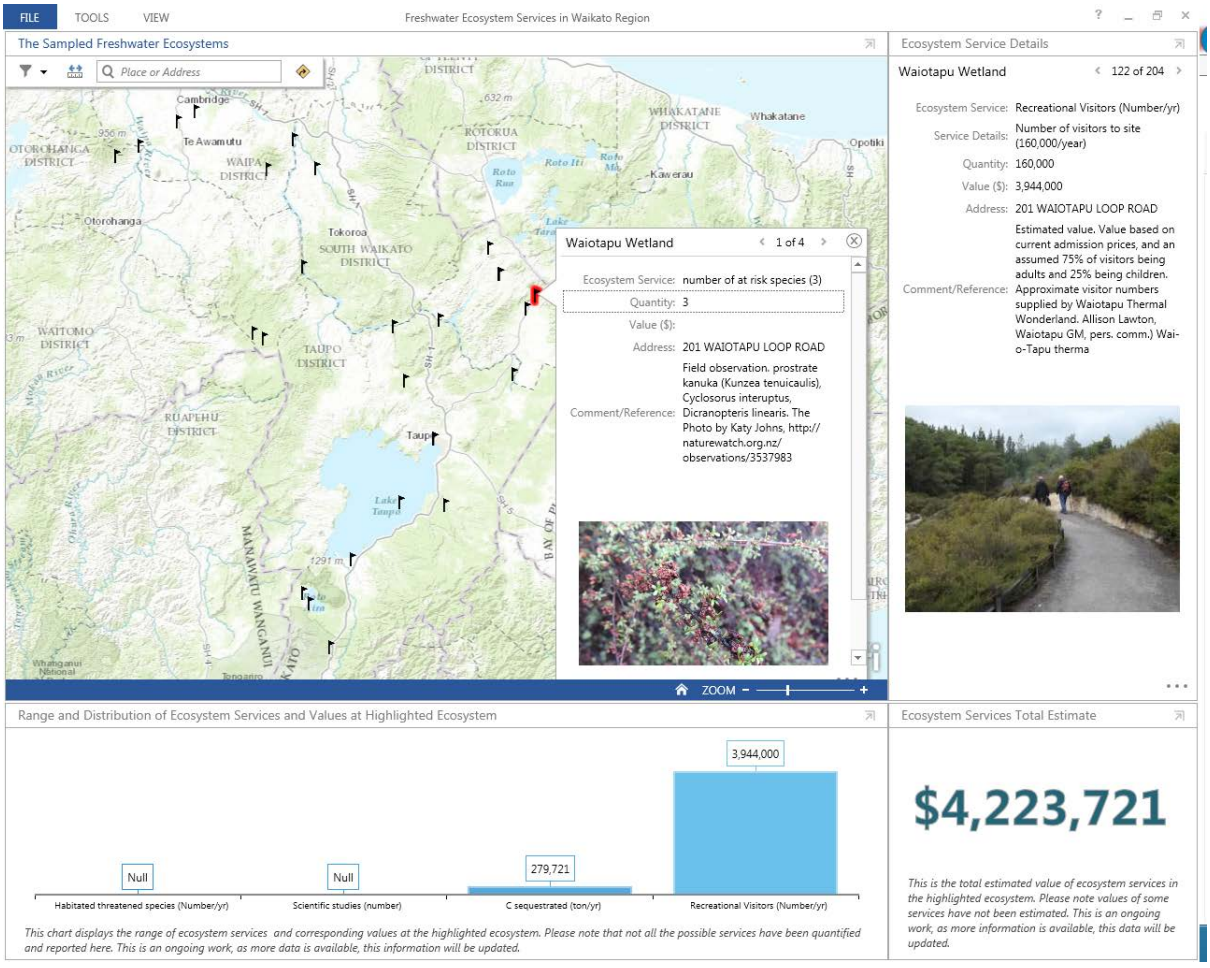

Figure 2: Freshwater Ecosystem Services Visualization tool: An interactive knowledge platform for ecosystem service assessment

In summary, Figure 3 presents a summary of all the services being assessed and the corresponding total values across all the ecosystems. The cultural services from the ecosystems are assessed to be over $400m per year. The provisioning services are assessed to be close to $250m per year. As could be expected, the regulating and maintenance service category which the marketplace often doesn't capture or reflect the true value, but not in any way the least important, is assessed here at about $20m per year.

And so what? These results support the claim that the region, with the New Zealand's longest river (River Waikato) and most of the wetlands and the largest lake (Lake Taupo) in the country, is endowed with freshwater resources that provide habitats for the invaluable flora and fauna, waste removal, recreational and cultural values that are difficult to exhaustively measure in monetary terms. However, as the region also accounts for the substantial experience of the country's land and water use industries including intensive agriculture, urban expansion, etc. the challenge such as deterioration in water quality as well as over allocation of freshwater resources requires well thought plan for sustainable management of the demand and supply of the services required by both the ecology and the industries. Through this project, the council will be able to identify, the potential amount of services available at this ecosystems which are available for use among the industries and also meeting the ecological needs.

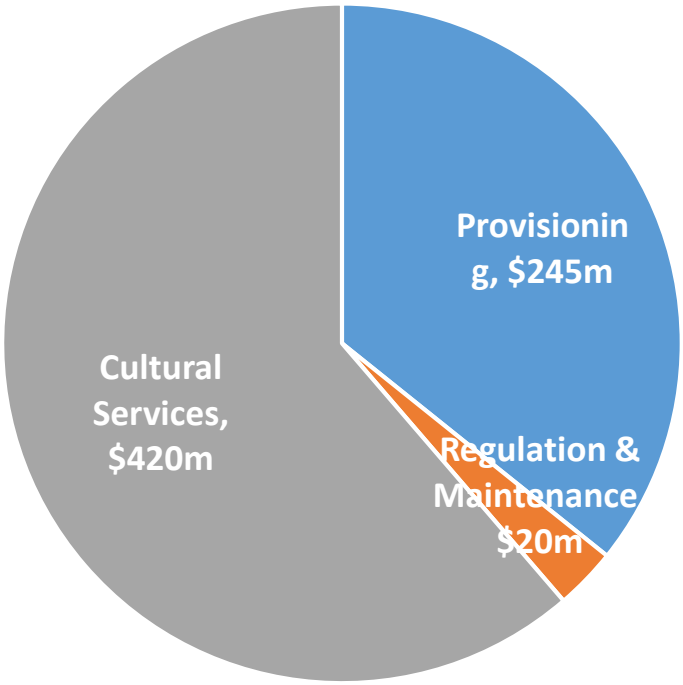

Figure 3: Estimated total value of the ecosystem services assessed across 38 Ecosystems in the region ($m/year)

Specifically, the results from this project are the basis for taking an ecosystem services approach to managing natural resources in terms of showing the range of services and the invaluable services they provide when considered as an ecosystem. There is a number of applications this information can be put to. For example, a number of water purification services were quantified. These include nitrate removal, sediment trapping, etc. These are crucial ecosystem services as the self-cleaning capacity of wetlands, rivers, streams and lakes results in the provision of clean water for multiple uses. These services reduce the costs of water treatment to the community by minimising the costs of technology and infrastructure in treating water of diffuse pollutants. The better the biodiversity or ecological status of a water body, the faster the nitrogen is removed.

The map gives indication of supply of ecosystem services available in the region, although the services are distributed across multiple ecosystems. For management purposes, the bar chart displays the amount of a range of ecosystem services at each ecosystem. The chart showing the services and values at a particular ecosystem allows one to monitor and assess the supplies and plan accordingly if it is seen that the service is low at a given ecosystem, especially the ecosystems where the biophysical ecological status are being monitored. In addition, the chart panel displays the range of services with corresponding values for an ecosystem. This allows to see a cumulative status of all the services, including provisioning, regulating, cultural and supporting services. This allows understanding of the relative value for all the available services in a particular ecosystem. This ultimately will help with the ***"enhance, maintain and or restore"*** strategy in resource management and allocation. These are baseline information for informed spatial planning for the protection of these ecosystems.

In terms of further research, there are many areas yet to explore in this concept of ecosystem services and how it relates to natural resources as natural capital. The assessments currently provide temporal units of the services but there is a plan to monitor the trends in the level of services so that these can be compared to demand for the same services. This will eventually indicate the need for enhancement and or restoration work necessary. Likewise the value of the services will also inform investment worth on the ecosystems. In addition, while some of the services assessed are direct contribution to some dominant economic activities in the region such as farming and hydro-electricity generation, how these activities contribute to or impact on the potential level of services will be considered in the further research.

In addition, future research is needed to cover ground water ecosystems and interactions with surface water ecosystems as well as updating and refining the maps and database with up-to-date information. The further research would include studying how economic concepts and tools can help equip society with the means to incorporate the values of nature into decision-making at all levels. More specifically, to capture the position of agriculture in the region, integrating the ecosystem service concepts into agriculture so as to inform agricultural practices while enhancing ecosystem services will allow greater production of both market and non-market goods and services within environmental constraints. This integration will also allow a comparison of the total economic value of natural resource use with other potential uses in a way that includes the impacts of the activities above and beyond just the commercial value.

This study has also refrained from laying emphasis on cultural values as described in the general literature because this may not directly apply to the local people who benefit from the ecosystems. This is simply because while some ecosystems obviously and directly provide some cultural services, different groups might attach different values to those benefits (Barns, Henry and Reed, 2013). Future research should address the specific values of iwis in the region.

CONCLUSIONS

If the concepts of freshwater ecosystem services have an imperative, it is that we need to find better ways of reconnecting people with nature so that we may conserve and sustain both biodiversity and our wellbeing. And one of the ways the broader fields of economics is contributing to this is going beyond GDP to measure the wealth/wellbeing of a community - This is not marketization or commodification of nature. It is simply to apply economic pragmatism to the challenge of governance and regulation of natural resources. Also to change the way we think about nature. Measuring and communicating the importance of nature to people. In this study, we have assigned monetary values to some services where we could yet, there are a wide range of services, not appropriate to assign value and other areas difficult to assign value.

The MEA (2005a,b) has been applied with expert judgement to identify the presence of ecosystem services and to quantify the service. Dollar values were also assigned where practicable. We have used the fresh water ecosystem service concepts to characterise the region's fresh water resources. This is an advancement of Council's work programme to better understand and account for natural resources in the region. The first phase of this project has focused on the fresh water ecosystems namely rivers, streams, wetlands and lakes of the Waikato-Waipā catchment.

Scaling the field data to catchment level provides a significant conceptual problem, so the estimates are based on where there were enough data to approximate the values. This project benefits from a high level of professional expertise both within the organisation, and from independent consultants and research professionals. It is recognised that the data are likely to contain estimation and proxy bias, so are non-prescriptive. They are nevertheless considered to be a good starting point for appreciating the services from the environment. The database and the maps provide opportunities for discussion and further research work to establish more accurate and useful information to inform policy on natural resource management. Another application will include climate change mitigation and adaptation strategies and guiding the development of a regional offsetting programmes.

Limitations of the study and further research

It is acknowledged that this study is not a full ecological impact assessment, as the framework being applied is strictly within the concept of ecosystem assessment rather than the guidelines and framework provided by the Environmental Institute of Australia and New Zealand (EIANZ) detailed in the EIANZ (2015). However, the monitoring programmes that generated the biophysical data, and the published national and regional databases being used in this study were assumed to have complied with those guidelines.

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