Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2016/041

Central and Arctic Region

Putting offsetting and monitoring on the map: tracking and monitoring fish habitat and productivity changes using GIS

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May 2016

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Bakelaar, C.N., Doolittle, A.G., Randall, R.G., Doherty, A., and Thomas, J. 2016. Putting offsetting and monitoring on the map: tracking and monitoring fish habitat and productivity changes using GIS. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/041. iv + 10 p.

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ABSTRACT

The objective of the Fisheries Protection Program (FPP) in Fisheries and Oceans Canada (DFO) is to maintain or enhance the ongoing productivity and sustainability of commercial, recreational and Aboriginal fisheries. One component is ‘ensuring that proponents of projects that cause serious harm to fish are required to offset that harm to maintain and enhance the productivity of the fishery’ (DFO 2013a). Monitoring and reporting of conditions are part of the offsetting plan. A component of an effective monitoring plan could be to develop and implement a geographic information system (GIS)-based ‘Geospatial Decision Support Tool’ as a framework. The key inputs (data management, spatial datasets, and proponent data) and outputs (habitat assessment and visualization tools) of the proposed GIS tool are described, along with the role of science.

Mettre en place sur la carte les mesures de compensation et de surveillance : suivre et surveiller l’habitat du poisson et les changements de productivité au moyen d’un système d’information géographique

RÉSUMÉ

L’objectif du Programme de protection des pêches(PPP) de Pêches et Océeans Canada est de maintenir ou d’améliorer la durabilité et à la productivité continue des pêches commerciales, récréatives et autochtones du Canada. L’un des aspects du programme consiste à « obliger les promoteurs de projets qui causent des dommages sérieux aux poissons à contrebalancer ces dommages afin de maintenir et de renforcer la productivité de la pêche » (MPO 2013a). La surveillance des conditions et la production de rapports à cet égard font partie intégrante du plan de compensation. La conception et la réalisation d’un outil géospatial d’aide à la décision fondé sur un système d’information géographique pouvant servir de cadre de gestion contribueraient à la mise en œuvre d’un plan de surveillance efficace. Les principaux intrants (gestion de données, ensembles de données spatiales, et données des promoteurs) et extrants (outils d’évaluation et de visualisation de l’habitat) de l’outil SIG proposé sont décrits, de même que le rôle du Secteur des sciences.

INTRODUCTION

Fisheries and Oceans Canada's (DFO's) Fisheries Protection Program (FPP) has the mandate to provide for the sustainability and ongoing productivity of commercial, recreational and Aboriginal (CRA) fisheries. This mandate is achieved through the administration and enforcement of the fisheries protection provisions of the *Fisheries Act.* As the single point of contact between DFO and development project proponents, FPP is also responsible for regulatory review pursuant to the Species at Risk Act. As part of the review process, proponents submit information related to their proposed work site (in-water or on adjacent land) along with proposal details. These data/information are used by DFO staff to assess the impacts of the project on fish and fish habitat. If a proposal requires a subsection 35(2)(b) *Fisheries Act* authorization for causing serious harm to fish that are part of or support a CRA fishery the proponent is required to prepare and submit an offsetting plan to counterbalance the serious harm. The offsetting includes a monitoring plan to ensure the effectiveness of the offsetting.

A Geographic Information System (GIS) can be used as a mechanism for storing habitat information provided by proponents as well as a decision support tool for managers. The decision support tool would facilitate: quantifying (measuring) habitat areas impacted at site, watershed, or ecosystem levels; identifying locations for offsetting opportunities; and evaluating the effectiveness of habitat alterations. This paper proposes a "Geospatial Decision Support Tool (GDST)", which will provide an improved ability to store data and information within their spatial context thus providing opportunities to better monitor and assess offsetting. Ultimately, FPP's responsibility to maintain or enhance the ongoing productivity and sustainability of CRA fisheries (*Fisheries Act*) could be aided by using a GIS-based tool.

An example of an existing and well used geospatial tool is the National Aquatic Species at Risk Web Mapping Tool. This customized web mapping application is designed to provide a data integration window for geography-based decisions founded on science research and advice.

RATIONALE

DRIVERS FOR THE DEVELOPMENT OF A GEOSPATIAL DECISION SUPPORT TOOL

There are 3 drivers behind the rationale for the development of a GDST for the Fisheries Protection Program (Figure 1):

Driver # 1: The Fisheries Protection Policy Statement is intended to provide guidance to Canadians to ensure they are complying with the *Fisheries Act*. The Policy promotes the Government's ability to address key threats to the productivity and sustainability of its fisheries, through standards and guidelines to avoid, mitigate and offset impacts to fisheries and to ensure compliance with these requirements. The GDST could be used to aid implementation of the provisions.

Driver # 2: The *Fisheries Act* requires that projects avoid causing serious harm to fish unless authorized by the Minister of Fisheries and Oceans Canada. This applies to work being conducted in or near waterbodies that support fish that are part of or that support a CRA fishery. After efforts have been made to avoid and mitigate impacts, any residual serious harm to fish is addressed by offsetting. Figure 2 provides the decision-framework used by DFO staff when assessing projects. Conditions related to avoidance, mitigation and offsetting are outlined in a *Fisheries Act* authorization. The GDST could be used to track offsetting sites.

Driver # 3: DFO Science has been asked to provide advice on what habitat variables to measure (metrics), and on designs for monitoring effectiveness of the offsetting plan. Advice was provided at CSAS Workshop on Monitoring Effectiveness of Compensation (DFO 2012a). See also Smokorowski et al. (2015) for details. The GDST could be used to help assess offsetting programs.

The concept of a Geospatial Decision Support Tool is proposed to implement and integrate DFO Science advice to meet some the decision-making needs and process steps of the FPP (Figure 3).

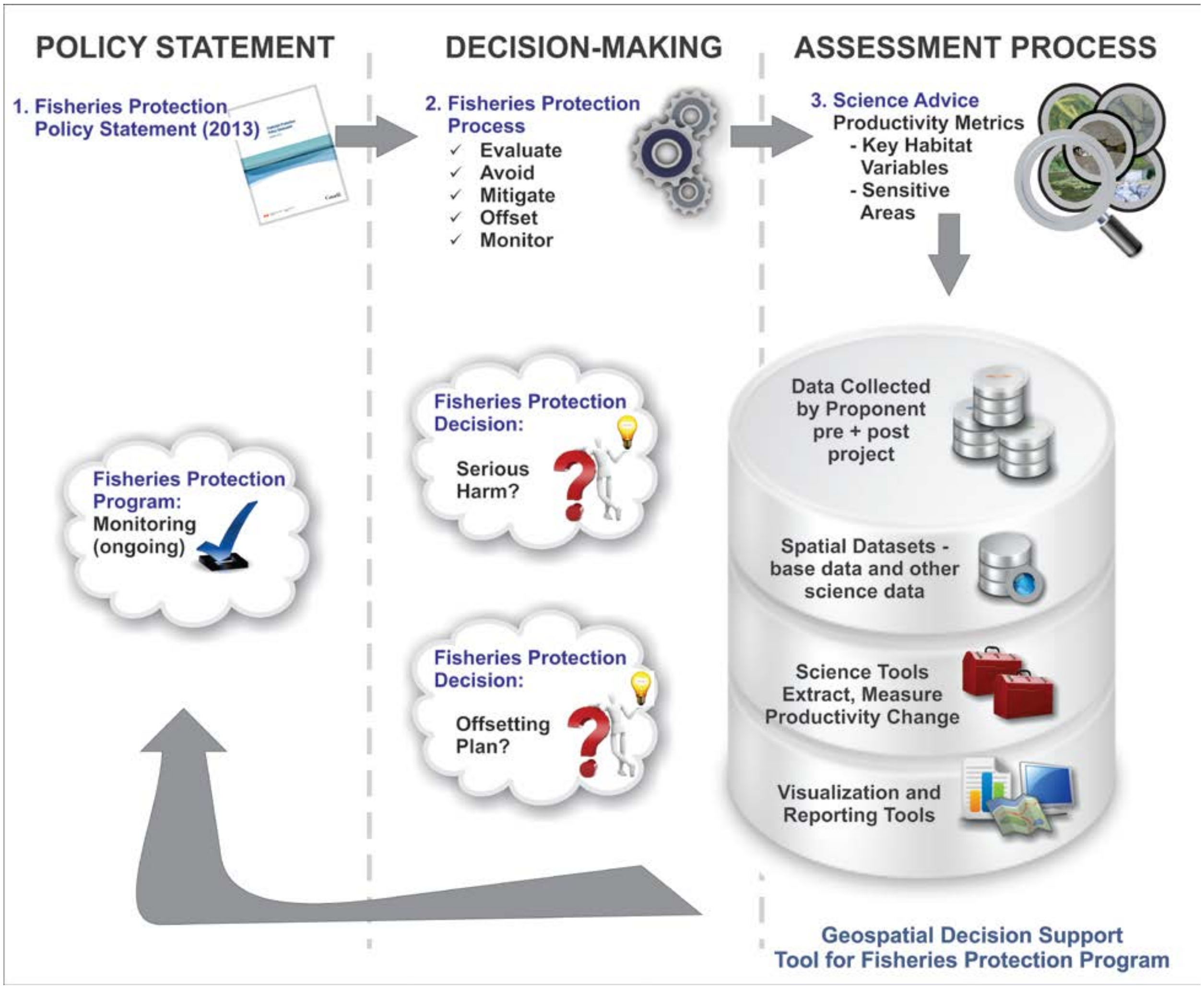

Figure 1. Conceptual diagram showing Geospatial Decision Support Tool (GDST) drivers within DFO framework.

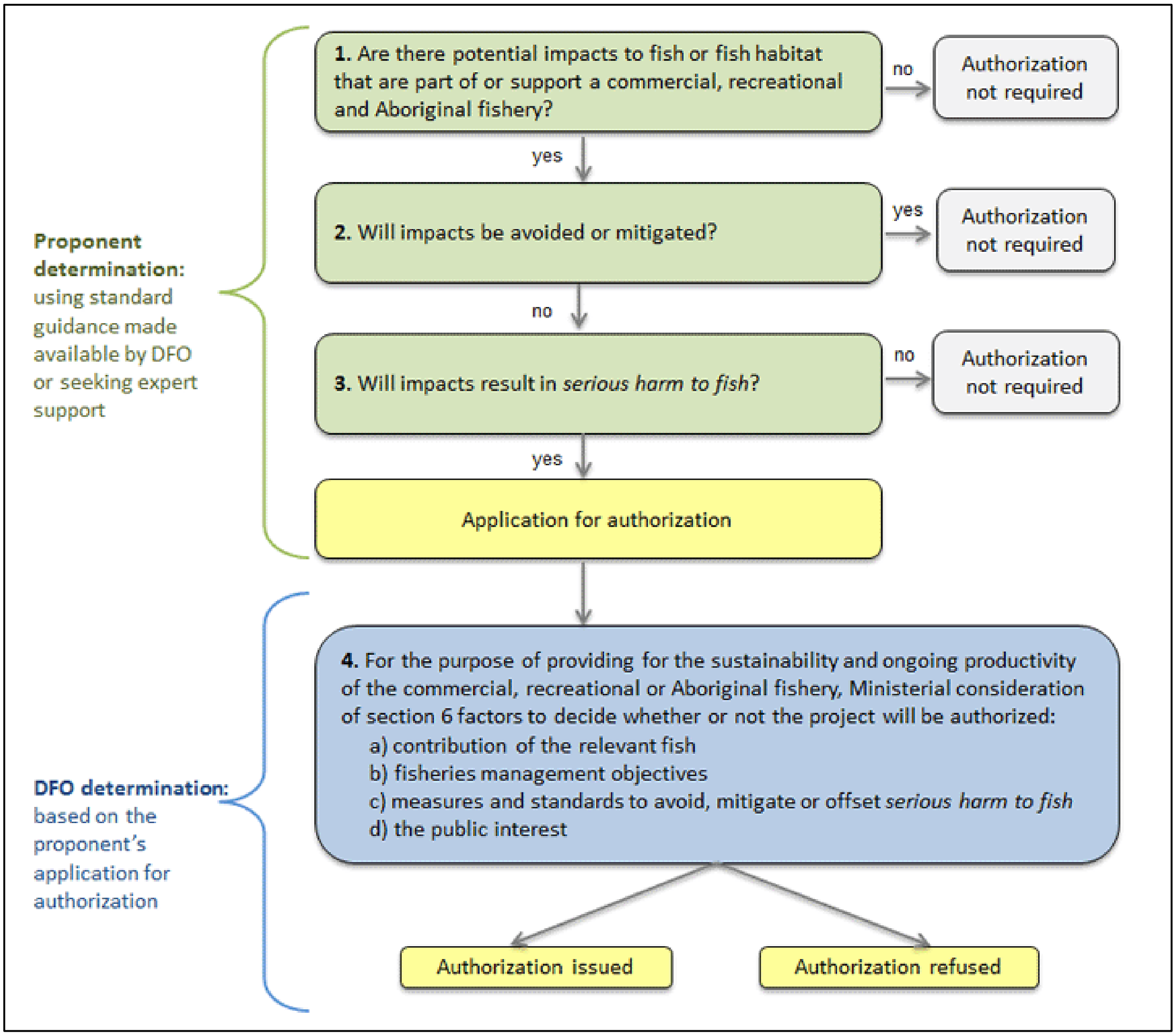

Figure 2. A summary of the development proposal review and decision-making process. (Source: Fisheries Protection Policy Statement, October 2013)

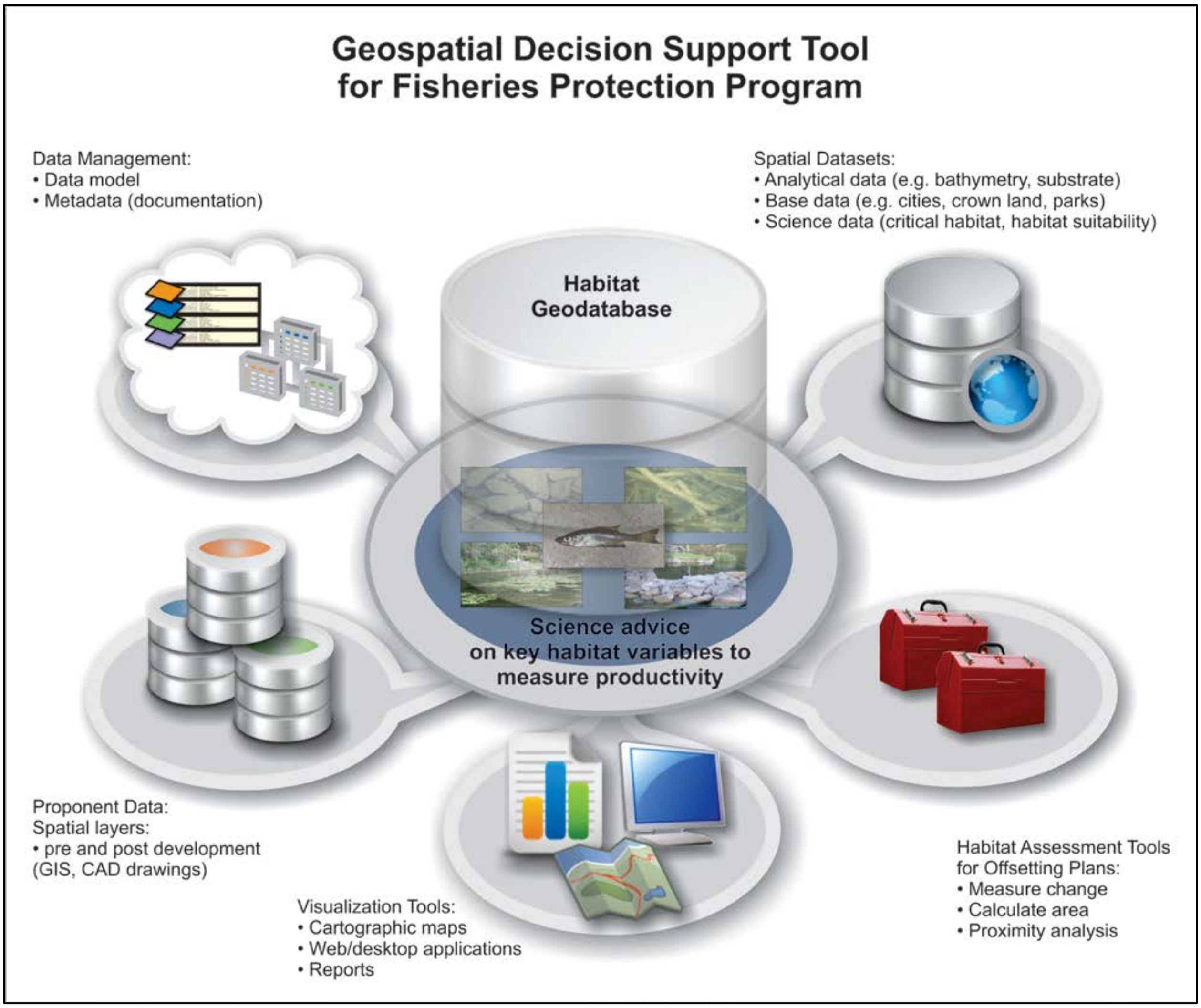

Figure 3. Conceptual model for a Geospatial Decision Support Tool (GDST) for Fish Habitat Assessment. Includes: spatial datasets and tools for data management, habitat assessment tools, and visualization.

POTENTIAL USE OF GIS IN THE FISHERIES PROTECTION PROGRAM REFERRAL PROCESS:

The FPP follows a process in which projects are reviewed for serious harm to fish. All projects submitted are assessed and the risk of the project is reduced by identifying opportunities for avoidance and mitigation. Spatial context is required for the following simplified referral process (Figure 2) steps:

1. Location info for DFO referral
2. Quantify and describe residual serious harm
3. Quantify and describe offsetting plan
4. Monitor

Data regarding fish and fish habitat is often provided by proponents when they submit a proposal to DFO so that the FPP can assess a project's potential impacts. Habitat and fisheries data are often provided to DFO by proponents; however, to improve this process, the data and workflow (including data gathering, storage and use) could be streamlined. This involves standardizing the data and data formats required from, and submitted by, proponents, thus ensuring information needed by FPP to support decisions is readily available. The proposal process would also be expedited by assisting the proponent to focus on important habitat variables acceptable to DFO.

Data can be leveraged by storing them in a common or centralized geodatabase (Figure 3), allowing DFO to build a habitat information ‘library’. Initially, information will be gathered at the site level but, over time, the accumulation of data may permit assessment of impacts and changes at broader scales such as watershed and ecosystem.

Importantly, the GDST would complement the existing FPP's Program Activity Tracking for Habitat System (PATH). It would be linked to the GDST in two ways:

1. PATH contains the metadata for each referral project and the data layers that the proponent provides (linked through the GDST data management architecture)
2. PATH project records can be displayed as a spatial layer ('dots' on the map) and queried using the customized habitat assessment tools as required by FPP.

ROLE OF DFO SCIENCE

DFO Science is integral to the development of the GDST by identifying metrics and indicators (DFO 2012a; DFO 2013b) that are important for measuring the quality and quantity of fish habitat that is required to sustain healthy fish populations and communities. A series of recent Canadian Science Advisory Secretariat Science Advisory Reports were prepared in response to the amendments of the *Fisheries Act* and are relevant (DFO 2014a, b, c). Science has informed the creation of science-based tools (e.g., Habitat Ecosystem Assessment Tool (HEAT), (formerly known as Defensible Methods, Minns 2001) that can be used within the GDST which will allow habitat managers to determine the effectiveness of measures of habitat protection and/or change.

The Science sector will advise the relationship between key habitat variables and fish productivity (DFO 2012a, DFO 2012b, Minns et al. 2001). By doing so, they inform the development of data models that leverage targeted habitat data collection and storage to meet the final goal of maintaining and enhancing ongoing productivity and sustainability of CRA fishes.

GEOSPATIAL DECISION SUPPORT TOOL

A useful Geospatial Decision Support Tool will use a geodatabase framework that offers the user and data managers the ability to:

- Store a rich collection of spatial data in a centralized location
- Apply sophisticated rules and relationships to the data
- Define advanced geospatial relational models (e.g., topologies, networks)
- Maintain integrity of spatial data with a consistent, accurate database
- Work within a multiuser access and editing environment
- Integrate spatial data with other IT databases (e.g. PATH)
- Easily scale the storage solution
- Support custom features and behaviour

- Leverage DFO spatial data to its full potential (ESRI)

Building a GDST for FPP will require participation from the Ecosystems and Fisheries Management (EFM) and Science sectors. Before detailing the technical requirements of GDST, it is important to:

- Understand the DFO business needs (i.e., meet the objectives of the FP Policy).
- Incorporate science advice regarding how to assess productivity and habitat (indicators, metrics, modeling variables).
- Alter the regulatory review process to incorporate digital (GIS) data layers from proponents pre and post development
- Integrate science data and scientific tools to provide evidence-based metrics for productivity applied during referral review and offsetting process

Figure 3 provides a graphical representation of the inputs and outputs of the GDST. At the centre is a container showing the storage and organization of data and tools that allow a user (FPP) to visualize and assess a project thus enabling the decisions required to meet the policy goals. The foundation of the geodatabase is science advice regarding key habitat variables required to measure impacts on productivity and effectiveness of offsetting plans.

These key habitat variables drive each of the other components including:

- Information to be collected by the proponent, and how it will be stored (standardizing type of data, formats, metadata)
- Additional information needed to support the decision-making process (geographic extents, existing analytical data, presence of Species at Risk, aboriginal lands, etc.)
- Scientifically-based geo-processing and reporting tools are required to generate meaningful results or cartographic outputs such as a maps showing impacted area downstream of site based on stream flow and sedimentation.

INPUTS AND OUTPUTS TO THE GDST

Inputs

Data Management

Information required to help inform decisions should be developed within a data management framework. This includes architecture components such as data storage (database, servers) and accessibility (networks, software). Data management also in includes documentation (metadata) of the data sources, contents, constraints and usage. The DFO PATH database can be linked to the GDST providing metadata for referral projects and the ability to generate referral points (as a spatial dataset) in the mapping window.

Data modelling is a key component of the geodatabase framework. Relationships among the data are defined to accommodate subject-specific queries that drive decision support information as output.

Spatial Datasets

Spatial datasets (GIS layers) are the information pieces that comprise a map. Spatial information stored in a geodatabase is unique from information stored in a spreadsheet or document because it is positioned in its 'real world' location. All spatial data, meeting GIS standards, can be aligned with each other thereby giving the user a location-based perspective of the data that exists for that place in the world. There are three types of data that would be incorporated into the GDST:

- Base Data (e.g., stream network, water bodies, legal and watershed boundaries)
- Analytical Data (e.g., bathymetry, flow, substrate)
- Science Data focused on FPP business needs (e.g. critical habitat for species at risk; areas with habitat suitability indices; classified watercourses)

Base data are layers that are usually provided by an agency that is an authority on the subject. For example, the Water Survey of Canada provides watershed boundaries, the Province of Ontario provides stream networks, municipal boundaries, etc. These data provide the spatial context for other data layers.

Analytical data are derived and assembled from "raw" records which are then interpreted to create a single layer or surface. For example, many depth soundings (single points spaced across an area) are interpolated to create a bathymetry layer where a lake is entirely covered with depth information.

Science data are layers that have processed one or more of the above layers to create interpreted information on a specific topic. This usually involved scientific research and study to produce a defensible output. For example, critical habitat polygons are created based on an understanding of the specific habitat needs of a species at risk. The polygons are delineated and saved as a layer to be displayed with the base and analytical data. Science data could also include site level sampling (e.g., points, transects, areas).

Spatial datasets considered to be important in the FPP decision-making process can be stored once and accessed many times (e.g. Species at Risk) within the geodatabase framework. They will also be the reference for future tools that are built into or connected to the GDST.

Proponent Data

During the referral process, proponents provide data to DFO, including spatial data (e.g., project footprint, fish assessment, habitat assessment). It is recommended that these data be provided in a standardized GIS format so they can be incorporated into the GDST.

Site information pre and post project development will allow measurement of change and ability to measure offsetting effectiveness (Machmer and Steeger, 2002) by obtaining a “snapshot” of a site prior to development (e.g., if a project involves infilling a body of water to build a marina, one could spatially measure how much fish habitat will be lost based on an area and depth).

Base data can be improved by incorporating current conditions not captured in existing spatial datasets (which can be dated or captured at a lower resolution).

Outputs

Assessment Tools for FPP

The potential value of the GDST for FPP is the integration of science advice and tools, providing the user with the ability to access and summarize important information required to make repeatable, defensible decisions. For example, the CSAS compensation workshop (DFO 2012a) will provide more guidelines on potential tools that could be incorporated into the GDST.

GDST may include decision support tools that:

- Identify opportunities for potential offsetting sites
- Highlight impacted area downstream of site based on stream flow and sedimentation

- Calculate area of in-stream habitat by user-drawn polygon selections
- Summarize, by watershed, type of offsetting created or the area of habitat impacted (possibly tracking cumulative effects)
- Interactive scenarios to evaluate offsetting options and measure changes e.g., improve quality of fish habitat
- Measure distance (proximity) to sensitive fish habitat, existing offsetting sites, etc.

Visualization Tools

A GDST user will often be required to provide rationale in support of a decision or proposal. This can be done by exporting results of the assessments (above) in the form of maps and reports that are easy to share and interpret. Visualization options are pre-programmed templates that address business-driven needs of the decision-makers and managers. These outputs may include:

- Maps of pre and post scenarios
- Reports identifying key habitat variables and statistics such as total area, habitat features, total habitat lost or gained
- Metadata report (documentation of the project or data layers)
- Graphs or tables of impacts (e.g., percent of watershed impacted by offsetting)

CONCLUSIONS

To meet the objectives of the CSAS compensation workshop (DFO 2012a), a GIS-based geospatial decision support tool is proposed.

By including a data storage framework and decision support tool into the planning of future offsetting activities, DFO would be better able to track offsetting effectiveness. A GDST also provides a mechanism for integration of proponent-collected data and science advice into FPP's decision-making processes by providing a single-window view for:

- Query and view of key habitat variables for effective offsetting identified by Science
- Input and view data from proponents
- Assessment tools customized to meet FPP business needs to quantify habitat change
- Visualization and reporting options to communicate decisions and sound rationale

A Geospatial Decision Support Tool would require a united effort of both the DFO Fisheries Protection and Science programs and would result in improved integration and, ultimately, meet the goals of the Fisheries Protection Policy Statement.

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APPENDIX: DEFINITIONS

Commercial, Recreational and Aboriginal (CRA) fisheries: Commercial, means that fish is harvested under the authority of a licence for the purpose of sale, trade or barter**. Recreational,** means that fish is harvested under the authority of a licence for personal use of the fish or for sport. **Aboriginal,** means that fish is harvested by an Aboriginal organization or any of its members for the purpose of using the fish as food, for social or ceremonial purposes or for purposes set out in a land claims agreement entered into with the Aboriginal organization. (*Fisheries Act* sect. 2(1))

Data management: the development and execution of architectures, policies, practices and procedures that properly manage the full data lifecycle needs of an enterprise. From the perspective of database design, it refers to the development and maintenance of data models to facilitate data sharing between different systems, particularly in a corporate context. Data Resource Management is also concerned with both data quality and compatibility between data models. (Data Management International Association)

Effectiveness monitoring: addresses the question of how successful a project ultimately is at restoring the ecosystem or component parts, relative to its initial goals and objectives. (Machmer and Steeger 2002)

Fisheries Protection Program (FPP): With the amendments of the fisheries protection provisions of the *Fisheries Act* coming into effect November 25, 2013, there was a need for a new Departmental approach to habitat management. FPP was formed to ensure commercial, recreational and Aboriginal fisheries are both productive and sustainable.

Geodatabase: A geodatabase stores GIS data in a central location for easy access and management. It can be leveraged in desktop, server, or mobile environments. It sits on top of a relational database management system, such as SQL Server, Oracle, or PostgreSQL, and supports all types of GIS data. (ESRI)

Mitigation: measures to reduce the spatial scale, duration, or intensity of adverse effects to fish and fish habitat that cannot be completely avoided. (DFO 2013a)

Offsetting: measures to counterbalance *serious harm to fish* by maintaining or improving fisheries productivity after all feasible measures to avoid and mitigate impacts have been undertaken. (DFO 2013a)

Ongoing Productivity: the potential sustained yield of all fish populations and their habitats that are part of or support commercial, recreational or Aboriginal fisheries. (DFO 2013a)

Review Process: The process followed by FPP practitioners to ensure proposed developments are in compliance with the habitat protection provisions of the *Fisheries Act*.

Serious Harm to Fish: The death of fish or any permanent alteration to, or destruction of, fish habitat. (*Fisheries Act* sect. 2(1))

Sustainability: Achieving a balance between the carrying out of current day activities while allowing for future generations of people to meet their needs related to fisheries.