Marine Research Sub-Programme
(NDP 2007–'13) Series

SeaChange
Casadh na Taoide

Compilation of Habitat-Based Catchment Information and Historical Eel Data in Support of Eel Management Plans 'EEL-PLAN'

Project-Based Award, Final Summary Report

Lead Partner: Compass Informatics Ltd

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Sea Change Casadh na Taoide

Marine Research Sub-Programme 2007-2013

Desk Study

EEL-PLAN - Compilation of Habitat Based Catchment Information and Historical Eel Management Plans

(Project Reference: DK/ME/07/006)

Summary Report

Lead Partner:	Compass Informatics Ltd
Partners:	Inland Fisheries Ireland
	National University of Ireland, Galway
Project Duration:	01/02/2008 to 31/09/2009

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1. PROJECT BACKGROUND

Introduction

This project was instigated in response to the decline in European eel (*Anguilla Anguilla)* stocks. Recruitment of the glass eel stage of the European eel has fallen since the 1980s, to about 1-5% of the historical level, and fishery catches have gradually declined to less than half the former level. The International Council for the Exploration of the Sea (ICES) continues to advise that the stock is outside safe biological limits and that current fisheries (and other forms of anthropogenic mortality) are not sustainable (ICES, 2000). Management measures must address all continental life stages of the eel with the specific objective of overall protection of the spawning stock.

Glass eel and elver fishing in Ireland is prohibited by law (1959 Fisheries Act, Section 173) and may only be carried out for the purposes of stock enhancement. Upstream migrating elvers have been captured since 1959 under statute, for transfer upstream around barriers; first on the Shannon, and more latterly on other rivers under the control of the Electricity Supply Board (ESB). The commercial eel fishery involves harvesting both yellow and silver eel in freshwater and in estuarine or tidal waters. The declared commercial eel catch in the Irish Republic (2001-2006) was 100-120tonnes, involving about 150-200 part-time fishermen, but inadequate reporting and illegal fishing made this difficult to quantify accurately. The cash value of the reported catch was therefore some €0.5-0.7 million (DCENR, 2008).

The European Eel Recovery Plan (EU 2007: COM (2005) 472 – final) requires that Member States assess eel populations, at the catchment level, against biological reference points set for silver eel escapement. River Basin District Eel Management Plans (EMPs), to be implemented by 1st July 2009, were central to the assessment. The primary objective of each EMP is to reduce anthropogenic mortalities so as to permit, with high probability, the escapement to the sea of at least 40% of the biomass of silver eel relative to the best estimate of escapement that would have existed if no anthropogenic influences impacted on the stock. Where comprehensive eel data are lacking, the target level of escapement can be calculated using historical datasets, habitat-based assessments of potential eel production and/or with reference to rivers of similar ecology and hydrography.

Eel Management Targets

Conventionally, management targets for fish stocks are set with the aim of keeping or returning the adult spawning stock to a level above that which ensures that the reproductive capacity is not reduced to the point that it is incapable of sustaining itself. Currently, no data exist that allow an estimate of this level for eels—particularly as the proportional contribution of silver eel populations throughout its range to reproduction of the European stock as a whole is unknown—but it is known that the stock is greatly diminished. The European Commission's proposal follows the line of argument and biological logic that fish stocks naturally overproduce eggs and fry and that this surplus is trimmed by competition and predation to fit the carrying capacity of the stock's environment. Carrying capacity is moderated by the availability of life stage-specific habitat, temperature tolerance, food productivity and other factors. It appears that a reduction in spawning capacity of between 30% and 50% will still enable most species to produce to full capacity. The EU target has been set at 40% of the Spawning Stock Biomass.

ICES and the European Commission have taken a pragmatic view that eel production and eel recruitment (*i.e.* spawning success) was fairly stable at historically high levels during the 1950s to 1970s, and the potential production of silver eels (the spawners) at that time would be a useful basis for a biological reference point. The value of a 40% silver eel escapement target is that it can be applied at any scale, provided that the eel population in question has recruits (glass eels, elvers or small yellow eels) and produces silver eels that escape to the sea.

Project Aim and Objectives

The overall aim of the project was to establish an information management framework, a national eel database (EEL-PLAN database) for the development of River Basin EMPs. Eel is widely distributed throughout different habitats, in salt and freshwater, and it seems impracticable to measure or estimate all the parameters in every catchment and fishery within each River Basin District (RBD) (Dekker, 2004). The proposed framework involved collation of base information to assist the publication of the initial national plan (DCENR, 2008) and, importantly, the establishment of an eel Geographical Information System (GIS) and database system for continued information collation, analysis, management and planning. The solution proposed was to develop this interactive GIS-based database which would be used to quantify and aggregate catchments of similar characteristics within each geographical area (area of similar eel recruitment characteristics) and by RBD. The outputs from the database would also be used to determine, from a '*dashboard decision matrix*', the general characteristics of the catchments and the general characteristics of the local stock. This would allow waterbodies to be grouped at an appropriate level, with regard to quality and precision of the data and resulting monitoring effort.

This study was originally conceived as a facility to collate all historical eel data to date to pre-inform fisheries management. However, the project outcomes indicate that the approach used is suitable for ongoing management within the context of future EMPs.

The research objectives of the project aimed to provide an integrated structure through which the national eel management capability would be established and taken forward in line with the objectives set out in the Regulations. Integrated eel management is at an early stage of development. It is anticipated that the technical framework developed through the project can provide a rational basis for this development and support the work of the Government's advisory Scientific Eel Group (SEG).

The EEL-PLAN database will be used to deliver on the objectives of the National Eel Monitoring Programme, which are to:

- Synthesise available information into a model-based management advice tool
- Estimate silver eel escapement
- Monitor the impact of fishery closure on yellow eel stock structure
- Carry out inter-calibration with the Water Framework Directive (WFD) sampling programme
- Compare current and historic yellow eel stocks
- Establish baseline data to track changes in eel stock over time
- Evaluate impedance of upstream colonisation, migration and water quality effects
- Determine parasite prevalence and eel quality

In 2009 the Central Fisheries Board[1] (CFB), now Inland Fisheries Ireland (IFI), was given the national eel monitoring role and will input all eel data into the EEL-PLAN database. Although the national eel management plans were submitted before the completion of this project, the data gathered will underpin the mandatory update report due in 2012. It is, in this regard, that the EEL-PLAN database will reach its full application potential.

The full report including data tables, analysis, evaluation and references is available here:

http://www.marine.ie/home/Publications/Publications/Marine+Research+Sub-Programme+%28NDP+2007-2013%29.htm

[1] The Central Fisheries Board (CFB) along with the seven former Regional Fisheries Boards (RFB) were amalgamated into one single agency, Inland Fisheries Ireland (IFI) on July 1, 2010.

2. PROJECT DESCRIPTION

The aim of the project was to provide a national eel database (EEL-PLAN) that would inform the management of eels in Ireland. Identified components of the database system included:

- information on eels collected prior to 1980; and
- information on the eel habitat variables, both quantitative and qualitative, to enable estimation of production and a system for referencing similar river systems based on ecology and hydrography.

The solution proposed was to develop an interactive GIS-based database that would be used to quantify and aggregate catchments of similar characteristics within each geographical area (area of similar eel recruitment characteristics) and by RBD.

The specific research objectives of the project were to:

1. Collate, digitise and analyse the available published and unpublished historical and more recent eel data as a basis for the National EMP and River Basin Management Plans;
2. Amalgamate catchment habitat data from Inland Fisheries Ireland (IFI), Marine Institute (MI), Environmental Protection Agency (EPA) and RBD Geographical Information Systems (GIS), into a single database to support the modelling of eel stocks on a sub-catchment basis; and
3. Compile a comprehensive eel habitat GIS, as an information framework, building on the existing salmon wetted area habitat quantification model (McGinnity et al., 2003), which would, inter alia, serve to integrate all data, as outlined in the aforementioned Objectives 1 & 2.

Within this research scope, the project deliverables were:

- Provision of a GIS database of sub-catchment lakes, river reaches and transitional waters, providing quantitative data on the presence of natural and artificial barriers
- Inventory of historical eel datasets/publications
- Digitised eel stock database
- Evaluation of acquired eel data against available fisheries models
- Gap analysis of survey data coverage (temporal and geographical) using the GIS database
- Provision of a complete GIS database package of catchment information for eel, to be utilised by IFI and the MI

The project was delivered through four work packages (WPs):

WP 1 – Eel Management GIS

WP 2 – Eel Stock and Fisheries Data

WP 3 – Information Gap Analysis

WP 4 – Eel System (Catchment) Evaluation

WP1 - Eel Management GIS

Eel management is required to integrate with other fisheries and water management initiatives with particular reference to the Water Framework Directive (WFD). An important objective of the project was to capitalise on and augment the national WFD GIS framework. The project used the standard WFD GIS definition of water bodies (river, lake transitional and coastal). As an extension to the WFD, the project devised a scheme of Eel Water Management Units (integrating connected freshwater and marine waters) which form a logical extension of the existing IFI freshwater salmon management units (McGinnity et al., 2003). These eel and salmon systems fit within the RBD and Fisheries Districts.

A key objective of this WP1 was to develop a formal eel survey database management system. This database would integrate eel stock survey data against a standard template of base GIS data (in particular, national registers of river, lake and estuarine water features); allow catchment based assessments of such survey data; perform habitat and accessibility assessment on a catchment basis; and provide tools for the reporting and mapping of the data.

The salmon habitat assessment (McGinnity et al., 2003) was expanded to include transitional waters and first order streams. In addition, lake habitat along the river network and habitat in isolated standing waters was partitioned. Each of these expansions has increased the quantity of potential eel habitat in Ireland compared to that estimated in the salmon habitat assessment.

The initial specification of the database was obtained through liaison between MI, IFI and National University of Ireland Galway (NUIG) and analysis of the content being collated on eel stock and fisheries characteristics. This established a three tiered hierarchical structure of the principal database components:

- Survey Sites (Table Sites)
- Survey Activities performed at the Survey Sites (Table Survey)
- Specimen Characteristics and other parameters obtained through the Survey Activities (Table Survey Sample)

WP2 - Eel Stock and Fisheries Data

The objective of this WP2 was to identify, extract and collate eel distribution, eel population and, primarily, individual eel data, from all available sources for incorporation into the EEL PLAN database. Individual eel data (especially length, weight, age and growth) were identified as potentially key components for modelling into the future. Various potential data sources were identified:

- Published and grey literature
- Data from historical fisheries
- Historical eel survey data including existing or developing IFI and MI databases

Published and grey literature

A comprehensive search identified numerous eel related publications and reports within IFI and MI, mainly emanating from the Fisheries Research Centre[2] (FRC). An extensive literature list was compiled and reviewed dating from 1909 to the present. Vast amounts of survey data were collated from numerous MI raw data files, digitised data from long-term MI studies on the Burrishoole system, and the extensive digitised dataset from the Northern Regional Fisheries Board-led Erne eel survey. These data were standardised for incorporation into the EEL PLAN database.

Data from historical fisheries

From the outset of this project, the potential value of long-term consistent eel survey or commercial datasets, to investigate population trends, was recognised. Descriptions of the historical fisheries by individual Fisheries District are presented in the main report. All available commercial data was incorporated into the database.

Historical eel survey data

For the purposes of the report, historical data were defined as data collected up to and including 2000. The literature review highlighted significant numbers of eel-specific research surveys carried out by the FRC commencing in the 1960s. A significant archive of supporting raw data sheets relating to these FRC survey reports and published papers spanning 40 years of work on eel research was unearthed. Site specific individual eel length, weight, sex and age data were recorded on the majority of the data sheets, together with sampling locations, effort and other relevant data. This extensive body of data was catalogued and data from systems/areas surveyed, including important fisheries such as the Shannon, Fergus, Blackwater, Corrib, Erne, Ballysadare, Garvogue, Barrow, Laune, Kenmare and the Nore, were

[2] Fisheries Research Centre (FRC) has since been incorporated into the Marine Institute (MI)

incorporated into the EEL PLAN database. All MI data on eels from the Burrishoole system, and all available raw data provided by NUIG for the Lee and Dunkellin catchments, were input.

The CFB had been collecting fisheries survey data from rivers, lakes, canals and transitional waters in Ireland for over 40 years. Up to 1980, this data, mainly from surveys of lakes for trout or coarse angling quality, was conducted by the Inland Fisheries Trust (IFT, now IFI). Fyke netting was undertaken in the course of the IFT surveys, particularly in coarse fish lake surveys, and this generated some useful eel data. Electrofishing surveys were also carried out during this period, mainly in the larger limestone trout rivers. Since 2000, all electrofishing surveys conducted by CFB have captured eel data and have provided high quality distribution and some length frequency data which has been incorporated into the EEL PLAN database. Allied to this, extensive monitoring of all fish populations in lakes, rivers and transitional waters by the CFB, which began in 2006 under the EU WFD, has begun to contribute significant added value to the national eel monitoring programme, which commenced in late 2008. The raw data from the 1998 – 2000 Erne Eel Enhancement Programme (Matthews et al., 2001) was also made available.

All of these survey sites were digitised and locations assigned in the EEL PLAN database.

Metadata

An important part of the EEL PLAN database was the creation of a metadata report. Metadata is an essential component of data management planning, and allows end users to both discover and use datasets which have been compiled by third parties.

Each dataset referenced in the database is described by a metadata record which is contained in a catalogue. The metadata complies with the ISO 19115 standard.

Two metadata reports have been built into the database to extract the relevant details into a report format: one report relates to the biological data; and the second report relates to the fishing authorisation data contained in the database (please refer to Appendix III). The relevant information includes outlining the sources of the data, its published status, ownership, data type and quantity. These metadata reports will reside with the database on the server. Reports will be generated, date stamped and stored to record database status at given times.

Data Quality and Query Creation

To extract data from the database, queries were created. The database queries were structured on a hierarchical basis with the lowest level being the **'Sites Level'** with the queries relating to survey work that was carried out at a particular site over a given time period. If repeat surveys were carried out at a particular site, an average value was reported.

The next level is the '**Lake Level'** where all sites located within a lake and in a given time band are averaged to give one answer to the query.

The other levels which will include data from rivers, lakes and transitional waters are the **'Catchment level**', **'Eel Systems'** (for example, the Suir, Barrow and Nore catchments are connected through one transitional waters and as such should be analysed together), '**River Basin District'** (to be compatible with the WFD) and **'Fisheries District'**. The Fisheries District is based on the Regional Fisheries Boards Districts which is how the commercial data has been reported.

The intervals used for the queries related to the best estimate of when the decline of eels commenced. The site and lake level queries are based on four temporal intervals:

- Pre 1980
- 1980 – 1989
- 1990 – 1999
- Post 2000

The higher level queries (catchment, eel system, RBD, Fishery District) used two temporal intervals:

- Pre 1980
- Post1980

WP3 - Information Gap Analysis

The objective of WP3 was to provide a mechanism to inform management and scientists on the availability and quality of habitat and eel data on an individual catchment basis as collated during the project. It was designed to provide a rational basis to make recommendations on further data requirements and provide a framework on which to base EMPs.

Excesses or deficiencies in data, as determined from gap analysis, are temporal or spatial. For this study five key query outputs were tabulated. At the catchment level, the queries related to sampling intensity for electrofishing, fyke netting, length structure, age structure and *Anguillicola crassus* for the pre- 1980 and post 1980 periods.

To make the analysis available for expert analysis, an internet-based map system or 'dashboard' was developed that provided two principal facilities:

- a synopsis of the habitat (WP1) and eel stock (WP2) data on a catchment basis
- access to the individual eel stock surveys

Specific design objectives of the dashboard system were:

- to provide access over the internet without the requirement for database and GIS software facilities
- to provide an intuitive interface which removes the requirement for the user to have specialist technical skills

The next step was to determine from the 'dashboard decision matrix' (Figure. 3.2, Section 3), the general characteristics of the catchments and the general characteristics of the local stock, an example of which had been demonstrated previously in the EU INTERREG III Indicang[3]project. This allowed waterbodies to be grouped at an appropriate level, with regard to quality and precision of the data and resulting monitoring effort.

WP4 - Eel System (Catchment) Evaluation

To date, there is no standardised method for estimating eel productivity and silver eel escapement. However, there are a number of models available in the literature, for example, Senario Based Model for Eel Populations, (SMEP), a length and age structured demographic model for European eel populations (DEMCAM), Reference Condition Model (RCM) and others. The various models differ in the type of data required and their relative emphasis on the importance of biological and geographical data. In WP3 the meta-dataset was evaluated to determine its capacity to support stock assessment of eel in Ireland. This project may ultimately be a precursor to the development of a specific eel model for Ireland and possibly fit any future EU standard modelling approach.

The project reviewed the available models to identify the relative importance of various parameters for both process and associative modelling. This review provided a scoring scheme that weighted each parameter according to its apparent importance for modelling in general. The database was examined spatially and temporally (pre and post 1980) at the catchment scale to evaluate the ability of the local data to support eel stock assessment. This review process identifies knowledge gaps in the database in terms of the type of data available

[3] Indicang - INDICateurs d'abondance et de colonisation sur l'ANGuille européenne *Anguilla anguilla*

and its spatial or temporal distribution. Importantly, the gap analysis and model evaluation informed the content and distribution of future monitoring programs.

Data modelling consists of exploring data-oriented structures to produce dynamics within a dataset which can, in turn, be extrapolated between discrete datasets (for example, from data-rich to data-poor eel catchment datasets). It is at catchment area, or waterbody level, where an estimate can be made of: the production of silver eel from the data available; and also to model the effect of management actions on the escapement target; or the impact of improvements to the environment on the carrying capacity of the different water masses (coastal lagoons, estuaries, continental areas, lakes). It seems reasonable to define a number of representative index, data-rich water bodies, similar to the approach adopted within the past decade for salmon management in Ireland.

For the other systems, it seems reasonable to establish a potential estimate of the silver eel production according to the characteristics of the environment, the eel stock and the fishery by using the transfer of stock characteristics from the index systems to other catchments. Such data transfer should be validated by local 'spot check' monitoring of stock and fisheries.

Eel productivity and silver eel escapement models fall into two major classes: **process models and associative models.** Process models attempt to predict population dynamics by integrating the effects of biological parameters such as natural mortality and growth. Associative models simply aim to establish a relationship between a given measured parameter (usually density) and environmental or anthropogenic factors. It appears most appropriate to assess the quality of the current EEL PLAN database for modelling purposes in general terms. Therefore, the parameters required by each process model and the biological data that is normally used to calculate each of those parameters was listed (please refer to Table 1 Appendix IV). It is, of course, possible that a given source of biological data might be used in the calculation of several parameters. A simple scoring scheme was developed by counting how frequently a given source of biological or geo-environmental data was required by the seven process based models reviewed. The process models reviewed are listed in Appendix II.

The associative models treat population dynamics as a black box and simply search for geo-environmental variables that may be related to variation in a measured (normally proxy) biological parameter. The associate models reviewed are also listed in Appendix II.

The outcome of this review is presented in Section 3.

3. Results and Outcomes

This project has delivered a GIS database of waters and habitat descriptors and associated database of eel population information based on the collation and analysis of available historical eel survey data together with an eel meta-database. The data were reviewed using the tools (defined queries and gap analysis) created within the database framework. A series of specific recommendations to enhance the operating procedures and develop the overall system and make the workflow, from survey collection through to analysis, assessment and reporting, more cost-efficient and effective are presented in Section 4.

Eel Management GIS

The GIS has been developed with a modular structure that reflects the requirements of the other project work packages. It contains 3 principal elements:

- the core of the system is provided as an ESRI ArcGIS (version 9.3) ArcMap Document. This contains custom modifications that perform specific functions for eel management.
- a web map interface (Google Maps) that displays the 269 eel catchment systems identified in the Republic of Ireland and shared cross border catchments. This can be accessed by non expert GIS users as a web resource from different locations. It presents important historical summary data (geographical and eel survey statistics) on a per catchment basis and the ability to visualise and generate reports for eel survey sites.
- integration of the GIS with a standalone SQL Server database of historical eel survey data (WP2). This facilitates gap analyses (WP3), reporting and system evaluation modelling (WP4).

The Eel Management GIS is built to be compatible with other related national water management systems, in particular, the WFD GIS used by the EPA and the Local Authorities. The central element of the WFD GIS is the standard definition of water features – both geographical dimensions and reference codes.

The Eel Management GIS is also designed to support information capture (field surveys), GIS and database analyses (assessment of geographical, environmental and biological factors) and reporting functions (from ad hoc queries to Management Plan support). These functions are considered to form the core of an IT system suitable for eel management.

The quantitative estimation of eel habitat availability, an important output from the project, is based on a two stage methodology. The first stage estimates the habitat on an individual feature basis (lake, transitional water or river segment (inter-confluence reach) basis). The second stage aims to determine the location of obstructions (artificial or natural) that may provide barriers to eel movement along the river systems. Currently the location of such barriers is not well known or recorded. To facilitate quantification of eel habitat in the future a GIS Tool has been developed (Barrier Manager) to allow recording and placement of potential eel obstructions and calculation of inaccessible habitat.

The CFB (2003, 2007) models to predict river channel wetted width exclude first order streams as these are largely non utilised by salmon. However, these have been included in the estimation of gross habitat for eel. The Barrier Tool provides an efficient method to record the distribution of obstacles to the movement of various species.

It is understood that the habitat utilisation by eels is opportunistic and this posed issues for quantification of eel habitat. Four specific approaches have been adopted and implemented in the GIS to quantify habitat:

- the geo-chemical signature of the waters arising from the geology in the catchments
- the complexity of the shoreline of lake and transitional waters
- the proportion of transitional waters shoreline open to the outer marine environment and aspect direction
- the relative distance of lakes and river reaches from the marine boundary

The project ran concurrently with the planning period laid down by the EU for the preparation of EMPs. Baseline information generated by the project provided important data for the national process of preparing EMPs. In some cases these data were used to populate the models for data rich catchments and also enabled an estimation to be made for data poor catchments.

Eel Stock and Fisheries Database content

The EEL PLAN Stock database contains in excess of 8,000 sites (Please refer to Figure. 3.1), over 16,000 individual surveys and statistics for 70,000 individual eels. These sites are widely distributed nationally. Of the 16,000 surveys entered, 10,856 were fisheries dependent surveys and 5,916 were fisheries independent surveys (Table 3.1), carried out by various organisations/agencies (Table 3.2). 70,055 individual eel length measurements (cm) were entered into the database spanning from the 1960s to 2008. Age, sex, maturity status and parasite (*Anguillicola crassus*) data were also entered.

Table 3.1 Division of surveys between fishery dependent (commercial data) and fishery independent surveys (research data).

Datasource	Number of Surveys
Fisheries dependent surveys	10,856
Fisheries independent surveys	5,916
Not recorded	90
Total	**16,862**

Table 3.2 Number of surveys attributed to the main organisations involved.

Organisation	Number of Surveys
Erne Eel Enhancement Programme (NRFB)	5,390
Central Fisheries Board	4,420
Regional Fisheries Boards	3,030
Fisheries Research Centre	2,144
Marine Institute	1,442

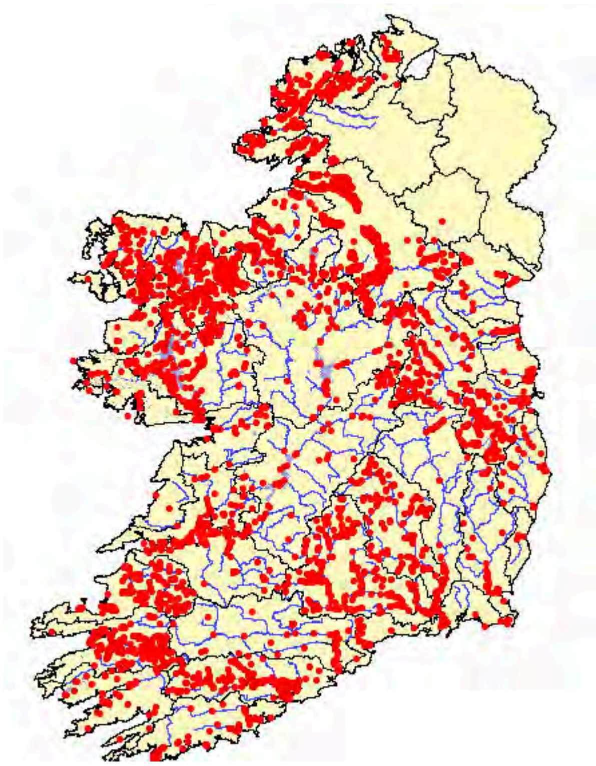

Figure 3.1 Distribution of survey sites in the historical eel stock database

Query Creation and Data Quality

The initial queries were created to provide a general overview of database content and to evaluate the key biological information[4]. Only electrofishing and fyke net survey data were used in the queries as these represent the majority of survey methods in the database.

Data quality is defined by the availability of total sampling or fishing effort, or where the survey is deemed 'eel-specific' in the target species field in the case of electrofishing. Fyke net surveys which reported detailed effort data (number of nets and net nights) were considered high quality. Data from other capture methods (for example, coghill nets, baited pots, V-wing fykes) were not supported by sufficient detail regarding sampling effort (number of units or time fishing) and are considered lesser quality. Insufficient longline data were available to the project to consider this methodology for generation of high quality data outputs. Effectively, only eel-specific electrofishing and detailed fyke net sampling are regarded as sources of high quality data at this time.

The queries allowed the high quality data to be analysed together (for example, fyke net surveys that did not record number of nets and number of nights are not captured in the query). Quantitative electrofishing surveys that recorded the number of passes and number of electrofishing units are analysed together. This quality filter ensured that only good quality data is extracted and used in the analyses. Where full survey details were not available, a presence/absence query was created to determine the distribution of eels within a system but not the density.

The queries included:

- Presence /Absence of eels (electrofishing survey)
- Minimum Density (electrofishing survey)
- Total Catch (electrofishing survey)
- Catch per Unit Effort (Fyke net survey)
- Length Distribution Frequencies
- Age Distributions
- Growth
- Abundance of *Anguillicola crassus*
- Intensity of infection

[4] For further detail on eel database queries, please refer to Appendix VII of the main report available here: http://www.marine.ie/home/Publications/Publications/Marine+Research+Sub-Programme+%28NDP+2007-2013%29.htm

- Prevalence of *Anguillicola crassus*

The database is a living entity which will evolve as the National Eel Management Programme proceeds. When data are added to the database the queries will require expansion and new queries will have to be created.

Gap analysis

The dashboard matrix was one of the key outputs from the EEL PLAN project (Figure 3.2).

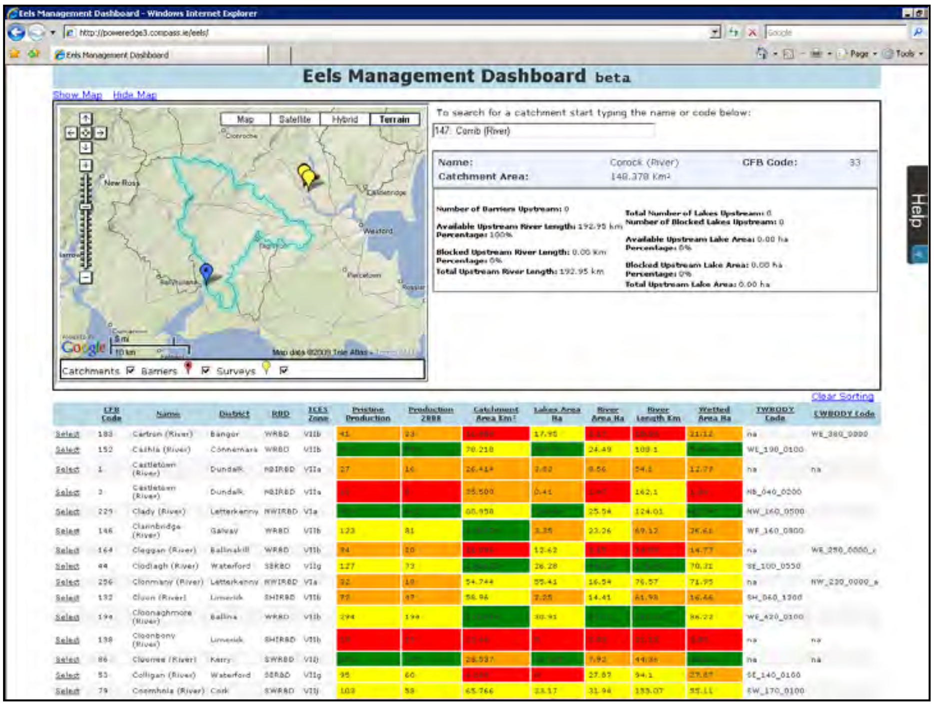

Figure 3.2 Catchment Dashboard Interface

Apart from providing an accessible platform for quality and precision level grouping of catchment data, it will serve to drive the monitoring programme where gaps are identified. The perspective on these issues within the project has been considerably assisted through interaction with an external advisory group. The technical framework developed through the project can provide a rational basis for this development and support the work of the Government's advisory Scientific Eel Group (SEG).

System Evaluation

It is accepted that modeling will be required to transfer estimates of pristine (pre 1980) and current silver eel production, to allow comparisons to be made between systems and overall production, from data-rich to data-poor systems. Some approaches have been outlined by the ICES Working Group on eels which complements those presented in previous working groups and in EU SLIME[5] (ICES 2008), however, the science is still evolving. One major project, EELIAD[6], aims to integrate and take advantage of significant recent improvements in techniques such as animal tracking, genetics and advanced modeling. The techniques will be combined in a large-scale field programme that will run between 2008 and 2011 and will be linked to studies and observations undertaken in other research and monitoring projects in freshwater and brackish environments to enable a comprehensive understanding of the life-cycle of eels to be developed.

It is unlikely that data coverage will be sufficient in the near-term to estimate population dynamics in all catchments from the assessment of survey data. This fact is well recognised in the National EMP, where an emphasis is placed on the extrapolation of estimates from a limited number of index catchments. The project has progressed the development of modelling methods and also leaves a legacy of novel GIS derived metrics so that the combination of geographical and environmental factors can be explored further. Preliminary GIS metrics from the project have already been used in the first National Eel Management Plan.

Eel productivity and silver eel escapement models fall into two major classes: **process models and associative models.**

System evaluation identified only one catchment, the Shannon, where all relevant data types are available for the ***process models*** in the post-1980 period[7]. The important 'Total Commercial Catch' data were not available at the catchment level for the majority of catchments. The top four scoring catchments post-1980 in terms of the application of process models are the Erne, Corrib, Srahmore and the Moy. These catchments are the index sites used in the management plans and were monitored intensively in 2009 under the national eel monitoring programme.

For this project it was decided to use the top three ranked basin scale descriptors to determine if the data in the database could be applied to the ***associate models***. The three parameters were density, barriers, and distance to sea (Please refer to Table 3.3). While density and distance to the sea are available, the barrier data available to date is not sufficient to assess production of eels in a system.

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[5] SLIME: Study Leading to Informed Management for Eel
[6] EELIAD: European Eels in the Atlantic: Assessment of their Decline
[7] For more detail on the process model evaluation, please refer to Appendix X of the main report available here: http://www.marine.ie/home/Publications/Publications/Marine+Research+Sub-Programme+%28NDP+2007-2013%29.htm

Table 3.3 Date requirements for the associate models

Data type	Models reviewed (coding below)	Count
Eel density (relative or absolute or presence absence)	1,2,3,4,5,6,7	7
Obstructions (where located in downstream reaches of catchment)	1,2,3,5,7	5
Distance to sea	2,4,5,6,7	5
Geographical area	1,5	2
Habitat Quality	2,5	2
Temperature	2,5	2
Lakes (downstream)	1	1
Land use type	1	1
Depth	4	1
Flow velocity	4	1
Cumulated river length upstream	5	1
River width	5	1
Strahler rank/ Shreve index	5	1
Altitude	5	1
Electrofishing method	5	1
Gradient	1	1
Discharge	1	1

4. Recommendations

Given the imperative behind eel stock assessment and management it would be very worthwhile to further the achievements of the project through the implementation of a series of consolidation activities. The project presents recommendations for the establishment of some standard operating procedures and system development tasks which could make the workflow, from survey collection through to analysis, assessment and reporting, more cost-efficient and effective.

An extensive list of recommendations has been outlined below but two priorities emerged from the study which are:

- A multi species assessment of barriers on Irish rivers should be undertaken. This body of work would be of significant benefit to a number of EU and national programmes such as the WFD, Habitats Directive, Salmon Management and the Eel Monitoring Programme.
- A vast quantity of eel biological data was unearthed over the course of the study but, due to time constraints, much of this data is yet to be digitised. A user-friendly data entry interface should be developed for the NDP Eel Database to ensure the digitisation of the remaining historical data in addition to the current data being collected under the National Eel Monitoring Programme. The inclusion of contemporary data will enhance the utility of the database to adequately indicate the temporal and spatial nature of the eel stock.

The quality and quantity of data available for some well-studied catchments serves to reinforce the paucity of data in many catchments. Over time this can be mediated through the collection of further data, as identified in the gap analysis and model evaluation, and through targeted survey effort. Several key recommendations that will improve the efficiency of eel management assessment and planning emerged from this project. It is hoped that these recommendations will be delivered under the National Eel Monitoring Programme. The recommendations are:

1. To continue collation/collection of historical and new data

- **Ongoing data entry** - substantial quantities of additional historical (for example, ESB data and other recently retrieved data) and current data are required to be entered into the database.

***Recommendation**: a comprehensive, user-friendly data entry interface should be developed to allow for rapid and quality assured data entry. New sites should be entered using the yet to be developed GIS Survey Site Manager Tool to ensure efficient and accurate site placement.*

- **Eel condition quality -** the quality of downstream migrating eels should be examined to determine their ability to complete the spawning migration.
  ***Recommendation**: Parasite loadings, fat content and general condition of silver eels needs to be monitored.*

- **Standard reporting format for commercial fisheries –** data quality from the commercial fishery was non-existent or poor.
  ***Recommendation**: if the commercial fishery re-opens, a standard reporting format should be developed, similar to that being used for salmon catches, to allow for accurate reporting of eel catch statistics.*

- **Repeat key historical surveys -** high quality pre1980 surveys were carried out by FRC (for example, Lough Derg) and CFB (for example, Boyne).
  ***Recommendation**: these and similar surveys should be repeated to provide current assessments and quantify the decline in eel stocks*

2. To use the gap analysis decision matrix to target future survey effort

- **Transitional water and coastal embayment habitat use -** transitional waters (both large and small) and coastal embayments may provide the potential for significant eel production
  ***Recommendation:** several strategically located transitional waters and embayments should be surveyed.*

- **Glass and Elver Life stages –** the eel has a complex lifecycle and it is difficult to monitor all life stages and understand the variations in abundances arising from environmental factors. The current database is lacking in the glass eel and elver stages.
  ***Recommendation:** to counter this deficit a long term glass eel and elver monitoring programme should be undertaken in the Corrib catchment to complement existing long-term datasets for the Shannon and Erne systems.*

3. To develop a Standard Operating Procedure for the field collection of barrier information and enter the data to the GIS with the new Barrier Management tool

- **Identification of obstacles to eel migrations (barriers) -** the distribution of obstacles to eel along river courses is not well known or recorded. This project has developed a GIS Barrier Management Tool to record these features which could be most cost-effectively delivered under a number of existing work programmes (for example, WFD, Habitats Directive, catchment-wide electrofishing and IFI salmon spawning assessments).
  Recommendation: *develop a standard operating procedure to record and describe eel obstacles. The roll-out of any targeted national eel barrier survey should be targeted on a priority eel catchment basis (for example data-rich catchment).*

- **Distribution of Eels in relation to barriers -** interrogation of the database showed that eels are widely distributed in Irish catchments.
  Recommendation: *detailed analyses of barriers for eels (at different life stages) recorded through field surveys should be undertaken to refine the understanding of effective habitat utilisation.*

4. To integrate GIS analysis with cross-linkages with other environmental programmes

- **Integrate and utilise linked environmental databases -** additional GIS based analysis of historical and current environmental variables are available from organisations including EPA, IFI, National Parks and Wildlife Service (NPWS), Office of Public Works (OPW) and Coillte.
  Recommendation: *all relevant databases should be integrated into the analyses to provide a comprehensive analysis of national eel habitat.*

5. To enhance data analysis methods

- **Transitional water residency –** eels may reside permanently in transitional waters or migrate between these waters and freshwater. Studies on the microchemistry of otoliths in eels taken in transitional waters will provide quantitative data on residency periods.
  Recommendation: *retain samples of eel for microchemical analysis of otoliths and supplement this with tagging studies to monitor movement between freshwater and transitional waters.*

- **Eel stock database analysis -** scope exists for a detailed analysis of the eel length, weight, age and parasitology data within the database and their potential relationships with the novel GIS variables which have become available through this study.
  Recommendation: *undertake the analysis to determine how these physical GIS variables relate to eel biology and use the results to refine any subsequent modelling.*

- **'Eeliness' (habitat suitability)** – the database will allow the determination of the relative suitability, based on the interplay of physical, environmental and biological factors, of habitat on a catchment or eel system specific basis. This would allow for the identification of similar systems, based on ecology and hydrography, and for the application of productivity estimates from data-rich to data-poor systems.
  Recommendation: *undertake the analysis to determine how these physical GIS variables relate to eel habitat suitability and explore the potential to apply estimates from data-rich to data-poor systems.*

- **Modelling -** it is necessary to be aware of developments in the modelling environment as it will not be feasible to sample all catchments and modelled estimates of production will have to be applied. Cognisance of the shortcomings within models and the available data within the project led to the application of an interpolation approach which may prove applicable in the future.
  Recommendation: *the use of 'Ordinary Kriging nterpolation along River Networks' (Please refer to Appendix V) should be pursued as, for example, it may facilitate assignment of predicted density values to connected fluvial reaches in the system within a defined distance. Other developments in the eel modelling field should be closely monitored.*

5. References

DCENR (2008). *National Report for Ireland on Eel Stock Recovery Plan, Including River Basin District Eel Management Plans*. Department of Communications, Energy and Natural Resources.

Dekker, W. (2004). *A procrustean assessment of the European eel stock*. ICES Journal of Marine Science, 57; 938-947.

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Appendix I: Eel Management Systems Development Concept

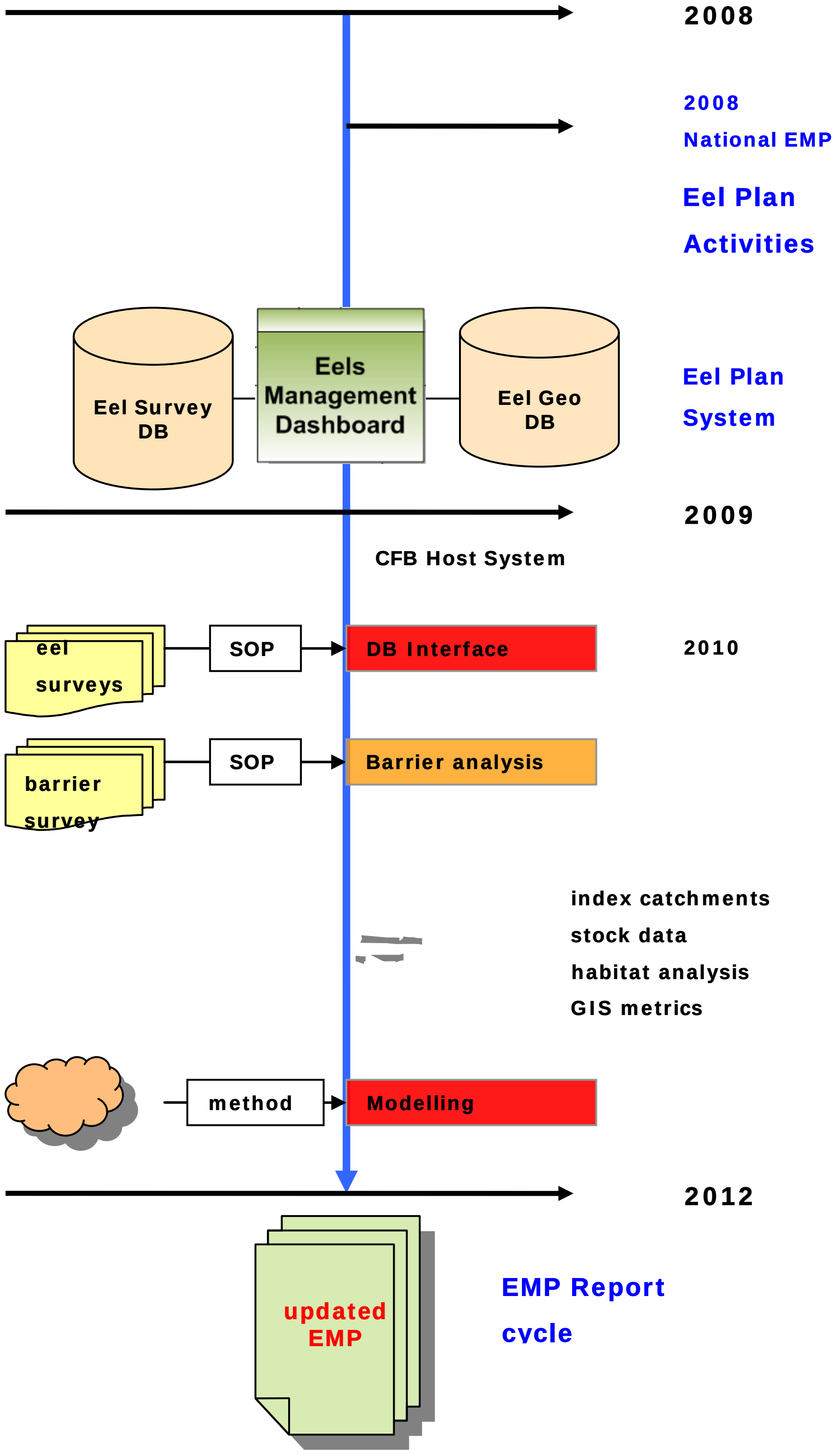


Figure 1: Eel Management Systems Development concepts

APPENDIX II: MODELS REVIEWED

Process models reviewed

- The Irish stock assessment suite of models (IRMOD, Ó Néill and Poole 2008) was developed to project the impact of various management measures on compliance with the EU eel regulation;
- SMEP simulates population dynamics between undifferentiated eels, male and female yellow eels and silver eels across four seasons and for each reach within a catchment;
- DEMCAM covers the continental stage of the eels life cycle from recruitment to migration and defines the eel stock and the harvest structured by age, length, sex and maturation stage on an annual basis;
- GLOBANG simulates eel population dynamics within a hydrographical network and integrates the main biological processes of ageing, recruitment, sexual differentiation, silvering, natural mortality and movement;
- SWAM adopts a very simple female-only stock assessment that assumes constant mortality rates, growth rates and length of spawners;
- LVPA is a standard Virtual Population Analysis model as routinely applied in marine fish stock assessments adapted for length structured data;
- GEMAC investigates how glass eel fisheries and intake pumping affect the number of settled glass eels per area in a specified estuary

Associative models reviewed

- Aprahamian, M. W., Walker, A. M., Williams, B., Bark, A. and Knights, B. 2007. *On the application of models of European eel (Anguilla anguilla) production and escapement to the development of eel management plans: the River Severn*. ICES Journal of Marine Science 64: 1472-1482
- Ibbotson et al., 2002. *Colonisation of freshwater habitats by the European eel.* Freshwater Biology 47: 1696-1706.
- Laffaille et al., 2005. *Temporal changes in European eel stocks in a small catchment after installation of fish passes.* Fisheries Management and Ecology 12: 123-129.
- Laffaille et al., 2003. *Spatial Organisation of the European eel in a small catchment.* Ecology of Freshwater Fish 12: 254-264.
- Hoffman et al., 2008. *Working paper presented in:* ICES, (2008). *The report of the 2007 Session of the Joint EIFAC/ICES Working Group on Eels. Bordeaux,* Sept. 2007; ICES CM 2007/ACFM;23.

APPENDIX III: METADATA PROFILE

Metadata profile for the National Development Plan Eel Database – Biological Survey Data

Analysis of the requirements set out by the INSPIRE Directive, ISO Standards and OGC Specifications the following ISO elements will be used to catalogue surveys (not including purely commercial) datasets included in the NDP eel database:

- Dataset Title
- Data Type
- Topic Categories

Responsible Party

- District
- Catchment
- Date
- Dataset Abstract

Keywords

Dataset Character Set

- Dataset Language. – English
- Dataset Distributor. = CFB
- Dataset Format. = SQL
- Dataset Lineage
- Metadata Point of Contact
- Metadata Date Stamp
- Reference System
- Spatial Scale/Resolution
- Spatial Representation Type
- Full Metadata Record**
- Access Constraints
- Online Link

*** Please note that the user is not required to create this element as this is handled by ISDE metadata browser software.*

Metadata profile for the National Development Plan Eel Database – Commercial Authorisations Data

Analysis of the requirements set out by the INSPIRE Directive, ISO Standards and OGC Specifications the following ISO elements will be used to catalogue Commercial Authorisations included in the NDP eel database:

- Dataset Title
- Data Type
- Topic Categories

Responsible Party

- District
- Date
- Dataset Abstract

Keywords

Dataset Character Set

- Dataset Language
- Dataset Distributor
- Dataset Format
- Dataset Lineage
- Metadata Point of Contact
- Metadata Date Stamp
- Reference System
- Spatial Scale/Resolution
- Spatial Representation Type
- Full Metadata Record**
- Access Constraints
- Online Link

*** Please note that the user is not required to create this element as this are handled by ISDE metadata browser software.*

APPENDIX IV: DATA REQUIREMENTS FOR PROCESS MODELS REVIEWED

Table 1: The data requirements for the process models reviewed (grey=required)

		IRMOD	SMEP	DEMCAM	SWAM	LVPA	GLOBANG	GEMAC
Recruitment	Recruitment series			I	I		I	
	Recruitment numbers		I		I		I	
Natural mortality	Length	I	I	I	I	I	I	I
	Sex	I	I	I	I	I	I	I
	Age	I	I	I	I	I	I	I
(Fishing mortality)	Total catch	I	I	I	I	I	I	I
	Catch structure	I	I	I	I	I	I	I
	Fishing effort	I	I	I	I	I	I	I
Biomass	Weight	I				I	I	
Growth	Age	I	I	I	I	I	I	
	Length	I	I	I	I	I	I	
Maturation	Age	I		I			I	
	Stage	I	I		I	I	I	
	Length	I	I	I	I			
	Sex		I	I		I	I	
Differentiation	Recruitment numbers				I			
	Length						I	
	Sex				I		I	
Stock structure	Length	I	I	I	I	I	I	I
Density	Relative density		I					
Dispersal	Dispersal speed		I				I	I
Carrying capacity	Density/biomass		I				I	
	Recruitment numbers		I				I	
GIS	Wetted area	I						
	GIS linked river reaches		I				I	
	Distance to sea		I				I	
	Barriers	I	I					
	Salinity flow temperature							I
Anthropogenic impacts	Total catch	I	I	I	I	I		I
	Catch structure	I	I	I				
	Fishing effort			I				I
	Fishing mortality						I	
	Stocking		I					
	Barriers	I	I					
	Hydropower mortality	I						I
Silver Eel Output	Escapement	I			I			

APPENDIX V: DENSITY INTERPOLATION

Ordinary Kriging interpolation along river networks

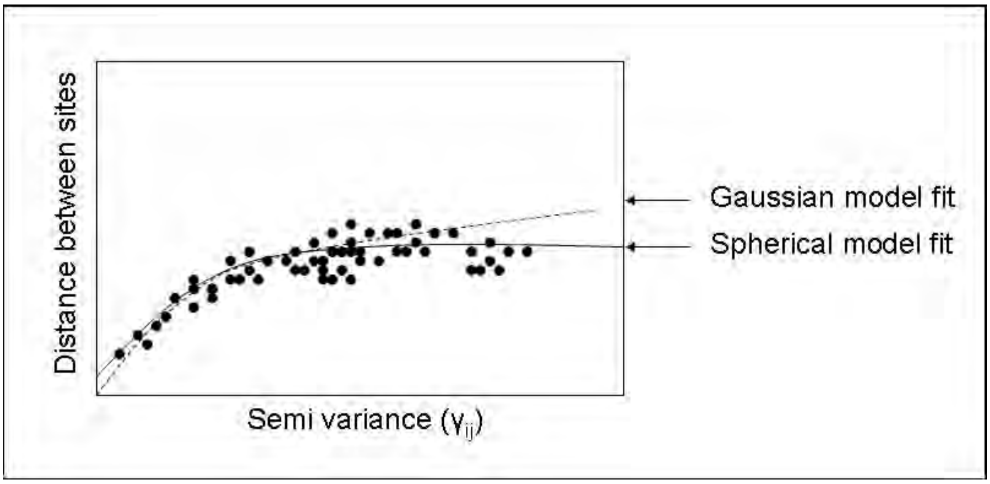
- Specific/challenging database/GIS requirements
- calculation of distances between each connected pair of sampling location
- calculation of distances between each reach centre-point and the sampling locations in the same catchment.
- simple algebra
- matrix algebra: matrix multiplication, inversion

Step 1

Calculate Semi-variogram

The idea is that we use all the data to determine how the variance between two points varies with increasing distance between those points. If all measurements were identical, then we would have no uncertainty in extrapolating data spatially. If there is no tendency for nearby locations to be similar then we have no basis for extrapolating. However, we expect that nearby measurements will be somewhat correlated (the extreme being that two measurements at the same site should be identical assuming no measurement error or temporal variation) and more distant measurements will be less correlated. At some phenomenon-specific distance there will be no correlation between measurements and it is clearly nonsensical to extrapolate information beyond this distance (the information will be no better than applying the mean of the data).

If desired it is possible to calculate average semi-variances for each distance interval. This might reduce computing time.



Requirements of GIS/Database

We would require a matrix of riverine distances (d) between all 'connected' survey locations (x_n). Unconnected survey locations should be given a 'null' value of say 9999999km

And a matrix of semi-variances (γ_{ij}) between all 'connected' survey locations for each parameter of interest

In defining the basic semi-variogram function, only accurate distances should be used (so actual rather than nominal geo-locations only)

Actually, what we ultimately need is the average semi-variance within each 1km (?) length interval. We can derive this outside the data-base and return the semi-variance function to the query builder for the subsequent interpolation steps. However, there may be quite a large number of points (i.e. ~ [number of sites]2). It would be nice to automatically calculate the average semi-variance for each length interval (pivot-table style) such that the output is merely 200 datapoints, assuming connected sites are not above 200km apart.

There should be user input into the selection of the appropriate model (e.g. Gaussian, Spherical, exponential, linear etc.). Suggestions on how to integrate this process into a user-friendly database tool would be welcome. One way might be to plot the graph above automatically and fit each of the models to this then prompt the user to select the correct model. This will require fitting of several models to the data by least means squared method. It would be possible to export the 200 data points and run them through a stat package so as to determine the appropriate curve and function.

Output

A function that allows us to estimate the semi-variance between any two points given the distance between them. This informs as to the distance weightings for our extrapolations and also the uncertainty associated with each extrapolation (i.e. the extrapolation of information to each reach).

Step 2

Calculate Kriging Weights

We are now thinking in terms of each individual reach/water body. Each reach will have a set of connected survey sites and each survey site will be assigned a relative weighting, unique to each individual reach for which we are extrapolating information. Intuitively, this process seems computer intensive.

The expected semi variance between each reach centre point ($x_◦$) and each survey site (x_n) (i.e. $\gamma(x_n, x_◦)$ or $\gamma_{n.◦}$) is calculated using the semi-variogram model calculated in Step1. We have already calculated the semi-variances between each sample site pair. The Kriging weights are calculated as follows:

Note the new parameter μ, the Lagrange parameter that is necessary to fulfil some assumptions of the Kriging method. Used in determining error see step 4.

A constraint should be introduced to this step such that only sites within a certain distance are included in the interpolation. This distance will be user-defined but is empirically derived from the semi-variogram in step1. Effectively the plateau in the figure above.

Requirements of GIS/Database

- the distance from each reach centre-point to each survey location
- conversion of this distance into an expected semi variance using the model developed in Step 1 above.
- Matrix algebra – namely calculating the inverse of a matrix and matrix multiplication.

Output

A set of kriging weights for each survey site unique to each reach. This will define the relative influence of each survey point on the estimate for each reach.

Step 3

Interpolation

Output

A sophisticated interpolated value will be calculated for each reach of the water network. This interpolated value will be based primarily on the nearby connected sample sites but it also includes information derived from the whole database of sites. The pattern of extrapolation will differ between the parameters measured and might even inform as to some underlying biological phenomena. It is also possible/desirable to limit the range of influence of survey points (i.e. extrapolation fails for any reach more than xkm from a survey site). The range is derived empirically from the semi-variogram in step 1. This process will increase the computational efficiency.

Step 4

Calculate uncertainty associated with extrapolation i.e. Ordinary Kriging Error Output

Each reach will be assigned an uncertainty. Reaches with no data within 'range' can be classified as unknown (or more correctly simply use the standard deviation and mean of all measurements). Each reach will have a wetted area associated with them. This wetted area has now been assigned an extrapolated value and a variance. The extrapolated values can be used to generate catchment-level summary statistics. The variances are also associated with wetted area and can be preserved in these summary statistics to yield the associated uncertainty at the catchment level. Finally, a simple query can be defined to select the reach yielding the maximal reduction in uncertainty at the catchment or national level. This can then be used to quantitatively and adaptively inform sampling. It would also allow managers to define the level of uncertainty that should be aimed for e.g. reduce our uncertainty in parasite prevalence by 10%. It would also allow us to determine the cost/effort associated with such a target.

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