FRS: ORIGINAL ROAME INITIATION FORM

Work undertaken for this ROAME project will be performed in compliance with the requirements of the Joint Code of Practice for Research, and will be internally audited within the first year. See the Quality System Intranet pages for guidance.

1.	**Project Number:** *Allocated by FRS Director of Science*	SF0280
2.	**Project Title:**	Fishery Management models for interacting, sustainable Scottish salmon sub-stocks.
3.	**Project Leader:**	Prof. W.S.C. Gurney (Strathclyde) / Dr P.J. Bacon (FRS FL)
4.	**Marine Directorate Customer Division:**	Aquaculture and Freshwater Fisheries Division
5.	**Marine Directorate Contact:**	Louise Donnelly , Manson Wright
6.	**Start and End Dates:**	01-Apr-2009 ~ 31-Mar-2012
7.	**Version Control**	Copies of substantively changed versions must be saved to “nts2/shared/ROAMEs, contracts and SLA’s”
Version Number:		1
Date of Agreed Proposal: *(Date proposal agreed with customer)*		Nov 08
Date of this Version:		23/01/09
8.	**Keywords:**	salmon population assessment fishery management models

9. **Summary Costs**
For each year of the project, including contract cost - detailed costs in **Appendix 1**

Year	Total Estimated Annual Cost (£’s)	Total Estimated Staff Resource (man years)

10. Policy Rationale

Completed by, or in consultation with, policy customer.

Overview

Atlantic salmon are the most economically important species of freshwater fish in Scotland. They also have a high conservation value, as demonstrated through numerous Natura designations under the EU Habitats Directive. The assessment of Atlantic salmon and other salmonids is a central part of the FRS FL mission on fisheries management for the SG. Scotland has a unique diversity of salmon run-timing which greatly enhances the commercial value of Scottish salmon fisheries. In the past this diversity, which is maintained by genetically different stocks from different environments of the same large catchments, provided sporting opportunities in most months of the year, greatly extending the economic opening season to rural fisheries and hotels. However, in recent decades the populations and catches of early-running salmon have declined markedly. These large multi-sea-winter fish are the anglers' prime target and breed most commonly in the high altitude nursery tributaries of catchments. Because these fish are genetically distinct, FRS FL has always advocated conservation and management measures that distinguish between the different types of salmon within catchments. Salmon managers broadly concur, and have, for example, targeted Catch and Release policies to favour the large, early running upland stocks.

However, the salmon life-cycle is very complex and long. Small one sea-winter grilse inter-breed with large multi-sea-winter salmon within the same small sub-catchments. This, combined with the three to five year delay between salmon egg production and the return of survivors as adults makes it hard to discern the true effects of the only feasible management actions: complete or seasonal fishery closure, net buy-outs and catch and release. This difficulty is exacerbated by the wide annual variation in numbers of salmon returning to monitored rivers.

Accordingly FRS FL is trying to encapsulate its knowledge of the state of Scotland's salmon stocks into a model which both represents the fundamental biology of the salmon life-cycle and is adequately founded on the best available Scottish data.

The overall objective of SF0274 was to construct a salmon model capable of operational use in a management context. The design of such 'operational' models is distinct from that of the 'process' models used for scientific hypothesis testing. In management models key biological processes should be represented generically rather than specifically, and the associated parameters should be as close as possible to observable quantities, even at the cost of a weaker relation to underlying process. The key to an effective operational model lies in the identification and generic representation of the processes controlling population productivity and abundance.

Project SF0274 has provided the scientific and modelling foundations for constructing a useful management models (using highly focused process models), and drawn attention to remaining uncertainties. SF0280 proposes to build the best elements of those scientific insights into a management model which is as robust as possible to the remaining doubts. It is also proposed that the modelling work guides and supports future fieldwork (*not costed within this proposal*) to obviate the remaining uncertainties. This approach will serve three functions: (i) it will provide a pragmatic tool for salmon management, based on current best-knowledge; (ii) it will be developed through active collaboration with salmon managers and designed to meet their priority goals wherever possible; (iii) its structure and detail will be kept flexible to the identified uncertainties, so that the implications of new knowledge can be more readily incorporated as new key information becomes available. The modelling and fieldwork will need to consider different locations to allow for the fact that salmon populations and stocks in different regions of Scotland are differently structured.

Progress during SF0274

Time series data from the Girnock Burn, which showed strong temporal patterns in development period from ova to smolts, were used to inform and preliminarily parameterise a detailed process model of development through the riverine stage of the salmon life-history (the 'Smolt-split' model, CJFAS *in press*) and to assess the effect of long-term temperature changes in determining smolt production and smolt age-class structure. The key conclusion of that work was that, while decadal temperature trends were potentially implicated in visible reductions in ova to smolt development time, total smolt production was mainly determined by a strong non-linear (density dependent) 'stock-recruitment' relationship between the numbers of spawning females and the consequent abundance of late-summer fry.

The second theme in SF0274 started as an attempt to understand the sea-phase of the salmon life-cycle and utilised data from the Girnock and Baddoch Burns as well as the North Esk. The work produced a series of strategic models that aimed to obtain hard-to-observe parameters through evolutionary-optimality arguments. The broad outcome was an understanding that the widespread co-existence of grilse and multi-sea-winter spawners represents a stable genetic polymorphism which must be maintained by asymetric competition between fish at a very local (spawning sub-catchment) scale. Since the outcome of this competition is characteristically different in different environments (upland environments are dominated by large numbers of MSW fish with small numbers of grilse, while lowland environments are dominated by grilse with few MSW fish) it must take place within the riverine environment rather than at sea. This finding is crucial, as it shows that considerable influence on overall population status could be exerted by manipulating the freshwater environment, which is considerably more amenable to management by Scottish fishery owners than is the marine environment. It is also the one for which the Scottish Government has the most direct responsibility (Habitats and Water Framework directives, as well as economic fishery interests). The remaining challenge is to clarify which aspects of salmon biology the management of freshwater can influence cost-effectively, and how best to achieve and monitor those interventions.

Our conclusion that the key non-linearity (density dependent processes) in salmon population dynamics occurs within sub-populations within sub-catchements in freshwater has already allowed us to construct a prototype management model. This initial version is for a single 'deme' (sub-population) and incorporates the insights discussed above, in as general a form as can presently be arranged. The resulting model is structured around annual cohorts, but takes careful account of the inter-generational mixing inherent in variable riverine development time (typically 2 or 3 years). The model treats grilse and salmon independently and takes specific account of their genetic differences. Moreover, it is sufficiently efficient to allow robust calculations of probability distributions for the outcomes of different management scenarios. Such risk information is vital in an uncertain world. For example, the model can estimate the relative risks of salmon population extinction under different proposed management regimes. It can even estimate auto-correlation functions between salmon cohorts. This last property is especially critical for the evaluation of management policies where the fishery take in any given year generally depends on the observed spawning stock in the previous year. Preliminary findings show that such ‘fine-tuning’ to last year’s fish stock data could often be a seriously inferior strategy to adjusting management targets based on the average performance of local salmon stocks over the previous 5 to 10 years.

A future programme -- SF0280

A single-deme model that is robust to many circumstances

The (robust) conclusion from SF0274, that salmon stocks are divided, even within a single catchment, into sub-populations with distinctive dynamics, implies that even within a single catchment, salmon management ought to be informed by a linked set of population models, each focussing on a distinct deme, analogous to a `salmon run-time group'. Our prototype management model has so far been preliminarily parameterised only for an upland environment (the Girnock Burn). Our first development must therefore be to parameterise and validate it against such data as are currently available for other environments (lowland and intermediate).

The next exercise in validation of the single-deme model will be to attempt to post-dict the effects of historical management actions in rivers (such as: net buy outs; altered dates of fishing seasons; catch-and-release) on subsequent salmon stocks. These trials can be expected to clarify aspects of the model structure (for example the genetic basis of the salmon/grilse polymorphism) which are currently a little arbitrary. In parallel with this validation exercise we shall investigate optimal protocols for employing sparser and noisier data. This will permit us to define a modified model complexion, still appropriate to a given single deme, that can be used with reduced versions of the relatively complete datasets complied for the Girnock, Baddoch and North Esk. The reduction of data may entail some loss of precision, and a goal of this aspect of the work will be to see which bits of information provide the most understanding of previously unmodelled salmon populations.

Once the single-deme model is capable of passing the post-diction test we shall start to collaborate closely with selected salmon managers. Our aim in this will be to refine and extend the questions the model readily answers to encompass as many as possible of those which are relevant to a practical river-fishery manager. Our hope (and expectation) is that this process will result in the managers involved 'buying-in' to the population-dynamic paradigm encapsulated by the model and hence to its implications for fishery management.

A catchment-wide salmon model of multiple but largely non-interacting salmon demes.
One of the remaining difficulties in our understanding is that, although we know salmon hatched in one tributary or river sometimes ‘stray’ to another when they themselves spawn, we have a poor knowledge of the frequency of this, and an even worse understanding of how well the offspring of such strays survive. However, such effects are likely to be generally small, and indirect, compared to the effects of human fishery practices within and between rivers. We thus propose to represent the salmon demes within a catchment by a set of parallel demes which do not interact by inter-breeding but which are exposed to the same gamut of human fishery risks. Those fishery risks could change from (modelled) river to river, and over time and season within rivers. We note that some demes (early running upland MSW) would be immune to some fishery protocols (netting starting in June) whereas others (grilse) would not. It is precisely the consequences of these complexities of management and fish life-styles that this ‘non-interacting demes’ model is intended to elucidate, especially as the early running fish are more susceptible to rod capture.

Our first step in this direction will be to construct a multiple deme model of a single catchment (for example the North Esk) and repeat our post-diction test to investigate the accuracy with which the composite model predicts changes in the overall composition of the fishery by sea-age and run-time groups. This non-interacting demes model will be rolled out to participating river managers with a view to producing a practical tool for river assessment.

A Scotland-wide salmon model of multiple but largely non-interacting salmon demes
One of the central problems facing FRS FL at a practical level, which also requires solution to inform SG’s commitments to NASCO, is the management of the Scottish National salmon stock. Since this stock is spread over many catchments, each structured at a sub-catchment level, it might be expected that a national stock model would be an exceedingly cumbersome object. It seems plausible, however, that a model composed of representations of a much small group of 'pseudo-demes', each representing the aggregation of equivalent demes from the component catchments would be capable of yielding significant insights about broad policy goals and outcomes. Our final theme in SF0280 will thus be to investigate, in collaboration with the Salmon management group at FL Montrose, the construction of an appropriately aggregated pseudo-deme structured national stock model, which we shall again test by attempting to post-dict the outcomes of past management changes such as coastal net buyouts.

Outline of proposed additional Lowlands fieldwork for SF0280

Background.

There are four key aspects to the data and processes that are needed to underpin the models being developed under both the present and proposed SF0274 project. All aspects need to be resolved at a smallish, sub-catchment, scale.

KA.1 The Adult aspect of stock recruitment. Namely numbers, sizes and sea-ages of adults at spawning time. Needed to elucidate Stock-Recruitment and fecundity processes at spawning time.

KA.2 The precise mechanistic process(es) underlying the density-dependence known to occur between ova–deposition and the summer fry (census) densities. One needs to isolate and describe the dynamics of the control mechanism of grilse/2SW genetic polymorphism.

KA.3 The population densities and size-at-age distributions (mean & variability, ie Probability Density Function=PDF) of juvenile salmon (fry and parr) in late summer. Preferably also some indication of the seasonal shape of the growth-curve that produces these summer resultants at the site.

KA.4 A sample of (relative numbers and) size at age measurements of juvenile emigrants (smolts and autumn parr).

We opine that KA.1~4 are about equally important at any new site, and agree that they are easiest to enumerate in the order: KA.3 summer electro-fishing; KA.4, sample of smolts; KA.1, adult breeder biometrics; and that KA.2 is presently an unknown quantity for which measurement methods are consequently not available.

We note that KA.1,2,4 are well established at the Girnock, but that none of them are reliably known at any lowland study site, for which the parameters are likely to be radically different. The critical need is to establish them as firmly as possible for a lowland study site, in order to scope the approximate upper and lower limits of the salmon's population responses, probably mediated by sea-age and run-time differences, between 'upland' and 'lowland' situations.

Accordingly, the more immediate and most pragmatically feasible advances will come from measurements of KA.1,2,4 in the lowlands. Ideally this would be done by a similar pair of traps (adult,smolt: ascending, descending) to those at the Girnock. But this is not feasible in the short-term, and the high capital cost of installing such a facility would almost certainly demand proof-of-concept, in the form of initial work that showed the site was suitable and the potential data thus worthy of the costs.

This pragmatic field research strategy hence explicitly defers investigating KA.2 (identify the DD mechanism) to a later date.

Feasibility and resources.

This proposal concentrates on pragmatic initial ways that FL staff in the Resources and Environment Groups could estimate KA.1,2,4 at a new, informative, lowland site during the period 2009~2011. This assumes a staff-replacement (B1) in the resources group during early 2009, and that staff and resource levels would permit the 'Girnock monitoring' (SLA SF010) to continue at some 938 person*half-days and that resources freed-up by the curtailments and ends of ROAMEs SF0272 & SF0273 would allow the re-direction of some 530 person*half-days to the fieldwork aspect of SF0280.

We note that the scoping study of salmonid dynamics in lowland agricultural streams (jointly undertaken by FL Resources and Environment groups on tributaries of the river Isla in 2007) revealed an important, but awkward, situation which must be adequately dealt with by the current proposal. At these sites (and probably elsewhere) juvenile salmonids in lowland water bodies appear either to have extremely high mortalities (unlikely) and/or to be much more mobile (moving outside the bounds of normal electro-fishing sites[1]) over the spring and summer growth period; they are consequently are not susceptible to repeat capture at a particular site.

In developing a field approach to assess fish performance in such areas this difficulty must be overcome , as the modelling approaches need to know whether the captured fish are reliable indicators of 'individuals living in the monitored environment' and that such estimates are not potentially biased by 'size-selective' mortalities or dispersals.

Proposed supportive Fishery studies.

Preparatory studies.

To accommodate anticipated staff shortages in early 2009, the supportive fishery work would start with a **desk-study**. This would collate existing data from the environmental extremes (uplands, lowlands), and undertake empirical analyses to scope the likely fieldwork constraints. In particular, the start and end of the growing season and the times (ages) between parr reaching PIT-taggable size (~70 mm) and smolting size (~110 mm).

In parallel with these desk studies, a number of field-visits to the proposed study site would be undertaken, and water samples collected for analysis. Local land-owners would also be contacted, to check that the necessary access permissions could be obtained.

Principles of proposed fieldwork

Juvenile survival, movements and growth (KA.3)

We propose to that the study site should be the Water of Cruick, on the river North Esk near Edzel. It is entirely a lowland agricultural system, having a confluence with N Esk south-east of Edzel at OS 362,600

[1] In lowland sites most parr (> 80%?) move appreciable (>> 30 m) distances from one month to the next, whereas in upland burns < 15% of parr more > 15 m.

m E, 765,800 m N. It is relatively narrow (some 6 m wide at its North Esk confluence). The local landowner(s) are sympathetic to FL, and have allowed electro-fishing in the past. Thus preliminary data, including a (fairly complete) six-year temperature record are available.

A key challenge of the proposed fieldwork is to discriminate between (i) apparent mortality and (ii) recapture failure due to the home-ranges of juvenile salmonids[2] living in lowland Scottish agricultural settings being much larger than those in upland burns. We plan to do this by building on experiences gained during SF0273. This project revealed the greater movements of lowland salmonids on the Isla tributaries in 2007. During 2008 and 2009, the exisiting SF0273 project will also allow us to trouble-shoot the technology that will alleviate the difficulty. It will develop, on the Newmills burn, the use of: (a) a cross-river PIT-tag double-loop aerial system that records the directional movements of tagged fish up and down stream (through the c 3m * 1.2 m aerial placed around the channel); (b) a PIT-tag detector mounted on a pole, that can identify the position of previously marked individual fish without the need for re-capture by electrofishing.

Emigration estimates (KA.4)

In the emigration seasons (autumn parr and spring smolts), particularly at smolting time, the cross-river PIT-tag aerial will record the emigratory passage of marked juveniles. By deploying a Rotary Screw trap adjacent to it, we will also obtain vital complimentary data. In particular, the ratio of tagged to untagged fish at the RST, which, combined with the numbers of tagged fish recorded at either and both of the PIT-aerial and RST will allow us to estimate the total ‘up river’ population size. The fish caught at the RST will also provide size measurements (lengths) and scale-samples for aging, yielding the necessary size-at-age data.

Electro-fishing and fish survival studies

Cross-river PIT array.

Preminary fieldwork (1-pass EF) at a few (3) sites in spring will establish when the salmonids in the stream are big enough to take PIT tags. Once that date is past, an intensive program of PIT-tagging (1 pass EF) will be undertaken to mark a large sample of parr. The sites for this fieldwork will be carefully distributed around the cross-channel PIT detector. In the first year we will guess that spacings of [25, 50, 100, 200, 400, … m] upstream and downstream will be appropriate. Once this is done, if all the fish in the Cruick stay within 15 m of their initial capture site (as they do over summer at the Girnock) we would not expect to see any PIT-tagged fish at the cross-river PIT-aerial. If on the other hand, as we believe from the Isla work, they move several hundred meters over the course of a month, then we would expect that large proportions of the ‘nearby’ EF marked fish would transit the aerial, and decreasing proportions of the more remote ones. Analysis of these combined data will tell us the ranges of movements that occur, and help us to plan the next season’s fieldwork more effectively.

PIT reader on a pole.

The Cruick is sufficiently narrow that the PIT tag aerial mounted on a pole should allow us to re-locate many marked fish without the expense of re-capturing them by electro-fishing. We will use this method at and between the EF-capture sites to gain a more detailed picture of fish survivals and home-range sizes, from which we will be able to ascertain the spatial scale of the environment they use and hence of the environmental variability (temperatures, food, shelter, etc) which they experience. We will occasionally obtain more comprehensive samples of such information by arranging guide-nets across the river leading to a circular ‘escape-hole’ surrounded by the PIT-aerial. EF probes will be used to help ‘herd’ fish from a say 20 m section of burn through this constriction, thereby obtaining a quick but more comprehensive and less-biased sample of the marked fish present.

Summer density survey.

A few sites will be surveyed by multi-pass electro-fishing in late summer, in order to quantify the densities and sizes-at-ages at the stage of the season when most fishery information is collected. As at the Girnock, this will be combined with another multi-site, 1-pass survey. This will supplement the 3-pass details by: estimates of relative numbers; estimates of sizes-at-ages; provide an opportunity to PIT-tag the later-growing fish prior to their emigration (we anticipate that many of the faster-growing Cruick parr will leave as 1+ smolts the following spring).

[2] Note. SF0280 is primarily about salmon. But trout and sea-trout are important in lowland situations too, and this proposed field study will allow us to collect data on both species at little extra cost.

Summary: juvenile salmonid populations.

The combination of techniques outlined above will comprehensively allow us not only to enumerate KA.3 and KA.4 above, but also to cross-check the findings from one method with those of another.

Enumerating adult productivity.

We propose to use two initial methods to begin to understand the numbers of adult salmon breeding in the Cruick. We note that, as we particularly need to know the sea-age and sexes of the fish, along with their sizes and weights, it is imperative that we catch and handle at least a sample of ascending adults. We note that, if we can subsequently enumerate the ratio of marked to unmarked fish, we can then begin to describe the full population.

Adult capture.

Two methods of capturing adults will be investigated initially. First, the use of a temporary ‘diversion' fence (net, cf Catamaran Brook design) to direct fish into a catching box or net. This will require regular attendance, and will not work well, if at all, in spates, when many adults run. Second, we will use a combination of ‘tangle nets' and ‘electro-fishing' to ‘herd' adults into capture sites. These two approaches will provide samples of adult fish that have entered the Cruick burn. These will be subject to the standard (Girnock) procedure [record; sex, length, weight, hook-marks, etc; photograph?; adipose sample for DNA analyis]. In addition, critically, each adult will be PIT-tagged (?under the skin?). The PIT tags may allow us to identify marked adults using the PIT-pole reader (and thereby get a rough ratio of marked to unmarked adults). The cross-river PIT-array aerial will almost certainly let us record the emigration of (kelt) adults over the cross-river PIT-aerial.

Redd counts will also be attempted.

Subsequently.

A key to proper understanding and modelling a lowland salmon population will be to extend the description of the handled adults to an accurate enumeration of the entire adult breeding population, and thus a Stock-Recruitment relationship. That extension is outside the scope of this 2009~2011 ROAME proposal, but we note that it could be accomplished by subsequent, or possibly even parallel work. There are three possible routes.

First, to sample ova from identified redds, and fry the following summer, and use DNA paternity / maternity methods to show how many breeding adults were not among those captured for (DNA and other) sampling.

Second, to install a DIDSON acoustic camera adjacent to the cross-river PIT aerial, and use those combined technologies to estimate the ratio of PIT-tagged to non-tagged adults.

Third, to install a pair of (Girnock style) upstream and down-stream traps, and thus enumerate the entire population.

Until this proposed 2009~2011 pilot study is undertaken, it could not be estimated which of those supplementary methods would be most likely to succeed, nor even if any of them could be financially justified.

11. Policy Objective

Completed by, or in consultation with, policy customer.

1. To define a working version of the single-deme model that is suitable for development into a tool for managing local river salmon stocks within a single catchment. To parameterise this single-deme model for sections of a well-documented river (eg upland, mid-reaches and lowland sections of the North Esk).
2. To validate the single deme model by postdicting the effects of past management actions on the chosen test river (e.g. net buyouts)
3. To investigate the losses of understanding inherent in having data of lesser extent, detail or quality from other rivers (eg Spey, Tay, Tweed), by experimentally removing example sub-sets of data from the full North Esk information.

4. To work with local salmon managers (eg Spey, Tay, Tweed) to produce an operational single deme model for local management.
5. To aggregate a group of single deme models into a catchment model, assuming that, by definition, straying between demes has minimal demographic impact. To validate this model by post-dicting the effects of past management actions.
6. To explore with local salmon managers the optimal protocols for parameterising, validating and exploiting the model from (5) above in practical catchment management
7. To develop a robust deme-structured tool for strategic management of the national Scottish salmon resource (eg by aggregating by common run-time or altitude classes across catchments) and make a comparative evaluation of this approach versus an (ICES/NASCO) aggregation of undecomposed catchments .
8. To train FFL staff in the use and interpretation of these models so as to facilitate the evaluation of alternative fishery, environmental and conservation management strategies. To publish the scientific basis for the new models, and give demonstrations and workshops on their use and interpretation to salmon managers.

.

12. Scientific Rationale

The outcome of the project will provide the Scottish Government with a set of evaluated case-studies on the insights gained by utilising dynamic mathematical models of the complex life-history of wild salmon and their exploitation by human fisheries. The experience thus gained will inform the collection of future data on wild salmon to enable better management of the Scottish national resource. The models will permit the clearer interpretation of the benefits of past and future management actions on different segments of the salmon population and the economic and conservation consequences to the Scottish people.

13. Science Objective and Description

The proposed model recognises:

1) the existence of a stable genetic polymorphism between grilse and salmon (1SW, MSW)
2) that this polymorphism is maintained by localised asymetric competition at a sub-catchment scale
3) Competition between fish is mostly within a year class (generation) but that inter-generational mixing plays a key role in determining the autocorrelation between cohorts from different years.
4) model parameters should be MEASUREABLE (with as much relevance and ease as possible).
5) stochasticity and computational efficiency are necessary to a model managers can have confidence in.
6) male and female salmon run at different times, are subject to distinct exploitations, and thus need to be modelled independently.

Example questions which the models will be able to answer

1) Probability distribution of future population size (including extinction risk)
2) Mean and variability in yearly and medium term averages of the salmon catch
3) Changes in deme and catchment-wide stock composition attendant upon changes in generational mixing (i.e. alterations in growth rates and size at smolting)
4) Interactions between environmentally induced changes in population characteristics and fishery exploitation (e.g. if generational mixing is reduced, do we need to change the way we manage the populations)
5) Changes in the composition (and hence monetary value) of salmon catches.

The proposed program of work has six themes.

1) Technical development of the single-deme model.

a) parameterisation for different demes within a well documented river (e.g. North Esk);
b) investigation of the loss in predictive potential inherent on use of partial or indirect data (eg catch data

to approximate adult return numbers)

c) parameterisation for river systems with different characteristics (e.g. Spey, Tay, Tweed) using the direct and indirect data already available;

d) refine and test the model's description of fish *growth and* competition mechanisms in other (especially lowland) environments.

2) Development of the single-deme model for salmon management.

a) Collaborate with river board mangers and other stakeholders to define key answerable questions, and protocols for the model's use

b) Develop a model formulation to optimise the model's managerial potential

c) Investigate the model's ability to 'post-dict' the system's response to past management perturbations (e.g. net buy-outs, curtailed fishing seasons, catch and release)

3) Development of a catchment management model

a) Investigate the aggregation of physically separate demes within a catchment (can we regard all upland areas as a single deme ?).

b) Define a protocol for the allocation of life-cycle effects between Stock to Fry Recruitment (S-R, Density Dependent) and non-S-R (Density Independent) parts. Note that this partitioning does **not** need to be uniform across the multiple demes within the model.

c) Develop a protocol for using both partial and indirect data across a single catchment and across multiple catchments

4) Development of a Scottish national salmon stock management model

a) Investigate the optimal spatial granularity for a national Scottish model and evaluate different ways of aggregating it, given the limitations of existing and likely future fishery data (eg within catchments versus within altitude bands across catchments);

b) Investigate the national model's ability to post-dict decadal population changes;

c) In collaboration with SG personnel, develop a model formulation to optimise management abilities for the wild Scottish salmon resource.

5) Roll-out of modelling technology.

a) Train FRS FL staff in the use and interpretation of the new models.

b) Work with fishery managers to develop and document case-studies of using the models to enlighten (and improve) the management of particular exemplar Scottish rivers.

c) Discuss the wider requirements of salmon management with SG, SEPA, SNH and salmon management and conservation interests (eg AST, RAFTS, etc)

d) Give demonstrations and workshops to other salmon managers on the value of the new models.

6) Refine and publicise the scientific basis for new models.

a) Conduct investigations into key unresolved process issues – notably the selective basis of run-time differentiation between demes, and the detailed genetic basis of maturation time determination.

b) Publish scientific papers and other reports to establish the scientific validity of the new models and to promote their use by managers of wild Scottish salmon.

14. Milestones (1st Year only, specifying staff/role responsibilities and target dates) and Experimental Timetable (Year by Year)

Year 1:

Milestone	Responsible Person

Subsequent years:

WE HAVE YET TO WORK THIS OUT IN DETAIL :

OUTPUTS

Collated data

-

Discussions with salmon managers

-

Software and case-study documents on the use of model versions 1,2,3 & 4 above

Scientific publications

a) data analysis paper on basis for local competition between 1SW and MSW fish
b) data analysis/stratigic modelling paper on stock recruitment curve shapes and their importance
c) Modelling paper on optimality, control and the salmon/grilse polymorphism
d) Modelling paper on a generation structured stochastic stock-recruitment model for salmon management

15.1 Anticipated Scientific outcome *Enter number for each subset*

Publications in refereed journals	Four
Presentations at lectures/meetings	3
Articles in trade journals/popular press	2
Presentations to the Industry	2
Internal/confidential reports	2
Presentations to SG	3
Other (specify)	**??? workshop on model use to Trust Biologists ???**

16 Additional research funding:

16.1 Additional research funding sought
Current or upcoming bids for funding

Brief description of level of funding and type of work bid for	*Bid deadline*

16.2 Additional research funding gained
Funding that will contribute to this project

Brief description of level of funding and type of work	*Period of contract*

17. Project Data Management:

17.1 Will new data be acquired or does the project utilise existing data (internal or external)

The project will use existing FRS FL data to parameterise the initial models, for upland salmon populations. It will require additional data for two sub-purposes.
a) to parameterise similar models for lowland salmon populations. Much of this will be gained by additional FRS FL fieldwork that is costed within this project
b) by utilising existing data from collaborating fish trusts. As explained above, part of the aim of this aspect of the work is to discover exactly what data the (better supplied) Fishery Trusts have, and the limitations that the availability of such local data put upon the extend and soundness of management advice that can be based upon it. We note that this aspect is exploratory: we do not know the extent of the available data, and so cannot pre-judge its worth or limitations.

17.2 Format or structure of data *(brief description of data formats – e.g. paper/electronic and whether the data will be held in a structured (e.g. database) or unstructured (e.g. multiple datasheets) format. Also include whether additional ICT resource is required.*

FRS FL's own data.
A separate FRS FL initiative aims to migrate much of the necessary data into centralised FRS FL data-bases during the course of this project. However, this will probably be achieved to late for the project to benefit from increased efficiency of data access, although the utilised data should be archieved in such forms by the end of the projects.
External data from Fishery Trusts.
A minority of external data are held in SFCC format. Again, it is hoped that these will migrate into a centralised data-base over the course of this project. However, this is again likely to be too late to give this project any efficiency savings. The majority of data required from collaborators is in unknown formats. We understand much of it will be in electronic form (spreadsheets, *.csv files, etc), but recognise that some will probably still be on paper formats (notebooks, record sheets, etc). We note that: (a) this is an inevitable consequence of the proposed collaboration; (b) we will include ease of access to electronic data as one aspect of deciding which Fish Trusts we can most profitably collaborate with in this initial phase.

17.2 Data care *(including intended storage location(s) during project and long term archiving)*

FRS FL data.
We hope that the data-base developments mentioned above will allow FRS FL's own data to be archieved in such formats by the end of the project.
External data from Fishery Trusts.
We hope that some of the external data will be archieved in SFCC's new data-base by the end of the project. Data on different aspects (smolts, adult salmon, salmon catches) etc are in unknown formats and currently owned by the Trusts. We cannot comment on what long-term access restrictions the different Trusts might want to put on those data. We would encourage them to make them available, but it would almost certainly be counter-productive to try and pressurise them in this regard.

17.3 Person responsible for the data sets

FRS FL data-base manager

17.4 How will access to data be facilitated (internally and externally)?

Access to FRS FL's data.
There are plans for FRS FL's electro-fishing 'FishObs(ervation)' data base, and key associated data sets, to serve as a pilot project for the implementation of access to electronic meta-data on FRS data holdings. These data would thus be at the fore-front of FRS's activities in this regard.
External data.
As explained above, we presently do not know what long-term arrangements can be entered into in these regards

18.	Risk Management:
18.1	**List main risks to the project's success, and define mitigation strategies.** ***(Reference programme risk register if applicable)***
ICT failure – ensure secure backup Redeployment of staff in response to continually evolving SG priorities – design of project is such that work programme would be delayed as opposed to terminated.	

Appendix 1

A. Resources: Annual Costs *(Give estimates for all years of project)*

Year	Estimated costs -				
	Staff Inc. overtime, overheads	**T&S**	**Consumables**	**Ships** Inc. charters, sea allowances	**Total**
2009/10	108631	4469	9013		122,113
2010/11	114010	4469	9013		127,492
2011/12	119658	4469	9013		133,140
Total					

Estimated Staff Requirements (in half days per grade and total costs) -

Year	C2	C1	B3	B2	B1	A4	A3	A2	Others	Cost	O/T	T&S	*Total man years
2009/10				386	140								1.32
2010/11				386	140								1.32
2011/12				386	140								1.32

*Assume average of 200 production days per year (400 half days)

B. Resources: Contracts linked to this project *(Give estimates for all years of project)*

Contract No. and title: University of Strathclyde

Year	Estimated costs				
	Staff Inc. overtime, overheads	**T&S**	**Consumables**	**Ships** Inc. charters, sea allowances	**Total**
2009/10	51,163	1,000			52,163
2010/11	40,930	1,000			41,930
2011/12	30,698	1,000			31,698
Total	**122,791**	**3,000**			**125,791**

C. Resources: Capital requirements

Item(s) required	**Cost**
None	

Contingency plan if capital item(s) not acquired