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Evaluating an ecosystem service provided by Atlantic salmon, sea trout and other fish species in the River Spey, Scotland: The economic impact of recreational rod fisheries

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ABSTRACT

In 2003 a study was undertaken in the River Spey catchment, north-east Scotland, to estimate the economic impact of recreational rod fisheries for Atlantic salmon (*Salmo salar*), brown and sea trout (*S. trutta*), pike (*Esox lucius*), and non-native rainbow trout (*Oncorhynchus mykiss*). Thirty-one fishery owners and 372 anglers completed questionnaire surveys on average catches and angler effort in 1998–2002. Anglers reported their daily expenditure, and the CogentSI model was used to derive multiplier effects. Total annual angler days were 54,746, of which 74% were from salmon and sea trout anglers. Angler expenditure was estimated to be £11.8 million annum^{-1}, of which £10.8 million was generated by salmon and sea trout anglers. Accounting for multiplier effects, fisheries contributed £12.6 million annum^{-1} to household incomes and 420 full time equivalent (FTE) jobs in the catchment. Of this, salmon and sea trout fisheries contributed £11.6 million annum^{-1} and 401 FTEs. On average rod caught salmon and sea trout contributed approximately £970 fish^{-1} to household incomes, equating to £26 smolt^{-1} and £1 m^{-2} annum^{-1} for riverine nursery habitat. The capital value of the salmon and sea trout rod fishery was £56.7 million. Comparison with a national survey of angler expenditure in 2003 suggests that the relative impact of salmon and sea trout in the Spey catchment's economy is one of the highest in the country. The application of angler expenditure as an evaluation of utilitarian ecosystem services provided by fish species and freshwater habitat is discussed.

1. Introduction

Ecosystem services are the benefits that people obtain from ecosystems (Millennium Ecosystem Assessment, 2003). With growing competition for natural resources, there is a requirement to establish the value of the ecosystem services that they provide to better inform trade-off decisions (Costanza et al., 1997; Daily, 1997; Daily et al., 2000; de Groot et al., 2002). In Scotland the introduction of the EU Water Framework Directive (2000/60/EC) provides an opportunity for the integrated management of water resources based on balancing environmental objectives with human demands (Holzwarth, 2002; SEPA, 2008). Although Williams et al. (2003) estimated the value of 17 ecosystem services across Scotland, including those provided by lakes and rivers, little information exists on the value of ecosystem services at the catchment scale with which to inform local management decisions.

Fish provide ecosystem services which may have two forms of value, defined as use ('utilitarian' or 'instrumental') and non-use ('existence' or 'intrinsic'; Farber et al., 2002; Millennium Ecosystem Assessment, 2003). In supporting recreational rod fisheries, some fish species provide an ecosystem service of utilitarian value. One expression of this value is the expenditure of anglers and the economic activity generated by this expenditure in the local economy. It is also possible to link this economic activity to the underlying ecosystem functions that support fish production, such as nursery habitat, and infer a value to these functions (de Groot et al., 2002). However, these exercises are usually limited by the availability of necessary ecological information for the fish species concerned (Soderqvist et al., 2005).

In Scotland stocks of native freshwater fish are pressured by human demands for fisheries, water abstraction, industrial and agricultural pollution, and habitat degradation (Anon., 2001). In response to this, previous studies have estimated the economic activity supported by commercial netting and recreational rod

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Table 1
Details of statutory fishery close seasons and 5-year average rod catches (1998–2002) declared to FRS for the Spey catchment, and numbers and response rates of the 41 owners surveyed.

Species	Fishery close season	5-year average FRS rod catch	Responses to owner questionnaire	Response rate (%)
Salmon	1 October–10 February	7599	31	76
Sea trout	1 October–14 March	3772	31	76
Brown trout	16 October–14 March	NA[a]	9	NA
Rainbow trout	NA[b]	NA[a]	5	100
Pike	NA[b]	NA[a]	2	NA

[a] Statutory submission of rod catches is not required.
[b] No statutory close season.

fisheries for Atlantic salmon (*Salmo salar*) and sea trout (sea-running brown trout, *S. trutta*). These have calculated values at the river catchment, regional and national scale based on sales of fish caught from commercial nets, and expenditure of anglers in rod fisheries (e.g. TRRU, 1982; Mackay Consultants, 1989; Mills, 1989; Deloitte and Touche, 1996). A more recent study by Radford et al. (2004) has estimated the regional and national economic impact of rod fisheries for salmon, sea trout, brown trout and other non-salmonid fishery species such as pike (*Esox lucius*), plus 'put-and-take' fisheries for non-native rainbow trout (*Oncorhynchus mykiss*). However, none have examined the economic impact of rod fisheries as an evaluation of an ecosystem service, or inferred this impact to the value of juvenile recruits supporting the fishery or the nursery habitat producing these recruits.

The River Spey is the second largest catchment in Scotland, and is considered one of Europe's premier salmon and sea trout rod fisheries (Sandison, 2001). In response to the Water Framework Directive's introduction the statutory authorities responsible for planning and management of natural resources in the catchment developed the River Spey Catchment Management Plan (SNH, 2003). To inform the future management of rod fisheries relative to other recreational and industrial activities, the authorities commissioned this study of the economic impact of fisheries within the catchment in 2003. Unlike previous studies of the Spey by TRRU (1982) and Mackay Consultants (1989), ours included all fisheries. By combining the economic impact of the salmon and sea trout fishery with ecological data on freshwater nursery habitat and smolt production we also inferred economic values for these attributes. Here we present the results of the study, and assess their application in terms of evaluating an ecosystem service provided by fish species in the Spey catchment.

2. Study area

The River Spey catchment, located in north-east Scotland, has an area of approximately 3000 km^2, and flows into the Moray Firth (57°40′N, 3°30′W). It contains a population of approximately 23,000 residents, plus un-quantified numbers of tourist visitors (SNH, 2003). Land cover is dominated by heather moorland, pastoral and arable agriculture, forestry and native woodland. Water-based industries include abstraction from four upper sub-catchments for hydro-electricity generation schemes in neighboring catchments, and one commercial aquaculture site for rainbow trout. Water is also abstracted by whisky distilleries, public and private water supplies and some irrigation (SNH, 2003). Recreational boating is also popular, with sailing on some lakes ('lochs') and canoeing and rafting on the river (Riddington et al., 2004). Fifty percent of the catchment is covered by the Cairngorms National Park, which was established in 2003 to promote appropriate sustainable development and biodiversity conservation.

The freshwater area contains self-sustaining populations of native salmon, brown and sea trout and pike. In 1992 the UK government adopted the EU Habitats Directive (Council Directive 92.43/EEC), which aims to secure the favorable conservation status of listed species of European importance through the designation of Special Areas of Conservation (SACs) (Anon., 2000). In 1999 Atlantic salmon were identified as a qualifying species in the River Spey SAC.

Formal, regulated rod fisheries exist for salmon, sea trout and brown trout with statutory close seasons to protect spawning adult fish (Table 1). There are also rod fisheries for pike, and non-native rainbow trout are stocked into enclosed 'put-and-take' lochs, but no statutory close seasons exist for these species (Table 1). Native Arctic char (*Salvelinus alpinus*) and European eels (*Anguilla anguilla*) also exist in the catchment and are occasionally caught by anglers. There are no legal commercial or recreational net fisheries in the catchment. Some commercial salmon and sea trout netting stations exist in the Moray Firth, which historically have captured salmon returning to east coast rivers including the Spey (Shearer, 1986). However, the industry has declined since the 1980s (Butler et al., 2008), and in 1998–2002 the remaining stations had a combined 5-year average declared catch of 1369 salmon and 86 sea trout (Fisheries Research Services, unpublished data). Consequently catches of Spey salmon and sea trout are likely to be insignificant in comparison to rod fisheries in the catchment. Some Spey sea trout are occasionally caught by rod fisheries in other east coast Scottish rivers (Spey DSFB, unpublished data), but we also consider this to be insignificant relative to the in-river catch.

In Scotland rights of access to rod fisheries are private, and anglers must usually pay rent or purchase permits from the owner or tenant before fishing. One land owner may hold the rights to fish for several species. Salmon and sea trout stocks and fisheries in the Spey catchment are managed by the Spey District Salmon Fishery Board (DSFB), which has statutory powers under the Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003.

In 2003 there were 41 owners of salmon and sea trout fisheries in the Spey catchment, and their properties covered all the catchment's water bodies, and therefore potential fisheries for other species. Under the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951 owners of salmon and sea trout fisheries must make catch returns to the Scottish Government's Fisheries Research Services (FRS). At the time of the study the 5-year (1998–2002) average total annual Spey rod catch declared to FRS was 7599 salmon and 3772 sea trout (FRS, unpublished data; Table 1). However, records of brown trout, rainbow trout and pike catches are not required, nor are returns of catch effort for any rod fisheries.

3. Methods

The following data were collected using questionnaire surveys of fishery owners (or their tenants) and anglers during February–September 2003, the salmon fishing season months.

3.1. Owner survey: angler effort and catches

Using the Spey DSFB's register of fisheries, all 41 salmon and sea trout fisheries were posted a standard questionnaire which asked for estimates of the average fishing effort expended annually for each species in their fisheries during 1998–2002. Pre-survey

Table 2
Substitution choices given in the angler surveys, implications for the Spey catchment's economy, assumptions applied and resulting changes in angler expenditure.

Substitution choices	Implication for Spey	Assumption	Change in expenditure (£)
1. Target another species in the Spey catchment	Change in expenditure	Anglers spend average Spey expenditure for the substitute species, and maintain angler days for substitute species	1,523,029
2. Fish another fishery for the same species in another catchment	Loss		8,869,248
3. Visit Spey catchment but not fish for any species	Loss of rents or licenses	Anglers do not spend on fishing rents or permits, but maintain average Spey expenditure on other goods	97,266
4. Not visit the Spey catchment but visit another catchment and not fish	Loss		877,698
Total loss			9,844,212

inquiries with owners suggested that the majority of anglers visit every year, and hence the 5-year period was designed to capture the average fishing effort (and expenditure; see (b) below) of these anglers. The unit of effort used was an 'angler day', which equated to one person fishing with rod and line for part or all of one day. Effort was assessed separately for each species, since locations and fishing techniques are distinct. Brown trout, rainbow trout and pike angling is largely restricted to lochs, and owners were asked to identify the locations where fishing for these species took place. Salmon and sea trout are targeted simultaneously by anglers fishing in the river, and data for these species were therefore combined.

Owners were also asked to submit their 5-year average catch (1998–2002) for salmon and sea trout. This information was not available for other species because formal records are not usually kept in the absence of statutory catch reporting (Table 1).

3.2. Angler survey: expenditure estimates and substitution options

A standard questionnaire survey was distributed to anglers through all fishery owners, angling clubs, hotels and fishing tackle retailers within the catchment. They were asked to identify where they lived, their gender and age, the fish species targeted, and the number of angler days typically expended on each species annually during 1998–2002.

Anglers were asked to detail their typical daily expenditure in the catchment while fishing for each species. To estimate substitution effects, choice modeling was used. Anglers were asked to choose one of four options if the species they targeted were no longer available in the catchment (Table 2). The impact on the Spey catchment's economy was estimated from changes in the average daily expenditure resulting from substitution choices.

3.3. Scaling factors to account for owner non-response

Of the 41 owners of salmon and sea trout fisheries, 31 (76%) responded to the survey. Nine of these also provided information on brown trout, five on rainbow trout and two on pike angling (Table 1). To account for owners' non-response scaling factors were required to derive total angler days and expenditure. For salmon and sea trout this was calculated using the FRS catch statistics for the Spey. On average 5% of Spey owners did not submit catch returns to FRS in 1998–2002 (FRS, unpublished data). Without details on these fisheries, we assumed that they had an annual catch equivalent to the average for all Spey rod fisheries, and therefore scaled up the 5-year average catch by 5% to 7979 salmon, 3961 sea trout and 11,939 in total (Table 3). The 5-year average catch from the 31 owners who responded was 6493 salmon, 3789 sea trout and 10,282 in total. Hence we derived a scaling factor of 1.23 for salmon and 1.05 for sea trout. However, because salmon and sea trout angler days and expenditure could not be separated we used the combined scaling factor of 1.16.

The same approach was not possible for brown trout and pike fisheries due to the lack of official catch statistics. Instead we compiled a list from contemporary angling literature (Angling Times, 2001; Sandison, 2001; HCC Publishing Ltd, 2002) of all lochs where angling for each species occurs in the catchment, and compared these with the numbers reported on by owners. For brown trout, 24 out of 38 lochs and the upper River Spey were reported on, requiring a scaling factor of 1.58. For pike, five out of seven lochs and the upper River Spey were reported on, deriving a scaling factor of 1.4. For rainbow trout, all five known put-and-take lochs were reported on; therefore no scaling factor was required.

3.4. Multiplier effects of angler expenditure

To estimate multiplier effects, we applied the CogentSI model (for details see Riddington et al., 2006a). The model is based on input–output tables for each of the 32 Scottish Unitary Authorities, divided to correspond with Enterprise Areas. The Spey catchment corresponds to the Moray, Badenoch and Strathspey Enterprise Area. The model takes the estimated expenditure of anglers, removes taxes and those items retailed which are sourced outside the area, and then traces the expenditure both industry to industry (Type 1 multiplier) and via the wages of those resident in the area (Type 2 multiplier). The outcomes are summarized as gross output annum^{-1} and full time equivalent (FTE) jobs. Gross output is equivalent to the contribution to household incomes in the catchment.

3.5. Inferred values of nursery habitat, salmon smolts and rod caught fish

The total area of riverine habitat accessible to salmon and sea trout is estimated as 11,062,200 m^2. Surveys indicate that salmon utilize almost all of this area, with juvenile salmon found at 86–97% of sites visited across the catchment in 2002–2005 (Butler, 2003, 2004, 2005, 2006). Accessible loch habitat is scarce, and therefore contributes relatively little nursery habitat for salmon or sea trout.

Salmon and sea trout smolt production estimates have been made using rotary screw traps in the lower main stem in 2005–2007 (Laughton et al., 2008). Average recorded salmon production was 393,522 smolts (range 236,810–702,015). Average sea trout production was 53,541 smolts (range 27,320–77,973). Total annual salmon

Table 3
Calculation of scaling factors for the Spey salmon and sea trout catch, based on FRS catch data.

	Salmon	Sea trout	Total
Declared FRS 5-year average (1998–2002)	7599	3772	11,371
FRS 5-year average adjusted for 5% non-response	7979	3961	11,939
31 surveyed owners' total 5-year average (1998–2002)	6493	3789	10,282
Ratio of surveyed total to adjusted FRS 5-year average	0.81	0.96	0.86
Scaling factor	1.23	1.05	1.16

Table 4
Angler days estimated from fishery owner and angler questionnaire responses in 2003, and the implied response rate from anglers.

	Angler days from owners	Scaled angler days from owners	Angler days from anglers	Response rate (%)
Salmon and sea trout	34,917	40,544[1]	5861	15
Rainbow trout	8186	8186[2]	552	7
Brown trout	3047	4814[3]	834	17
Pike	859	1202[4]	177	15
Total		54,746	7424	15

Fishery owner estimates are scaled according to the approach described in Methods.
Scaling factors: [1] 1.16; [2] no scaling factor required; [3] 1.58; [4] 1.4.

Table 5
Angler days categorised according to angler origin and the species targeted.

	Salmon and sea trout	Rainbow trout	Brown trout	Pike	All species
Spey catchment	6386	1871	1910	300	10,467
Rest of Scotland	7805	3273	1562	603	13,243
Outside Scotland	26,353	3042	1342	299	31,036
All anglers	40,544	8186	4814	1202	54,746

Table 6
Gender and age characteristics of anglers (N) responding to the angler survey in 2003.

	Salmon and sea trout (N = 277)	Rainbow trout (N = 30)	Brown trout (N = 51)	Pike (N = 14)	All species (N = 372)
Gender (%)					
Male	91	93	86	100	91
Female	9	7	14	0	9
Age (%)					
<18 years	0	3	0	0	<1
18–25 years	1	7	4	14	2
26–45 years	17	30	24	29	19
46–60 years	42	33	49	43	43
>60 years	40	27	23	14	35

Anglers were categorised according to the species targeted.

and sea trout production combined averaged 447,063 smolts (range 264,130–779,988). Comparable data on the production of brown trout or pike are not available.

The 5-year average adjusted annual catch of salmon and sea trout in 1998–2002 was 11,939 (Table 3). We used this figure to infer the average gross output annum^{-1} generated by each rod-caught salmon and sea trout. Without catch records for brown trout, rainbow trout or pike it was impossible to do the same for these species.

4. Results

4.1. Angler effort

Having scaled for owners' non-response for each fishery species, a total of 54,746 angler days was calculated (Table 4). Of these, 40,544 (74%) were targeted at salmon and sea trout. The next most important fishery was rainbow trout, followed by brown trout and pike. There were 372 responses to the anglers' questionnaire survey, with 277 from salmon and sea trout anglers, 30 from rainbow trout anglers, 51 from brown trout anglers and 14 from pike anglers. By comparing total angler days from these responses with the total derived from owner surveys, the angler response rate was estimated at 15% overall, and 15% for salmon and sea trout (Table 4).

4.2. Angler characteristics

The majority of angler days were derived from anglers originating outside Scotland (57%; Table 5). This was largely driven by the high numbers of salmon and sea trout angler days generated by these fishermen (26.353), representing 48% of all angler days.

Anglers in all fisheries were predominantly male and aged between 46 and 60 years (Table 6). Of note was the high representation (82%) of salmon and sea trout anglers aged either 46–60 or >60 years.

4.3. Angler expenditure estimates for fishery species

Salmon and sea trout anglers had the highest average expenditure of £228 day^{-1}, and among them anglers visiting from outside Scotland spent the most (£304 day^{-1}; Table 7). By comparison anglers for rainbow trout, brown trout and pike spent £52, £72 and £38 day^{-1}, respectively. All anglers combined spent an average of £193 day^{-1}.

On average, fishing rents and permits was the major item of daily expenditure, followed by accommodation and food (Table 8). For salmon and sea trout anglers, rents or licenses were the greatest expense (£94 day^{-1}), while for brown trout, rainbow trout and pike they were comparatively low (£15, £16 and £1 day^{-1}, respectively).

Table 7
Average expenditure (£ day^{-1}) of anglers (N) in 1998–2002, differentiated by origin and the species targeted.

	Salmon and sea trout (N = 277)	Rainbow trout (N = 30)	Brown trout (N = 51)	Pike (N = 14)	All species (N = 372)
Spey catchment	122.51	26.33	34.84	37.44	97.32
Rest of Scotland	250.14	45.10	79.24	37.90	89.45
Outside Scotland	304.10	156.28	126.91	39.17	285.17
All anglers	228.44	51.80	71.82	37.79	193.17

Table 8
Average expenditure (£ day^{-1}) by category of anglers (N) in 1998–2002, differentiated by the species targeted.

	Salmon and sea trout (N = 277)	Rainbow trout (N = 30)	Brown trout (N = 51)	Pike (N = 14)	All species (N = 372)
Accommodation and food	87.46	17.63	34.09	16.85	74.59
Fuel and transport	14.89	11.14	11.40	4.10	13.96
Fishing rents and permits	94.48	15.46	16.13	0.62	77.56
Equipment	19.96	6.88	9.26	15.44	17.68
Ghillie or guide	11.65	0.69	0.94	0.78	9.38

Table 9
Total expenditure (£ annum^{-1}) by anglers, differentiated by origin and the fishery species targeted.

	Salmon and sea trout	Rainbow trout	Brown trout	Pike	Total
Spey catchment	782,349	49,263	66,544	11,232	909,388
Rest of Scotland	1,952,374	147,612	123,773	22,787	2,246,546
Outside Scotland	8,013,947	475,404	170,313	11,712	8,671,376
Total	10,748,670	672,279	360,630	45,731	11,827,310

Anglers' total expenditure was estimated by combining Tables 5 and 7. Total angler expenditure was £11.8 million annum^{-1}, of which salmon and sea trout anglers generated £10.8 million annum^{-1} (Table 9). Of this, £8.0 million annum^{-1} (75%) was generated by anglers originating from outside Scotland. Rainbow trout anglers generated £0.7 million, brown trout anglers £0.4 million, and pike anglers <£0.1 million annum^{-1}.

4.4. Substitution effects on expenditure

If rod and line fisheries for all species were no longer available, the catchment's economy would lose £9.8 million annum^{-1} of angler expenditure (Table 2). If salmon and sea trout alone became unavailable, the losses would be £9.4 million annum^{-1} to the catchment.

4.5. Multiplier effects

Applying the CogentSI model, rod fisheries generated a gross output of £12.6 million annum^{-1} which supported 420 FTEs in the catchment (Table 10). The majority (£11.6 million and 401 FTEs) were generated by the salmon and sea trout fishery. Adjusting for substitution effects, £10.9 million annum^{-1} and 366 FTEs would be lost to the local economy if rod fisheries were unavailable, of which £10.1 million annum^{-1} and 350 FTEs were contributed by salmon and sea trout.

4.6. Inferred values of nursery habitat, salmon smolts and rod caught fish

Based on the gross output from salmon and sea trout fisheries of £11.6 million annum^{-1}, and a 5-year average adjusted annual catch of 11,939, rod-caught salmon and sea trout generated approximately £970 fish^{-1} in the catchment. This equates to £26 smolt^{-1} and £1 m^{-2} annum^{-1} for riverine nursery habitat.

5. Discussion

There have been two previous studies of the economic impact of salmon and sea trout rod fisheries in the Spey catchment, by TRRU (1982) and Mackay Consultants (1989). From a questionnaire survey of fishery owners and angler interviews TRRU estimated a total expenditure of £16.6 million annum^{-1} (2003 prices), based on 62,230 angler days and an angler expenditure of £267 day^{-1}. Mackay Consultants used similar methods and estimated a total expenditure of £9.7 million annum^{-1} (2003 prices), 62,100 angler days and expenditure of £141 day^{-1}. By comparison our result of £10.8 million annum^{-1} total expenditure, 40,544 angler days and £228 day^{-1} expenditure deviates from both to varying extents. TRRU (1982) and Mackay Consultants (1989) do not provide sample sizes of owners and anglers they surveyed, which if small may have generated some of the variations in angler expenditure.

The decline in angler days from 62,100 in 1989 to 40,544 in 2003 has a clearer explanation. During the 1990s, spring-running salmon stocks in Moray Firth rivers declined due to elevated marine mortality (Butler et al., 2008). In response the Spey DSFB recommended that owners should conserve stocks by either delaying the start of the fishing season or curtailing fishing effort during February–May. In addition, bait fishing restrictions were introduced which may have deterred some anglers. This reduction in angler effort should be taken into account when interpreting salmon and sea trout catches for this period.

Our study has included rod fisheries for rainbow trout, brown trout and pike, which were not considered in the TRRU and Mackay Consultants' surveys. However, the economic impact of these fisheries is minimal relative to salmon and sea trout. Of an estimated total of 54,746 angler days, only 14,202 (26%) were derived from rainbow trout, brown trout or pike fisheries. Combined with low average daily expenditure for these species (£52, £72 and £38 day^{-1}, respectively) resulting partly from the lesser

Table 10
Total Spey catchment gross output (£ annum^{-1}) and full time equivalent jobs (FTEs) having applied the CogentSI model to (a) expenditure by anglers and (b) including substitution effects.

	Salmon and sea trout	Rainbow trout	Brown trout	Pike	Total
(a)					
Gross output (annum^{-1})	11,549,005	623,136	364,070	40,883	12,577,093
FTEs	401	7	10	2	420
(b)					
Gross output (annum^{-1})	10,085,746	453.768	307,421	34,280	10,928,236
FTEs	350	5	9	2	366

expense of rents or permits, the total estimated expenditure was £1.1 million annum^{-1}.

As for previous studies our results are estimates, and there are several sources of potential error. Although 76% of salmon and sea trout fishery owners responded to the questionnaire survey, a scaling factor was required to account for non-response, based on catch return rates to FRS. We assumed that the 5% of owners who did not provide returns to FRS had average catches equivalent to all other Spey fisheries. However, if their catches were lower than average we have overestimated the scaling factor, and therefore angler days, expenditure and economic impact. The reverse is also possible. A cruder calculation of scaling factors was necessary for brown trout and pike, based on the proportion of potential trout and pike fisheries reported on by owners relative to known fisheries. However, the error generated from these is unlikely to impact greatly on our results due to the limited amount of angler expenditure in these fisheries. Furthermore, angler expenditure was assessed from a modest overall questionnaire response rate of 15% of total angler days, and 15% of salmon and sea trout angler days. Also, it was impossible to calculate the number of anglers visiting the Spey, and the species they targeted. Hence we could not calculate the angler response rates, nor the level of non-response bias and its potential effect on our results.

As a consequence the gross output derived by the CogentSI multiplier model is also only a broad estimate. Gross output and the contribution to household incomes from all fisheries was £12.6 million annum^{-1}, generating 420 FTEs. Of this £11.6 million annum^{-1} and 401 FTEs were produced by salmon and sea trout fisheries. Unfortunately it was not possible to compare the impact of rod fisheries with other sectors such as whisky manufacture, agriculture, forestry or tourism because comparable data are not available at the catchment scale. The only comparison that can be made is with canoeing, rafting and sailing, which in 2003 generated £1.7 million annum^{-1} expenditure from 38,190 activity days, and gross output of £1.7 million annum^{-1}, equating to 48 FTEs in the catchment (Riddington et al., 2004).

This study also made a more realistic assessment of economic impact by estimating substitution effects. This demonstrated that the removal of all rod fisheries would result in the loss of £9.8 million annum^{-1} of angler expenditure, worth £10.9 million annum^{-1} in gross output and equating to 366 FTEs in the catchment. The removal of salmon and sea trout would be most significant, resulting in a loss of £10.1 million annum^{-1}, equivalent to 350 FTEs. This calculation is useful when considering the potential impact of stock collapses. Plausible scenarios include the introduction of the exotic parasite *Gyrodactylus salaris* which could deplete the salmon population to a fraction of its current level and severely curtail the rod fishery (Riddington et al., 2006b), as has occurred in parts of Norway (Johnsen and Jensen, 1986). Collapses in salmon and sea trout stocks have also been evident in regions where marine salmon aquaculture has been introduced (e.g. Butler and Watt, 2003; Ford and Myers, 2008), but currently there is no active marine aquaculture in the Moray Firth (Butler et al., 2008).

From our results we infer that each rod-caught salmon and sea trout contributed approximately £970 fish^{-1} to household incomes in the catchment. Other studies have shown that anglers' marginal utility does not necessarily increase if more fish are caught (e.g. Hundloe et al., 2006; Rolfe and Prayaga, 2006), and hence moderate increases or decreases in catches caused by management actions or natural variations in fish abundance are unlikely to result in marked alterations in angler expenditure, and therefore gross output. There is likely to be a complex relationship between catch, rents charged by fishery owners and angler expenditure, and a contingent valuation study of anglers would be required to fully quantify this on the Spey. Nonetheless it is reasonable to conclude that a change in catch is unlikely to result in a gain or loss in household incomes of exactly £970 fish^{-1}.

From the gross output of salmon and sea trout fisheries we infer that the value of riverine nursery habitat was £1 m^{-2} annum^{-1}. However, the productivity of riverine habitat for juvenile salmonids is not homogenous (Armstrong et al., 2003), and hence this value will vary spatially. For example, juvenile surveys in eastern Scottish rivers show that densities of pre-smolt salmon are highest in streams of 10–20 m wide, and more variable at larger stream widths (Carss and Marquiss, 1998). Furthermore, juvenile sea trout and brown trout densities in the Spey are highest in small streams up to 5 m wide (Spey DSFB, unpublished data). It should be noted that the contribution of marine habitat in the production of rod-caught fish has not been considered, and is effectively included in the inferred value of riverine nursery habitat. Also, we have not included the economic impact of Spey salmon and sea trout caught in net fisheries or other rivers. However, the vast majority of the annual catch of Spey salmon and sea trout is taken within the catchment, and hence the inferred value of riverine nursery habitat is not greatly underestimated.

We also infer that the average value of salmon and sea trout smolts combined was £26 smolt^{-1}. This was estimated from average counts in 2005–2007 when there was a wide range in annual production of salmon and sea trout smolts combined (range 264,130–779,988), indicating a potentially large variation in this value from year to year. Furthermore, these smolt estimates are derived from rotary screw traps sited in the lower main stem, approximately 10 km from the river mouth (Laughton et al., 2008). Hence smolts produced downstream from this site would not have been counted. Also, the traps were removed during peak flows. Consequently smolt outputs have been underestimated, and therefore our value is likely to be a slight over-estimate. As discussed above for riverine nursery habitat, our estimates do not incorporate the economic impact of fish caught in nets or other rivers, but this is unlikely to be significant.

Because our values are inferred from angler expenditure, which may be insensitive to marginal changes in catches and underlying fish abundance, they are only useful in certain circumstances. As presented in this study, they enable a comparison of the relative utilitarian values of an ecosystem service provided by different fish species within the catchment. The substitution analysis also provides some indication of the potential decrease in angler expenditure and economic output in the event of a collapse in fish stocks. The economic impact of rod caught salmon and sea trout could also be compared with that of fish caught in commercial net fisheries to inform management decisions on the relative economic benefits of rod and net fisheries (e.g. Mackay Consultants, 1989; Kennedy and Crozier, 1997; Indecon, 2003).

Because habitat and smolt values were also inferred from angler expenditure it is therefore not realistic to assume that the loss of 1 m^2 of salmon and sea trout nursery habitat will reduce household incomes in the catchment by £1 m^{-2} annum^{-1}. Similarly the addition of one smolt would not necessarily increase household incomes by £26 smolt^{-1}. For cost-benefit analyses involving nursery habitat and juvenile recruits it is more appropriate to apply the replacement cost method which evaluates the cost of man-made substitutes for ecosystem services lost (de Groot et al., 2002; Soderqvist et al., 2005). For example, in compensating for the impacts of predators such as fish-eating birds (e.g. Feltham, 1995; Marquiss et al., 1998; Cosgrove et al., 2004) or seals (e.g. Butler et al., 2006), or the introduction of non-native species (e.g. Hickley and Chare, 2004; Winfield and Durie, 2004), the cost of producing replacement juveniles from hatcheries can be used (e.g. Aprahamian et al., 2003, 2004). When examining trade-offs with industrial development such as water abstraction or hydro-electricity schemes which limit juvenile habitat (e.g.

Pillai et al., 2005; Reid et al., 2005), costs of rehabilitating or replacing lost habitat would be more relevant (e.g. Hendry et al., 2003).

It is important to note that there are alternative evaluations of ecosystem services provided by fish species, which cannot be added to economic impact. One measure of utilitarian value is the capital value of rod fisheries, which represents the profit an owner perceives he may gain from a fishery by selling permits. In 2003 prices for private salmon and sea trout rod fishing rights were £7000 and £200 fish^{-1}, respectively (Spey DSFB, unpublished data). With an average catch of 7979 salmon and 3961 sea trout in 1998–2002, the total capital value of rod fisheries for these species alone was approximately £56.7 million. Other measures of utilitarian values which we have not considered are the consumer surplus (i.e. the difference between what anglers would have paid versus the amount paid to fish) and producer surplus (i.e. the profits earned by fishery owners from selling fishing permits). There are also intrinsic, existence values of fish species which we have not investigated. These may be significant for salmon, since this species has been identified as a qualifying species in the Spey SAC, and native fish species contribute to the biodiversity values underpinning the Cairngorms National Park.

This study also highlights the importance and vulnerability of the tourism provided by rod fisheries in the Spey. A high proportion of angler days (48%) were derived from salmon and sea trout fishermen visiting from outside Scotland, and they had the highest daily expenditure (£304 day^{-1}) and generated the greatest expenditure of all types of angler (£8.01 million annum^{-1}). This suggests that much of the expenditure in the catchment will be susceptible to pressures which impact on travel, such as transport costs or air travel safety. Furthermore, most salmon and sea trout anglers were male (91%) and 82% were aged >46 years, emphasizing the importance of marketing to this cohort outside Scotland to maintain numbers of visiting anglers. The predominant source of angler days from outside Scotland also illustrates the risk of the introduction of *G. salaris* on angling equipment used in infected European rivers, one of the potential modes of transmission (Johnsen and Jensen, 1986). The vulnerability of the salmon and sea trout fishery also demonstrates the strategic importance of promoting the availability of the other fisheries in the catchment.

Our study provides an example of evaluating an ecosystem service, recreational rod fisheries provided by fish species and their habitat in a Scottish catchment. This evaluation is based on the economic impact of angler expenditure, and does not consider consumer or producer surpluses, or existence values. We have only inferred values for salmon and sea trout recruits and freshwater habitat due to the lack of equivalent ecological data for brown trout and pike, and these are not as useful for cost-benefit analyses as replacement cost estimates. Consequently we acknowledge that our data are partial estimates of the ecosystem service's values. However, they do provide useful information with which to make better-informed management decisions in the Spey catchment through the implementation of the EU Water Framework Directive.

Using benefit transfer the values could also be applicable to other Scottish catchments. In their 2003 national survey Radford et al. (2004) found that anglers' highest daily expenditure occurred in the Highland region, which includes the Spey catchment. Our results show that daily expenditure on the Spey was greater than this region's average for salmon and sea trout (£228 day^{-1} versus £186 day^{-1}) and brown trout anglers (£72 day^{-1} versus £65 day^{-1}), suggesting that ecosystem service values for these species in the Spey are some of the highest in the country. Any transferal of these and the inferred smolt and habitat values to other catchments in Scotland, or to national evaluations of ecosystem services (e.g. Williams et al., 2003) should take this into account.

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