VIKING WIND FARM, SHETLAND:

BASELINE ASSESSMENT OF FISH POPULATIONS

Waterside Ecology
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SUMMARY

Introduction and aims
The Viking Energy Partnership is developing a proposal for a 540MW, 150 turbine wind farm on Mainland, Shetland. During the construction of the proposed wind farm there will be physical disturbance to soils including removal that may alter the hydrological characteristics of the site. Soil exposure during construction may pose the risk of inputs of suspended solids to watercourses, causing siltation or sedimentation. Several of the streams will be directly affected by construction of track crossings. Impacts such as sedimentation or pollution may have consequences some distance downstream from the point source.

The aim of the work reported herein was to undertake a survey of freshwater fish in watercourses potentially affected by the proposed wind farm development. The fish survey describes the distribution and abundance of fish species at catchment level within streams that (i) will have turbines constructed within the catchment and/or (ii) will be crossed by new access tracks. Sites locations were chosen both to provide information on the distribution of fish in streams and to provide a baseline for monitoring.

Methods
Surveys were conducted on 11 catchments during late August and early September 2008. Data on absolute salmonid abundance were collected at a series of fully quantitative electric fishing sites (n=19), sampled by depletion methods. Excepting the Wester Filla Burn, at least one fully quantitative survey was carried out in each catchment, with more than one on the larger streams. As collecting fully quantitative data is time consuming an additional series of semi-quantitative sites (n=41) was surveyed in order to widen coverage and provide additional data on abundance. Correction factors for trout and salmon were calculated from fully quantitative data, allowing estimates of absolute fish abundance to be made at semi-quantitative survey sites. A small number of qualitative (presence versus absence) surveys were also conducted (n=6) in order to increase data on fish species distribution.

Non-salmonid species were counted at all survey sites, although it was not always practical to capture them. The SFCC Electric Fishing protocols suggest that where eels are not captured their number during the first electric fishing run through a site should be recorded. This procedure was followed for non-salmonid species at all sites.

All fish captured were held in covered bins prior to processing. Fish were anaesthetised using 2-phenoxy-ethanol to ease handling. Salmon and trout were identified and scored separately and counts of non-salmonids were recorded. Fork length of trout and salmon was measured to the nearest 1mm. Salmon and trout scales were collected to assist with age determination. Fish were allowed to recover fully in clean water before being released back into the survey reach.

Fish densities and error estimates at multiple run sites were calculated using the programme REMOVE (Clarke 1989). At single run sites minimum densities for fry and parr were estimated as number of fish caught divided by area. All densities are expressed as fish per 100 square metres (fish.100m^{-2}).

Main Findings
- Five species were identified in the 11 streams surveyed: European eel *Anguilla anguilla*, Atlantic salmon *Salmo salar*, brown and sea trout *Salmo trutta*, three-spined stickleback *Gasterosteus aculeatus* and flounder *Platichthys flesus* (Table I).

- Trout were present in all catchments surveyed. Trout fry density varied greatly between and within catchments (Table II), but parr density in most was fair or good by national standards (National Rivers Authority Fisheries Classification Scheme).

- A weak trout fry year class was apparent in some streams. This may be an artefact of site selection but equally may reflect year-to-year changes in recruitment. The spring and summer of 2008 were unusually dry, potentially affecting fry survival prior to survey.

- Trout abundance at several sites was affected by the presence of stocked fish. These were not always identifiable in the field.

- Salmon were present in only two catchments and densities were poor. One-year-old parr were identified in the Burrafirth catchment but fry were absent, suggesting sporadic spawning. Both fry and 1+ parr were present in the Laxo catchment, but numbers were low and distribution restricted.

***Table I**. Species occurrence by catchment.*

Catchment	Survey sites (n)	Eel	Trout	Salmon	3-spined stickleback	Flounder
Laxobigging	8	X	X			
Skella Dale	4		X			
Wester Filla	2		X			
Laxo	13	X	X	X	X	
Grunnafirth	5	X	X			
Crookadale	3	X	X			
Quoys	7	X	X			X
Kirkhouse	3		X			
Sandwater	3	X	X		X	
Weisdale	3	X	X			
Burrafirth	15	X	X	X		X

***Table II.** Mean density of trout and salmon by catchment (correction factors applied).*

Catchment	DENSITY ESTIMATE (fish.100m^{-2})			
	Trout		Salmon	
	0+	*1++*	*0+*	*1++*
Laxobigging	12.0	14.8	0.0	0.0
Skella Dale	4.4	12.8	0.0	0.0
Wester Filla	103.8	17.1	0.0	0.0
Laxo	38.5	14.1	0.5	0.5
Grunnafirth	6.4	12.0	0.0	0.0
Crookadale	20.8	9.0	0.0	0.0
Quoys	1.6	7.6	0.0	0.0
Kirkhouse	11.0	6.6	0.0	0.0
Sandwater	23.8	4.3	0.0	0.0
Weisdale	18.0	20.2	0.0	0.0
Burrafirth	21.8	9.4	0.0	0.9

1 INTRODUCTION

1.1 Aims

The aim of this work was to undertake a survey of freshwater fish in selected watercourses, in relation to a planning application for the proposed Viking Wind Farm, Mainland, Shetland. The survey identified fish species present at a series of electric fishing sites and provided quantified data on the abundance of trout *Salmo trutta* and Atlantic salmon *Salmo salar*.

1.2 Background

The Viking Energy Partnership (a partnership between Scottish & Southern Energy and Viking Energy Limited) is developing a proposal for a 540MW, 150 turbine wind farm on Mainland, Shetland. The planning application will be accompanied by an Environmental Statement (ES), part of which includes this report, detailing the findings of a survey of freshwater fish in catchments potentially affected by the wind farm development.

Surveys of the aquatic environment, including fish, are required to inform the environmental assessment of the proposed wind farm. The freshwater streams of Shetland are important spawning areas for sea trout and brown trout, the mainstay of local recreational fisheries. Salmon have also been recorded in several Shetland streams, including some that drain the core wind farm area. Concerns were raised during the consultation process about the potential for impacts on watercourses, mediated via changes in water quality, particularly siltation and increased levels of suspended solids.

1.3 Fish distribution in Shetland

In comparison with mainland Scotland, Shetland supports a very limited range of freshwater fish species. Davies *et al* (2004) list only eight species: European eel *Anguilla anguilla*, rainbow trout *Oncorhynchus mykiss* (an introduced species), Atlantic salmon, brown and sea trout, Arctic charr *Salvelinus alpinus*, three-spined stickleback *Gasterosteus aculeatus*, nine-spined stickleback *Pungitius pungitius* and flounder *Platichthys flesus*. Laughton Johnston (2002) suggests that lampreys (either *Lampetra spp*. or *Petromyzon marinus*) may also be present. However, there is no evidence for this. The national survey of lampreys during 2003-04 identified no records of lampreys from Shetland and none were found during a survey of seven streams (Watt & Ravenscroft 2005). Table 1 summarises the known distribution of each species in central mainland Shetland, based on Davies *et al* (2004) and records accessed via the National Biodiversity Network (NBN) Gateway.

Table 1. *Occurrence of freshwater fish in central mainland Shetland (based on D.A.F.F. data accessed via NBN Gateway)*

Species	Known or likely occurrence within study area
Eel	Widely distributed within study area.
Brown/sea trout	Widely distributed within the study area.
Atlantic salmon	Previously recorded in: Burn of Weisdale, Burn of Sandwater, Burn of Kirkhouse, Laxo Burn, Burn of Grunnafirth, Burn of Lunklett (Burrafirth).
Rainbow trout	Not known within the study area.
Arctic char	Not known within the study area. On Shetland, known only from Loch of Girlsta.
Three-spined stickleback	Recorded in all 10km grid squares covering study area (10km square resolution only).
Nine-spined stickleback	Not recorded in study area. Single record from 10km square HU50.
Flounder	Likely to be widely distributed in lower reaches of accessible streams.

1.4 Priority species for survey

Salmonids i.e. salmon and trout were considered the primary target for quantified survey. This was due to (i) their recreational and commercial value for sport fishing by local and visiting anglers (ii) the statutory status of Atlantic salmon. It was also considered important to collect quantified data on eels, due to current concerns over rapid declines in eel stocks.

Atlantic salmon are widespread in northern and southwestern Britain, but absent from large areas of south England due to poor water quality, barriers and habitat degradation (Davies *et al* 2004). Adult populations have declined throughout the salmon's north Atlantic range over the last ten to twenty years due to a reduction in marine survival (O' Maoileidigh 2002). In addition, the species is threatened throughout its range by pollution, over-exploitation, fish farming, habitat degradation, barriers to migration, predation and mis-management such as inappropriate stocking (Hendry & Cragg-Hine 2003). The Atlantic salmon is listed under Annex II of the Habitats and Species Directive. Salmon are also listed under the Bern Convention and the UK Biodiversity Action Plan.

The brown trout is distributed throughout the Atlantic, North, White and Baltic sea basins of Europe, from Spain to Russia. The species occurs both as freshwater resident forms (brown trout) and anadromous forms (sea trout). Although locally common, populations of brown trout and sea trout have declined in many areas due to pollution, disease and habitat degradation. Brown trout genetics are poorly understood but it is clear that numerous genetically distinct sub-populations exist. Unfortunately the phylogeographic structure of trout populations has been affected by stocking (Kottelat & Freyhof 2007) and many unique races may already have been lost (Antunes *et al* 1999). It has been proposed that brown trout be included on an updated UK BAP list (Biodiversity Reporting & Information Group 2007). The proposed list suggests that priority actions for trout are primarily research into taxonomy and ecology. Brown trout and sea trout are widespread in Shetland, although the sea trout stock component has declined significantly in recent decades.

Eel populations are currently in rapid decline throughout the Atlantic region, for unknown reasons. ICES consider that the European eel stock is outside safe biological limits. In September 2007 the European Union issued regulations (Council Regulation (EC) No 1100/2007) intended to underpin recovery of the stock of the European eel. The regulation requires member states to produce Eel Management Plans to reduce anthropogenic mortalities of eels. Target escapement of silver eel biomass is at least 40% of the escapement that would have been expected if no anthropogenic influences had impacted the stock. In addition, the eel is due to be listed on Appendix II of CITES from March 2009, limiting trade in eels from the EU to the rest of the world.

1.5 Salmon, trout and eel habitat requirements

The physical habitat requirements of juvenile salmonids have been subject to a considerable amount of detailed study; Crisp (1993), Hendry & Cragg-Hine (1996) and Summers *et al*. (1996) provide useful reviews. Habitat requirements are briefly summarised below and in Table 2, based on these reviews.

Female salmonids deposit their eggs in redds, which they excavate in gravel runs and the tails of pools. A good supply of oxygen is essential for eggs to develop and this is facilitated by a flow of water through the gravel bed. Clogging with fine sediment such as silt and fine sand reduces water flow resulting in egg mortality from lack of oxygen. Egg survival is also affected by redd 'washouts' during winter spates – the direct,

physical, scouring out of eggs from the gravel. Substrate stability, the dynamics of water flow and the weather all determine the extent of siltation and washouts.

After hatching the young fry disperse from the redds and set up territories. Salmon fry prefer fast flows (>30 cm/s) and favour areas with surface turbulence (riffle habitat). They require a rough bed of pebble, cobble and gravel. Trout fry often use slower flowing areas than salmon fry. Good cover is essential for maintaining high trout densities.

Salmon that have survived their first winter (parr) prefer deeper water (15-40cm) and a coarser substrate than fry, consisting of pebbles, cobbles and boulders. Cover is important to attaining high densities of juvenile salmon as they are territorial. Territorial aggression is reduced when parr are visually isolated from one another e.g. by boulders. During the winter juvenile salmon may leave shallow, fast flowing areas to seek shelter in deeper water. This is probably a response to poorer swimming performance resulting from low temperatures. Trout parr generally occur is slower flows than salmon parr. Cover is again essential and trout are often to be found along the banks of stream and rivers beneath undercuts, among tree roots or in marginal vegetation.

Adult salmon and trout require deeper water than do juveniles. Pools and deep glides are important resting areas for upstream migrating fish. Cover remains important for adult salmon, particularly in smaller streams. In larger rivers cover is less important as deep water provides refuge.

Vegetation in the riparian zone may play an important role in the ecology of a river and hence the habitat it provides for fish. Vegetation provides shade, reducing extremes of temperature in summer. It also provides energy through leaf fall, insect drop and dissolved nutrients, fish cover via roots and overhanging boughs and stabilises the stream banks and channel from erosion. Rivers are dynamic by nature and a degree of erosion and change is entirely normal. Indeed, the downstream movement of gravel and pebble is important to maintaining spawning and nursery habitats for fish. However, unnaturally high or low levels of erosion or sediment transport can have serious consequences for fish and their habitat.

Table 2. *Summary of habitat preferences of salmon and trout*

Life stage	Parameter	Preferred habitat	
		Salmon	**Trout**
Spawning	*Substrate*	Stable, not compacted. Mean grain size up to 80 mm. Fines<20%.	Similar to salmon but mean grain size usually 10 – 40 mm.
	Flow	20 – 50 $cm.s^{-1}$ up to twice female body length in $cm.s^{-1}$.	Generally 20-50 $cm.s^{-1}$, up to twice female body length in $cm.s^{-1}$.
Fry	*Substrate*	Pebble, cobble and gravel.	Variable, but cover essential.
	Flow	Fast flowing, 50-70 $cm.s^{-1}$	0-20 $cm.s^{-1}$
	Depth	<20 cm.	10-40 cm.
Parr	*Substrate*	Cobble and boulder.	Variable, but cover essential.
	Flow	Fast, 50-70 $cm.s^{-1}$	Slow, 0-20 $cm.s^{-1}$
	Depth	10-40 cm.	20-60 cm.

European eels are catadromous i.e. resident in freshwater but migrating to sea to spawn. Young elvers enter rivers in late winter and spring, migrating into all kinds of fresh waters. They do not migrate directly to the headwaters of all streams, but gradually disperse to become distributed through all suitable waters. Their dispersal capabilities are astounding, and they have been known to scale dam walls or crawl through damp grass during their migrations. The freshwater niche of the European eel is very broad and consistent eel-habitat relations are difficult to identify. Anguillid eels

appear to be generalists that are tolerant of and adaptable to a wide range of habitats under different conditions (Wiley *et al* 2004). Tesch (1977) suggests that so long as temperature and oxygen requirements are met, there are few stretches of water that are not suitable for eels. The main requirement for eels is cover, as they are averse to light and require suitable refuges during daylight hours. Eels of different size show different substrate preferences. Larger eels require large hollows, crevices or weed beds whereas small eels are sometimes abundant in cobble substrates, as they can burrow between the stones. Tree stumps, roots and other large structures provide ideal cover for eels. Eel diet is diverse, but the majority of diet consists of benthic invertebrates (Moriarty 1978; Kottelat & Freyhof 2007).

The three-spined stickleback is widespread in Scotland, including the Northern Isles. It exists as both a marine and a freshwater race. The marine race exhibits greater development of its external, bony plates and spines than the freshwater race (Maitland & Campbell 1992). The three-spined stickleback is considered to be one of the original post-ice age colonisers of Scottish streams, along with salmon, trout and eels. Three-spined sticklebacks may exist in a wide range of habitats, often favouring slow flowing reaches with abundant vegetation. They feed on insect larvae and zooplankton.

The flounder is generally regarded as a marine species, but is in fact quite common in the lower reaches of many rivers. It has been caught up to 50km inland in Loch Lomond (Maitland 2007). Young flounders often move into freshwater for a year or two before migrating back to sea. Flounders are commonly found over sandy substrates and feed on a wide variety of invertebrates. The diet of young flounders in freshwaters consists of worms, insects and molluscs.

2 METHODS

2.1 Rationale

During the construction of the wind farm there will be physical disturbance to soils including removal that may alter the hydrological characteristics of the site. As a result of soil exposure during construction, there is a potential risk of inputs of suspended solids to watercourses, causing siltation or sedimentation. In addition, particularly during construction, potential sources of pollution will be present on the site. Many of the stream that will be directly affected by construction e.g. by track crossings are tiny, possibly supporting few fish. However, impacts such as sedimentation or pollution may have consequences for fish some distance downstream from the point source. Therefore the survey was designed to describe the distribution and abundance of fish species at catchment level within streams that (i) will have turbines constructed within the catchment and/or (ii) will be crossed by new access tracks.

2.2 Site selection

2.2.1 Survey streams

Streams selected for survey are listed in Table 3 and shown on Figures 1 to 3.

***Table 3**. Catchments for survey and proposed number of survey sites.*

Catchment and major tributaries	Number of survey sites		
	Quantitative	*Semi-quantitative*	*Qualitative*
B. Laxobigging, North Burn, B. of Westerbutton, B. of Easterbutton	3	5	0
B. of Skelladale	1	3	0
Wester Filla	0	2	0
Laxo Burn, Gossawater, Easter Filla, Seggie	4	7	2
B. of Grunnafirth, B. of Forse	2	3	0
B. of Quoys	1	2	0
B. of Crookadale	1	4	2
B. of Kirkhouse	2	1	0
B. of Pettawater	1	2	0
B. of Weisdale	1	2	0
Burrafirth, South B. of Burrafirth, B. of Atlascord, Marrofield Water, B. of Lambawater, B. of Lunklet	3	10	2
TOTAL	**19**	**41**	**6**

2.2.2 Site selection within streams

Sites locations were chosen to (i) provide information on the distribution of fish in streams potentially impacted by the proposed development (ii) provide a baseline for monitoring potential downstream effects resulting from construction or operation of the wind farm. Sites were chosen to be representative of salmon and trout habitats in each catchment, based on the results of the visual inspections. Site locations for each quadrant are shown on Figures 1 to 3. A full list of survey sites is provided as Appendix 1. Site photographs are submitted electronically with this report along with detailed data on substrate, flow, depth and bank-side vegetation at each site. Copies are held by Waterside Ecology and can be provided on request.

2.3 Electric fishing

2.3.1 Survey types

The survey was intended to provide data on both fish abundance and fish distribution. Data on absolute salmonid abundance were collected at a series of fully quantitative

Figure 1. *Survey sites Delting and Collafirth. Closed circles are fully quantitative survey sites, open circles semi-quantitative.*

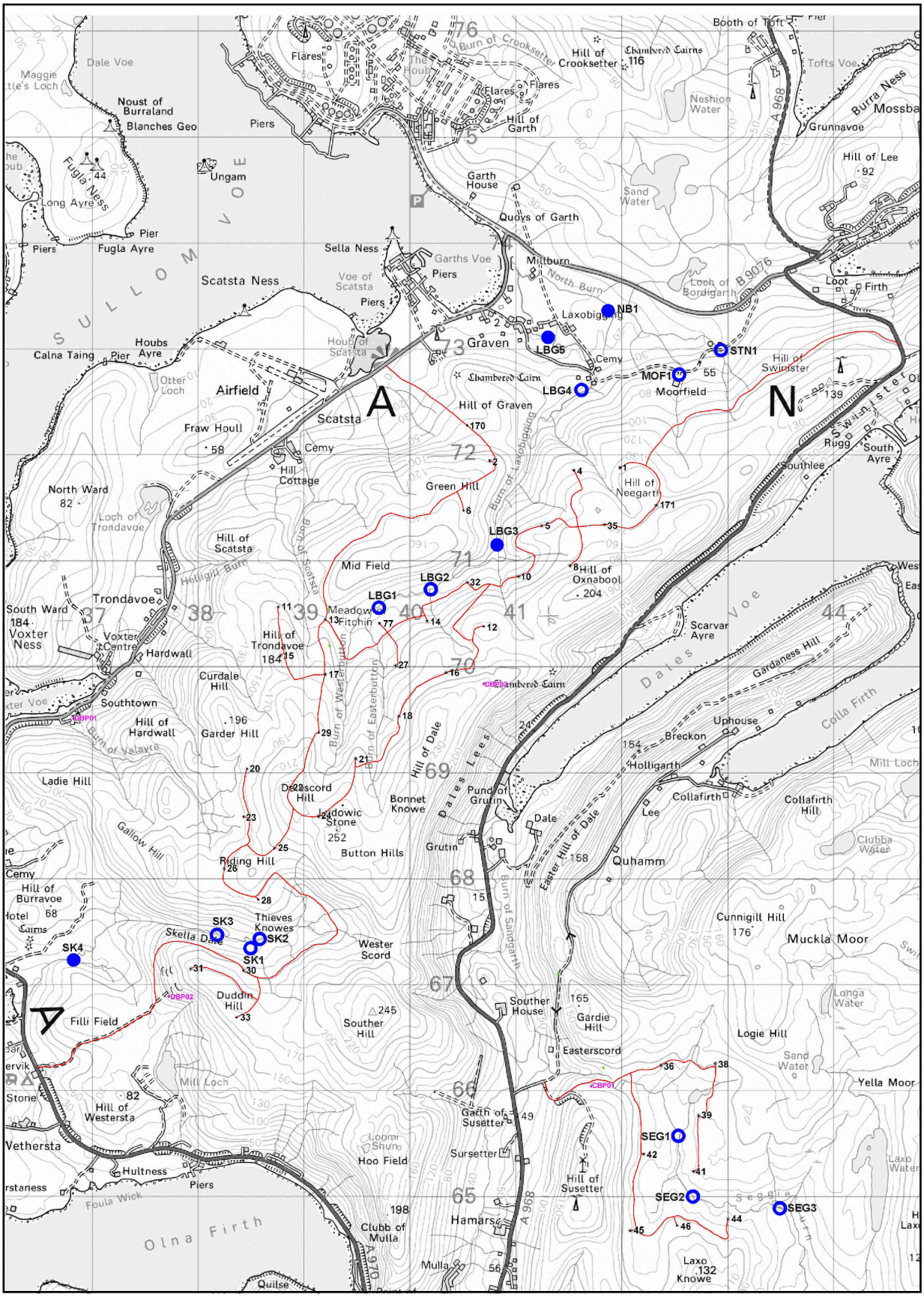


***Figure 2.** Survey sites Nesting. Closed circles are fully quantitative sites, open circles semi-quantitative, open triangles qualitative.*

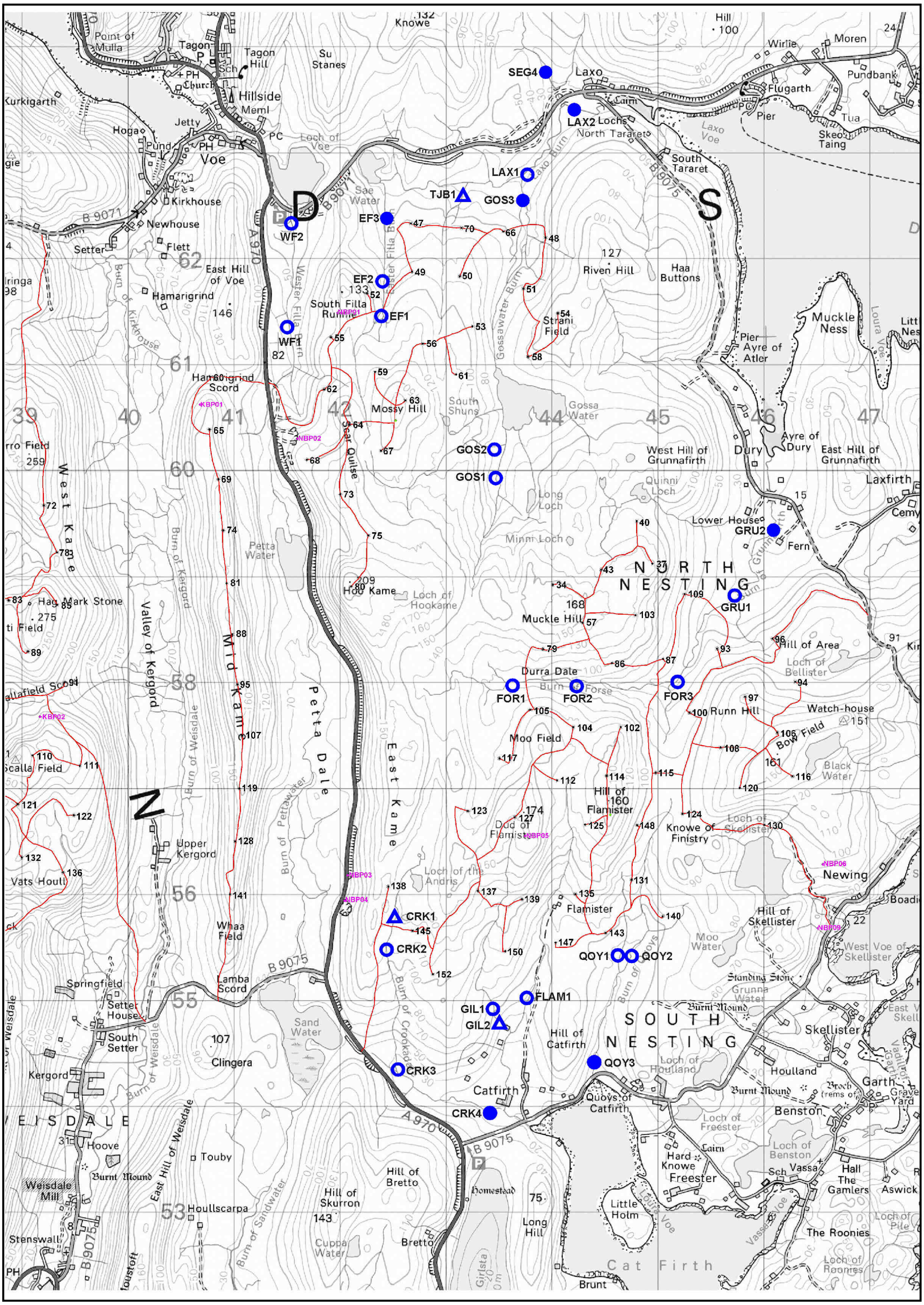
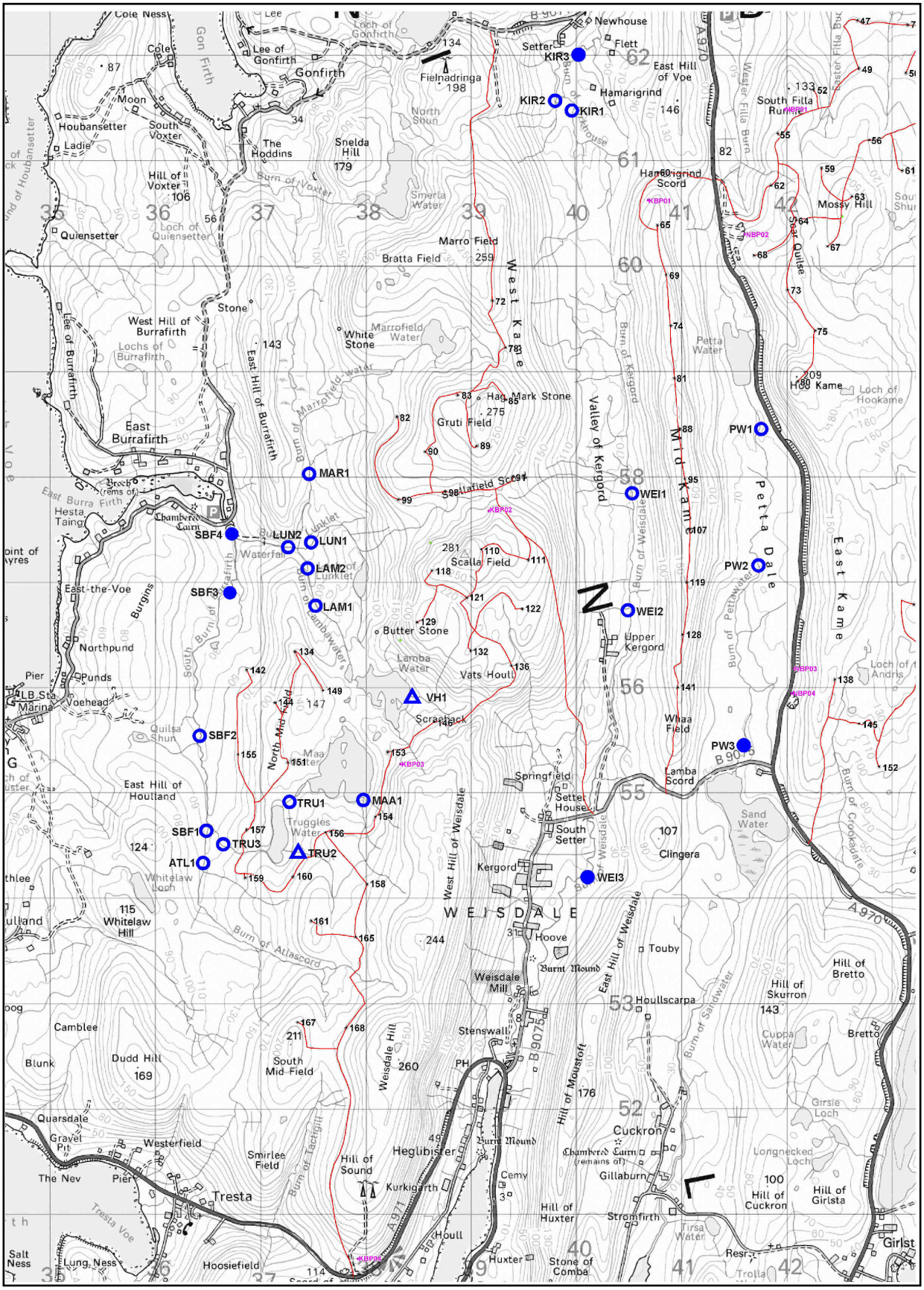


Figure 3. *Survey sites Kergord. Closed circles are fully quantitative sites, open circles semi-quantitative, open triangles qualitative.*



electric fishing sites (n=19). At least one fully quantitative survey was carried out in most survey streams, with several on the larger streams. As collecting fully quantitative data is time consuming an additional series of semi-quantitative sites (n=41) were surveyed in order to greatly widen coverage. Correction factors for trout and salmon were calculated from fully quantitative data to allow estimates of absolute fish abundance to made at semi-quantitative survey sites (see below). A small number of qualitative (presence versus absence) surveys were also conducted (n=6).

Non-salmonid species were counted at all survey sites, but it was not always practical to capture them. For instance, where large numbers of juvenile sticklebacks are present it would be difficult or impossible to capture all of them without significant disruption to salmonid survey. Similarly, where significant numbers of eels are present it may be difficult to efficiently capture both eels and salmonids during the same survey. This creates particularly problems at semi-quantitative sites where a consistent efficiency is required if minimum density data are to be used to infer absolute density (see section 2.3.3). The Scottish Fisheries Co-ordination Centre (SFCC) Electric Fishing protocols (SFCC 2007) suggest that where eels are not captured their number during the first electric fishing run through a site should be recorded. This procedure was followed for non-salmonid species at all sites.

2.3.2 Fully quantitative surveys

Fully quantitative surveys were carried out to SFCC protocols. Sections of stream were isolated using stop nets, to prevent fish from moving in or out of the site during surveys. The length of the survey section was at least five times wet width, much more in narrow streams, and included a variety of habitat types. Each section of stream was fished through at least three times using backpack electric fishing gear. The catch from each run through the site was held and processed separately. Multiple pass fishing allows absolute fish densities to be calculated, based on the decline in catch during successive runs (Zippin 1958).

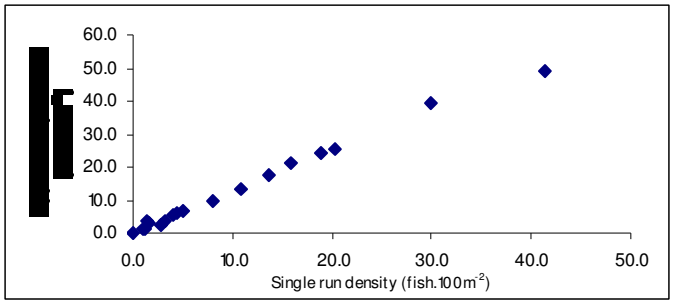
2.3.3 Semi-quantitative surveys

A series of semi-quantitative surveys was also conducted. No stop nets were used at these sites and a single electric fishing run was made through each. Generally, some fish will be missed during single pass electric fishing. The proportion missed depends on a variety of factors including conductivity, water depth, flow, habitat structure and the experience of the survey team. Correction factors for fish density from single run sites are provided in Figure 4. These are based on the relationship between the depletion (Zippin) estimates of absolute density from three-run, fully quantitative sites and the single run minimum density estimates (using only the first run) from those same sites. The data suggest that, as rule of thumb, about 80% of fish were caught in the first run through each site. No correction factor could be calculated for salmon fry as they were present at too few sites, so the correction factor for salmon parr was used.

2.3.4 Fish processing

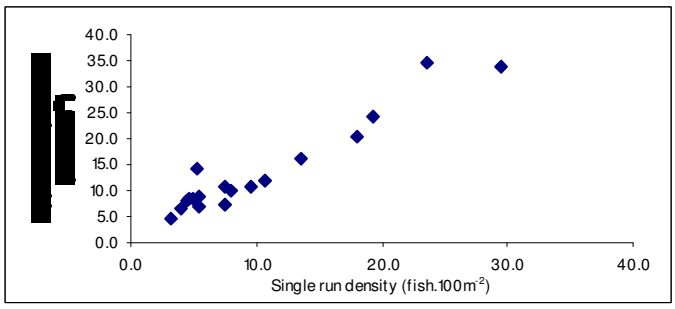
All fish captured were held in covered bins prior to processing. Fish were anaesthetised using 2-phenoxy-ethanol to ease handling. Salmon and trout were identified and scored separately and counts of non-salmonids were recorded. Salmonid fork length was measured to the nearest 1mm. Scales were collected to assist with age determination. Fish were allowed to recover fully in clean water before being released back into the survey reach.

***Figure 4**. Relationship between single-run minimum density and absolute density (Zippin density estimated based on multiple run depletion fishing) for trout fry, trout parr and salmon parr.*



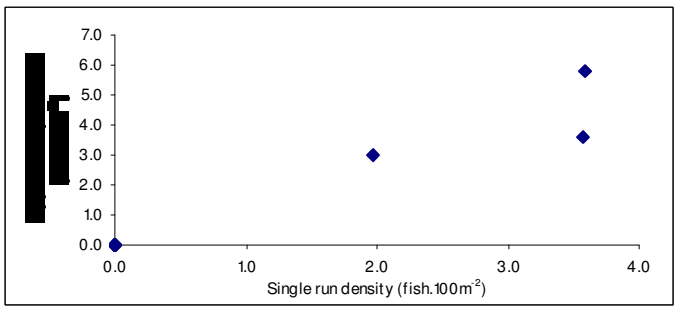
Trout fry

Absolute density = 1.27(minimum density)



Trout parr

Absolute density = 1.27(minimum density)



Salmon parr

Absolute density = 1.33(minimum density)

2.3.5 *Nomenclature and data handling*

Throughout this report, the term fry is used to describe young of the year. These fish are also referred to as 0+ (i.e. fish in their first year of life). Parr is used to describe fish of more than one year. The shorthand terms 1+ and 2+ refer to fish in their second and third year of life respectively.

Data were entered into MS Excel spreadsheets submitted with this report (*Viking fish data 2008.xls*). Fish densities and error estimates at multiple run sites were calculated using the programme REMOVE (Clarke 1989). At single run sites minimum densities for fry and parr were estimated as number of fish caught divided by area. Correction factors relating minimum density to actual density are described above. All densities are expressed as fish per 100 square metres (fish.100m^{-2}).

National Rivers Authority classifications (National Rivers Authority 1994) are used to describe salmonid densities in the text of this report. Thus, for example, if it stated that trout fry abundance in a stream was 'excellent', the density of trout will have been greater than 38 per 100 square metres (Table 4).

Table 4. *NRA National Fisheries Classification Scheme for Atlantic salmon and brown trout*

Classification	Density per 100m^2			
	Salmon fry	**Salmon parr**	**Trout fry**	**Trout parr**
A (excellent)	=>86	=>19.0	>38	>21
B (good)	45.0 – 85.9	10.0 – 18.9	17 - 37.9	12-20.9
C (fair)	23 – 44.9	5.0 – 9.9	8 – 16.9	5 – 11.9
D (fair/poor)	9.0 – 22.9	3.0 – 4.9	3 – 7.9	2 – 4.9
E (poor)	<9.0	<3.0	<3.0	<2
F (fishless)	absent	absent	absent	absent

2.3.6 Survey dates and conditions

Two teams of experienced and qualified surveyors carried out electric fishing surveys between 28th August and 9th September 2008. Surveys were suspended on 1st September due to high water levels. Water levels on all other days were low or only slightly elevated.

2.3.7 Stocking

Shetland Anglers Association regularly stocks trout fry into several of the survey streams. Data on stocking were provided in order to assist interpretation of electric fishing results. Members of the Association pointed out that most stocking is in the lower reaches of streams with good road access and that data at sites greater than 0.5km from road access are unlikely to be affected by stocked fry.

Table 5*. Trout stocking by Shetland Anglers Association.*

Stream	Year	Number of fish stocked
Dury Voe Burn	2007	1500
	2008	1000
East Burrafirth Burns	2007	1100
Burn of Laxo	2007	750
	2008	2000
Sae Water	2006	6000
	2007	2250
Laxobigging Burn	2004	2000
(Mostly below Dam)	2007	3500
	2008	6000
Petta Water and	2006	4000
outlet Burn	2007	1200
Sand Water Loch	2006	9000
	2007	4000
Burn of Skelladale	2003	2000
North Burn of Voe	2007	550

3 RESULTS

3.1 Delting

3.1.1 Burn of Laxobigging

Description and proposed wind farm developments

The Burn of Laxobigging flows northwards to reach the sea in Garths Voe, immediately south of the Sullom Voe oil terminal. It is a moderately sized stream, some 4m wide in its lowest reaches. Shetland Angler's Association considers that the stream is an important sea trout spawning stream (Shetland Angler's Association 2006).

A dam has been constructed at HU417727, about 2km up from the sea. This seems likely to prevent further upstream access for anadromous fish species. The dam was originally constructed to provide a water supply for a military base at Graven/Sullom Voe during WWII. It is thought that it no longer serves any purpose (David Pottinger, Shetland Anglers Association pers. comm.). Approximately 1km upstream from the dam there are two waterfalls at HU411720. The lower waterfall appears passable but the upper fall is a difficult obstacle and may be impassable at most or all flows.

Shetland Anglers Association stocked 3500 trout fry in the area below the dam during 2007 and a further 6000 during 2008.

Proposed turbine sites 1, 2, 5, 6, 8, 10, 12, 13, 14, 16, 18, 21, 24, 27, 29, 32, 35, 170 and 171 fall within the catchment. Stream crossing points (turbine access track) are proposed for the following locations:

- HU402706: Burn of Oxnabool, track between T14 & T32;
- HU396702: Burn of Easterbutton, track between T14 & T13;
- HU397691: Burn of Easterbutton, track between T18 & T21;
- HU394701: Burn of Westerbutton, track between T14 & T13;
- HU424717: Burn of Moorfield, track between T171 and T1;
- HU425723: Burn of Moorfield, track between T1 and A968 road;
- HU430724: Stenswall Burn, track between T1 and A968 road; and
- HU432726Stenswall Burn tributary, ca. – track crossing between T1 and A968 road.

Habitat and survey sites

Good quality juvenile salmonid habitat is present throughout the Burn of Laxobigging, Burn of Easterbutton and Burn of Westerbutton. Spawning areas suitable for both trout and salmon are present in the accessible reaches downstream from the dam. Above the dam, further areas of spawning substrate are scattered along the length of the stream. Patches of trout spawning habitat extend right up into the headwaters of the burns of Eaterbutton and Westerbutton. Young trout were seen in both these streams during a preliminary walkover survey.

North Burn is mainly rather slow flowing. Undercut banks and draped vegetation provide suitable rearing habitat for young trout. While the full length of the burn was not surveyed, those reaches that were examined lacked spawning habitat. North Burn is formed from the Stenswall and Moorfield Burns. These small streams have a few small patches of spawning habitat suited only to trout.

Other tributaries of the Burn of Laxobigging (Burn of Oxnabool, Runnar Burn and Burn of Berdale) are short and steep. Habitat suited to young trout is present only in small sections of the lower reaches of these streams. This and their small size suggest these minor tributaries do not contribute greatly to fish production.

Eight sites were chosen for survey, five in the Burn of Laxobigging and three in the North Burn sub-catchment (Figure 1, Table 6).

***Table 6**. Burn of Laxobigging catchment, survey sites.*

Site Code	Stream	NGR	Survey type	Description
LBG1	B. of Laxobigging	HU3975 7059	SQ	Riffle/runs & pools with gravel & cobble base.
LBG2	B. of Laxobigging	HU4025 7073	SQ	Mixed substrate and flow. Good habitat.
LBG3	B. of Laxobigging	HU4082 7118	FQ	Pools with bedrock - undercuts suited to trout. Riffle and run sections with cobble & pebble.
LBG4	B. of Laxobigging	HU4171 7271	SQ	Mixed habitat with pools and runs.
LBG5	B. of Laxobigging	HU4114 7311	FQ	Decent mixed juvenile habitat with areas suited to salmon and trout.
STN1	Stenswall Burn	HU4292 7296	SQ	Much bedrock. Generally poor fish habitat.
MOF1	B. of Moorfield	HU4257 7276	SQ	Steep, bouldery burn with mossy rocks and little pools suited to trout parr.
NB1	North Burn	HU4188 7337	FQ	Good bank cover. Decent juvenile trout habitat but stream lacks spawning habitat.

Survey types: FQ = fully quantitative; SQ = semi-quantitative.

Fish populations

Fish species present at electric fishing sites were trout and eels. No other species were encountered. Eels were present at seven of eight sites, including the uppermost site LBG1. Trout were present at all sites. Salmon were absent at all survey sites.

Mean density of trout fry and parr (corrected) were 12.0 fish.100m^{-2} and 14.8 fish.100m^{-2} respectively. Densities at site LBG4 were significantly affected by the presence of stocked trout fry. These were clearly identifiable by their large size (compared to wild fry), badly deformed fins and, in many cases, enlarged eyes. Discounting clearly stocked fry would give a density of 9 fry.100m^{-2} at this site and would reduce mean density to 9.7 fry.100m^{-2}. Without stocking, densities of wild fry may have been greater at site LBG4, since it was striking that the smaller wild fry were present only in very shallow edge areas, suggesting displacement by larger stocked fry.

***Table 7**. Trout abundance and number of other fish species, Laxobigging.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
LBG1	10.9	18.1	13.5	23.0	Eels (2)
LBG2	5.2	21.9	6.4	27.8	-
LBG3	1.3	9.5	*1.3*	*10.8*	Eels (3)
LBG4	22.4	9.8	27.8	12.5	Eels (11)
LBG5	13.6	19.2	*17.6*	*24.1*	Eels (23)
STN1	0.0	2.6	0.0	3.3	Eels (2)
MOF1	21.3	8.0	26.4	10.1	Eels (3)
NB1	2.7	5.5	*2.7*	*6.9*	Eels (5)
All sites mean	***9.7***	***11.8***	***12.0***	***14.8***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

3.1.2 Burn of Skelladale

Description and proposed wind farm developments

This is a small stream, approximately 3m wide in its lower reaches, flowing west into Busta Voe, south of the village of Brae. The stream has no major tributaries. It is considered a valuable sea trout spawning stream (Shetland Anglers Association 2006).

The lower 1km of the stream is fast flowing with boulder substrate and is rather unstable. Approximately 0.5km up for the tidal limit at HU365671 there is 2.5m high waterfall. There is deep pool below this and it seems probable that it is passable by larger sea trout and salmon. Around 0.5km above the waterfall there is a section of lower gradient where the stream meanders. Here, deposits of gravel and pebble provide spawning habitat suited to salmon and trout. There is around 0.5km of good quality juvenile salmonid habitat upstream from this area. Further upstream, the gradient increases and the streambed is mainly bedrock. A ≥5m high waterfall at HU376676 is clearly impassable to upstream migrating salmon or trout. Upstream from the waterfall there are long sections of habitat suitable for juvenile trout. Spawning substrates are present. The small stream joining from the south at HU385674 is steep with little spawning potential

Turbines 26, 28, 30 and 31 will be located in the catchment (Figure 1). Five road crossings over upper feeder streams are proposed as follows:

- HU390688: track between T28 & T30;
- HU392676: track between T28 & T30;
- HU393675: track between T28 & T30;
- HU389673: track between T28 & T30;
- HU386671: track crossing T28 & T30.

Four sites were chosen for survey (Table 8), three on the main stem of the Burn of Skelladale and one on the small, unnamed tributary joining from the south at HU385674.

Table 8. *Burn of Skelladale catchment, survey sites.*

Site Code	Stream	NGR	Survey type	Description
SK1	Unnamed tributary	HU3851 6726	SQ	Tiny stream, sometimes running underground. Some pools and shallow runs.
SK2	Burn of Skelladale	HU3856 6741	SQ	Glides, pool and pebbly runs.
SK3	Burn of Skelladale	HU3820 6747	SQ	Some long glide sections with undercut banks.
SK4	Burn of Skelladale	HU3679 6721	FQ	Very stable with boulder cover. Spawning habitat a short distance upstream.

Survey types: FQ = fully quantitative; SQ = semi-quantitative.

Fish populations

The only species captured during electric fishing was trout. Mean density of trout fry and parr (corrected) were 4.4 fish.100m^{-2} and 12.8 fish.100m^{-2} respectively.

Table 9. *Trout abundance and number of other fish species, Burn of Skelladale.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
SK1	0.0	1.9	0.0	2.5	-
SK2	11.1	11.1	13.8	14.1	-
SK3	3.0	11.0	3.7	14.0	-
SK4	0.0	18.1	0.0	*20.5*	-
All sites mean	***3.5***	***10.5***	***4.4***	***12.8***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

By national standards, trout fry density would be classified as fair to poor and parr density as good. The low ratio of fry to parr is striking and is quite consistent across sites, indicating a weak 2008 year class. This is unlikely to be an artefact of site

selection since (i) suitable fry habitat was present at all sites (all sites were at least 40m long with a variety of depth and flow) and (ii) spawning habitat was present near all sites with the exception of site 1.

3.2 Collafirth

3.2.1 Seggie Burn

The Seggie Burn is part of the Laxo Burn system. Data for survey sites on the Seggie Burn are presented within section 3.3.2.

3.3 Nesting

3.3.1 Wester Filla Burn

This is a very small stream with an average width of about 1m. It flows north into Loch of Voe, which is fished for brown trout. Sea trout and salmon do not have access to Loch of Voe or the Wester Filla Burn. Proposed turbines T55 and 62 fall within the catchment of the Wester Filla Burn. Two road crossing are proposed; the first at HU413608 (track A970 road & T62) and the second at HU419609 (track between T55 and T62).

Stream habitats in the Wester Filla Burn consist of numerous little runs, glides and pools. The lower and middle reaches contain excellent spawning habitat for trout in the form of gravel and pebble substrates in pool-tails and glides. Undercut banks with draped heather provide cover for young trout. Two sites were surveyed semi-quantitatively (Table 10).

***Table 10**. Wester Filla Burn, survey sites.*

Site Code	Stream	NGR	Survey type	Description
WF1	Wester Filla Burn	HU4153 6113	SQ	Pools and gravel runs with some boulder & cobble.
WF2	Wester Filla Burn	HU4153 6236	SQ	Shallow gravel and pebbles. Good fry habitat. Spawning habitat present.

Survey types: FQ = fully quantitative; SQ = semi-quantitative.

Fish populations

The only fish species present at survey sites was trout (Table 11). Fry were abundant, consistent with the presence of plentiful, good quality spawning habitat. Mean density of trout fry and parr (corrected) were 103.8 fish.100m^{-2} and 17.1 fish.100m^{-2} respectively.

***Table 11**. Trout abundance and number of other fish species, Wester Filla Burn.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
WF1	55.5	9.4	68.8	12.0	-
WF2	111.9	17.5	138.7	22.2	-
All sites mean	***83.7***	***13.5***	***103.8***	***17.1***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

3.3.2 Laxo Burn

Description and proposed wind farm developments

The Laxo is one of the larger catchments in Shetland; the Laxo Burn itself averaging some 7m in width in its lower reaches. It enters the sea in Laxo Voe, the northwest

extremity of the larger Drury Voe on the east side of Mainland. The catchment is complex with four main sub-catchments: the Seggie Burn, Mill Burn (including Burn of Sandwater and Laxo Water), Gossawater Burn (including Gossa Water, Corgill Burn and Burn of Dale) and Saewater Burn (including Sae Water and the Easter Filla Burn). The catchment is shown on Figure 2.

The Laxo catchment is potentially impacted by developments in the Collafirth and Nesting quadrants. All the Collafirth turbines (T36, 38, 39, 41, 42, 44, 45 and 46) fall within the drainage of the Seggie Burn. Nesting turbines 47 to 51, 53, 54, 56, 58, 59, 61, 63, 64, 66, 67, 70 and 75 fall within the southern part of the catchment, mainly in the drainages of the Gossawater Burn and the Easter Filla Burn. Road crossings are proposed at:

- HU421661: Seggie Burn, between T36 & T42
- HU426662: Seggie Burn, between T36 & T38
- HU428660: Seggie Burn between T38 & T39
- HU422604: Easter Filla Burn between T64 & T67/T63;
- HU424615: Easter Filla Burn between T52 & T49;
- HU430623: Thomas Jamieson's Burn between T47 & T70;
- HU437623: Gossawater Burn minor tributary, between T66 & T48;
- HU438623: Gossawater Burn, between T66 & T48;
- HU439622: Gossawater Burn minor tributary between T48 & T51 and
- HU439618: Gossawater Burn minor tributary between T48 & T51.

Habitat and survey sites

The Easter Filla Burn is the largest tributary of the Saewater Burn. It is a small stream, mainly <2m in width. Habitat consists of pools, riffles and runs with a moderate to steep gradient followed by a short, low gradient meandering reach just south of Sae Water. There are some good sections of spawning habitat in the lower reaches, suitable for trout or salmon. Further upstream in the steeper sections spawning habitat is present as small patches, suited only to trout.

Thomas Jamieson's Burn is a tiny (<1m wide) stream. It carries little water and no spawning areas were identified. Substrate is mainly peat.

The Gossawater Burn flows out of Gossa Water (HU436607) and joins the Saewater Burn to form the Laxo Burn. It is 2m to 3m wet width in its lower reaches. The gradient is moderate and good quality mixed juvenile salmonid habitat is present throughout. The best spawning areas are in the lower, meandering reaches, downstream from the track crossings between T66 and T48. However, small areas of spawning habitat are present all the way up to the loch. Spawning habitat in the Gossawater Burn is suitable for salmon and trout. The inflow streams at the south side of Gossa Water - Burn of Dale and Corgill Burn - contain excellent trout spawning habitat. Gossa Water is one of the most important sea trout fisheries on Shetland and these streams undoubtedly represent the main spawning areas.

Habitats in the Saewater Burn are highly variable. Around the confluence of Thomas Jamieson's Burn the stream is slow flowing and deep (>50cm) with growth of *Potamogeton* spp. Such habitat is best suited to trout parr and adult brown trout. Further downstream towards the Gossawater confluence it consists of alternating sections of run and glide, with substrates dominated by stable cobble, boulder and pebble. Some spawning habitat is present, suited mainly to salmon due the large grain size. Juvenile habitats are suited to both salmon and trout, with moderate flows and good cover both in-stream (cobble, boulder and macrophytes) and alongside the banks. Similar habitat continues all the way down to the estuary.

No obstacles were identified in the above streams that would impede access for migratory fish. The waterfall on the Laxo Burn immediately upstream from the tidal limit is clearly passable, but may delay access for fish during periods of low water.

The Seggie Burn is the largest tributary of the Laxo Burn, some 4m wet width in its lower reaches. It is around 5km in length. The lower 400m is steep and bouldery with large areas of bedrock. Above this the gradient eases and substrates consist of cobble, pebble and boulder providing good habitat for juvenile salmonids. Habitat suitable for salmon and trout extends upstream beyond Kingshouse (HU436649). A significant waterfall around 3m in height is present at HU43376492. The waterfall is not vertical and may be passable to larger trout or to salmon on high flows, but this is uncertain. Above the waterfall the stream is of low or moderate gradient and meanders between steep peat banks. Some good spawning areas are present, especially on the bends around HU430648. Smaller patches of spawning substrate extend into the upper reaches around HU425656, but these are of lesser quality and suited only to trout. The stream in these upper reaches consists of run and glide habitat with peat or gravel substrates providing little cover. However, the stream is only about 1m wide in these upper reaches, and good cover is present in the form of undercuts and draped vegetation along the banks. Such habitat is well suited to trout production.

Thirteen sites were selected for electric fishing in the Laxo Burn catchment (Table 12).

***Table 12**. Laxo Burn catchment, survey sites.*

Site Code	Stream	NGR	Survey type	Description
EF1	Easter Filla Burn	HU4240 6154	Q	Pools and runs. Cobble boulder and pebble substrate.
EF2	Easter Filla Burn	HU4242 6180	SQ	Runs, riffles and pools. Pebble and cobble. Meandering.
EF3	Easter Filla Burn	HU4242 6233	FQ	Runs, riffles and pools. Meandering. Good cover.
TJB1	Thomas Jamieson's Burn	HU4316 6251	Q	Mainly peat channel with few hard substrates. Tiny stream.
GOS1	Burn of the Dale	HU4349 5996	SQ	Lots of patches of spawning for trout. Sequence of pools and pebble/gravel runs.
GOS2	Corgill Burn	HU4353 6022	SQ	Cobble and pebble in runs and shallow glides. Good juvenile trout habitat with spawning.
GOS3	Gossawater Burn	HU4370 6254	FQ	Good mixed juvenile habitat, typical of lower stream.
SEG1	Seggie Burn	HU4253 6556	SQ	Narrow stream with little pools and runs. Undercut banks.
SEG2	Seggie Burn	HU4265 6500	SQ	Excellent bank cover but little cover in stream. Pools and runs.
SEG3	Seggie Burn	HU4354 6486	SQ	Good mixed juvenile habitat. Varied depth and flow with moderate cover and plentiful undercuts.
SEG4	Seggie Burn	HU4395 6377	FQ	Stable boulder and cobble with run/riffle/pool sequences. Good cover.
LAX1	Laxo Burn	HU4372 6277	SQ	Typical of reach - short sections of stony run interspersed with glides & pools.
LAX2	Laxo Burn	HU4416 6343	FQ	Stable, weed-covered boulder and cobble surrounded by gravel. Runs and glides.

Survey types: Q = qualitative; FQ = fully quantitative; SQ = semi-quantitative.

Fish populations

Fish species present in the catchment were trout, salmon, eels and three-spined stickleback (Table 13a and 13b). Trout were present at all sites. Salmon were present

in the middle reaches of the Seggie Burn around Kingshouse (site SEG 3), in the lower reaches of the Gossawater Burn (site GOS3) and in the Laxo Burn at site LAX1, near the Gossawater confluence. Eels were present in most streams, but confined to sites in the lower and middle reaches. Three-spined sticklebacks were identified only from the bottom of the catchment, at site LAX2.

***Table 13a**. Trout abundance and number of other fish species, Laxo Burn.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
EF1	present	present	present	present	-
EF2	41.9	6.2	51.9	7.9	-
EF3	18.9	3.3	*24.1*	*4.6*	Eels (1)
TJB1	present	absent	present	absent	-
GOS1	107.4	0.0	133.2	0.0	-
GOS2	120.8	12.1	149.8	15.3	-
GOS3	1.0	7.9	*1*	*9.9*	Eels (7)
SEG1	13.4	24.1	16.6	30.6	-
SEG2	12.2	28.4	15.1	36.1	-
SEG3	11.6	11.6	14.4	14.8	Eels (11)
SEG4	5.1	13.5	*6.7*	*16*	Eels (16)
LAX1	3.7	7.4	4.6	9.4	Eels (12)
LAX2	4.5	7.4	*5.9*	*10.8*	Eels (49), 3sp. stickleback (1)
All sites mean	***30.9***	***11.1***	***38.5***	***14.1***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

***Table 13b**. Salmon abundance and number of other fish species, Laxo Burn.*

Site Code	SALMON DENSITY (fish.100m^{-2})			
	Single run		Absolute	
	0+	*1++*	*0+*	*1++*
EF1	absent	absent	absent	absent
EF2	0.0	0.0	0.0	0.0
EF3	0.0	0.0	*0.0*	*0.0*
TJB1	absent	absent	absent	absent
GOS1	0.0	0.0	0.0	0.0
GOS2	0.0	0.0	0.0	0.0
GOS3	1.0	2.0	*1.0*	*3.0*
SEG1	0.0	0.0	0.0	0.0
SEG2	0.0	0.0	0.0	0.0
SEG3	0.0	1.7	0.0	2.3
SEG4	0.0	0.0	*0.0*	*0.0*
LAX1	3.7	0.0	4.9	0.0
LAX2	0.0	0.0	*0.0*	*0.0*
All sites mean	***0.4***	***0.3***	***0.5***	***0.5***

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

Trout densities in the catchment were highly variable. Excellent densities of fry were present in the Easter Filla Burn (sites EF1 and EF2) and in the inflow streams to Gossa Water (sites GOS1 and GOS2). Trout fry numbers in the Seggie Burn were good, except at the lowest site, SEG4. Trout parr numbers in the Seggie Burn were good or excellent

throughout. Trout fry numbers in the Laxo Burn itself were fair to poor, but parr numbers were fair, perhaps suggesting that trout parr drop down into the mainstem from the feeder streams where fry numbers were higher.

Average number of juvenile salmon was poor throughout the catchment and salmon were found at only three of thirteen sites. Salmon fry were present at low numbers in the lower reaches of the Gossawater Burn and in the Laxo Burn near the Gossawater confluence (site LAX1). Salmon parr were present in the lower reaches of the Gossawater Burn and in the Seggie Burn at Kingshouse (SEG3). No fry were found in the Seggie Burn, suggesting a missing year class.

3.3.3 Burn of Grunnafirth

Description and proposed wind farm developments

The Burn of Grunnafirth runs from west to east entering the sea in the southwest of Dury Voe. The stream is about 6km in length and some 4m wide in its lower reaches. The only large tributary is the Quinni Burn, which flows into the Burn of Grunnafirth about 400m up from the sea (Figure 2). The catchment is potentially impacted by developments in the Nesting quadrant. Turbines T40, 43, 57, 79, 86, 87, 93, 96, 100, 102, 103 104 and 105 are within the catchment. Four stream crossings are proposed at:

- HU450580: Burn of Forse between T87 & T115;
- HU438580: Burn of Forse between T105 & T79;
- HU455586: Burn of Grunnafirth between T109 & T93; and
- HU446591: unnamed inflow burn into Quinni Loch, between T43 & T40/37.

Stany Burn in the upper part of the catchment is small and mainly peat based, flowing between steep, incised peat banks. However, some patches of gravel at pool tails and on bends provide a little potential spawning habitat for trout. Further downstream the watercourse is called Burn of Forse. Good trout habitat is present in this stream with long reaches of cobble and pebble, mixed flows and good cover beneath overhanging banks. A 3.5m high waterfall at HU444580 is probably impassable, limiting upstream access for migratory salmonids. Proceeding downstream, the burn becomes more open in character and provides good quality juvenile and spawning habitat, suited both to trout and salmon. Similar habitat continues downstream to the sea, with only a few areas of bedrock and no significant obstacles to fish movement. The proposed stream crossing at HU455586 is in an area of good quality salmonid habitat, with spawning potential. Five sites were selected for survey (Table 14).

***Table 14**. Burn of Grunnafirth, survey sites.*

Site Code	Stream	NGR	Survey type	Description
FOR1	Burn of Forse	HU4362 5798	SQ	Deep, slow moving with hard gravel bed.
FOR2	Burn of Forse	HU4423 5799	SQ	Riffle, run & glide with mixed substrates.
FOR3	Burn of Forse	HU4519 5802	FQ	Stable cobble and pebble in runs and glides. Good salmonid habitat.
GRU1	Burn of Grunnafirth	HU4574 5885	SQ	Boulder & cobble in glides and runs. Good salmonid habitat.
GRU2	Burn of Grunnafirth	HU4606 5946	FQ	Mixed substrate in riffle, run and glide.

Fish populations

Two species, trout and eels, were present at survey sites (Table 15). Average densities of trout fry and parr were fair-poor and good respectively. Densities were highly variable. No trout were captured at the upper two sites on Burn of Forse (FOR1 and FOR2) but fry and parr densities at site FOR3, below the Twart Burn confluence, were good and excellent respectively. Trout fry numbers at the two sites in the lower

catchment were poor and, both at sites GRU1 and GRU2 were lower than trout parr numbers. Overall, the data suggest a weak 2008 trout year class.

***Table 15**. Trout abundance and number of other fish species, Burn of Grunnafirth.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
FOR1	0.0	0.0	0.0	0.0	Eels (2)
FOR2	0.0	0.0	0.0	0.0	Eels (6)
FOR3	15.9	29.5	*21.5*	*34*	Eels (13)
GRU1	3.9	13.8	4.9	17.6	Eels (3)
GRU2	4.0	4.6	*5.7*	*8.5*	Eels (10)
All sites mean	***4.8***	***9.6***	***6.4***	***12.0***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

3.3.4 Burn of Crookadale

Description and proposed wind farm developments

The Burn of Crookadale flows from north to south, joining the sea at the northeast corner of Cat Firth, in South Nesting. The Gill Burn and Burn of Flamister drain the slopes to the east of Burn of Crookadale. These two streams converge at HU436547 before their combined flows merge with Burn of Crookadale at HU435539, some 400m upstream from the sea. The streams are thought to be the main spawning area for sea trout in the Cat Firth locale. The catchment is potentially impacted by developments in the Nesting quadrant. Turbines T112, 125, 127, 135, 137, 138, 139, 145, 147, 152 and 150 are within the catchment. Two stream crossings are proposed at:

- HU425557: Burn of Crookadale between T138 & T145 and
- HU435559: Gill Burn between T139 & T137.

Habitat and survey sites

The Burn of Crookadale is a small stream, some 2m wet width upstream from the confluence with Burn of Flamister. The upper reaches, north of HU424555 flow between steep, incised peat. Current speed is moderate and the stream consists of runs, glides and little pools over mainly peat substrates. The stream then descends more steeply and is torrential in places, but without impassable falls, until the gradient eases above Park of Catfirth (HU424545). The lower reaches of the stream are meandering with good spawning substrate on several bends.

Burn of Flamister was examined only as far upstream as HU438550. These lower reaches meander between low banks and provide good juvenile habitat for trout. The substrates consist of gravel, pebble and cobble with occasional boulders. Substrates are stable, but not set into peat or compacted, and spawning habitat suitable for trout is present.

Gill Burn was examined upstream to HU434549. The lower reaches above the confluence provide suitable habitat for juvenile salmonids and patches of spawning habitat are present. A waterfall near the ruins at HU436547 appears impassable. Further upstream these are numerous small cascades, most of which are likely to be passable. Between these small cascades stream habitats appear well suited to juvenile trout with a good mix of pools and runs with plentiful cover.

Access for migratory fish into all the streams is likely to be impeded by a significant waterfall a short distance up from the sea at HU438538. This waterfall consists of two

vertical or near-vertical tiers. The larger of the two drops was estimated to be between 2.0 and 2.5m in height. As the fall is in a small gorge with vertical walls it was difficult to approach closely to get a better estimate of height. A small sea trout (estimated weight <200g) was seen jumping unsuccessfully at the lower fall on 1st September and the fall appears likely to be impassable for such a small fish. There is a small resting pool between the two tiers of the fall, but this appears to become washed through at high flows. This waterfall may be passable to salmon and large sea trout at moderate flows, but it is clearly a significant obstacle. It is unlikely that eels can ascend the fall directly.

***Table 16**. Burn of Crookadale, survey sites.*

Site Code	Stream	NGR	Survey type	Description
CRK1	Burn of Crookadale	HU4255 5584	Q	Mainly peat substrates. Pools and runs.
CRK2	Burn of Crookadale	HU4243 5548	SQ	Little pools interspersed with runs and glides. Little patches of spawning suitable for trout.
CRK3	Burn of Crookadale	HU4253 5429	SQ	Unstable gravel and pebble. Mainly glide.
CRK4	Burn of Crookadale	HU4339 5391	FQ	Meandering section with pools and runs.
FLAM1	Burn of Flamister	HU4379 5504	SQ	Nice little burn with stable bed and mixed flows/substrates.
GIL1	Gill Burn	HU4343 5484	SQ	Decent fish habitat with mixed flows and substrates. Above a waterfall.
Gil 2	Gill Burn	HU436547	Q	Mixed juvenile habitat below waterfall.

Fish populations

Four sites were surveyed on the Burn of Crookadale, two on Gill Burn and one on Burn of Flamister (Table 16). Trout were present in all streams. In Burn of Crookadale trout were present up into the higher reaches, with both fry and parr captured at site CRK1, upstream from the proposed crossing between T138 and 145. No trout were present at the single site above the waterfall on Gil Burn, but trout were present at site Gil2 immediately downstream from the falls. The only other fish species identified was eels, with one specimen captured from Burn of Crookadale. It is probable that the lower waterfall limits eel access into the catchment.

***Table 17**. Trout abundance and number of other fish species, Burn of Crookadale.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
CRK1	present	present	present	present	-
CRK2	3.3	11.7	4.1	14.8	-
CRK3	0.0	5.3	0.0	6.8	Eels (1)
CRK4	30.0	5.2	*39.1*	*14.3*	-
FLAM1	49.0	7.0	60.7	8.9	-
GIL1	0.0	0.0	0.0	0.0	-
Gil 2	present	present	present	present	-
All sites mean	***16.5***	***5.8***	***20.8***	***9.0***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

Trout density varied widely in the catchment. Fry densities were poor-fair at site CRK2. The lack of fry at site CRK3 may be because the better spawning habitat is further downstream. Fry densities at the lowest site, CRK4, were excellent as they were at site FLAM1 on Burn of Flamister. Parr density varied less between sites and average parr density was fair.

3.3.5 *Burn of Quoys*

Description and proposed wind farm developments

Burn of Quoys is a small stream, some 3km in length with a wet width of 3.5m in its lower reaches. In has one significant unnamed tributary, which converges from the northwest at HU446555. The catchment is potentially impacted by developments in the Nesting quadrant. Proposed turbines T131, 140, 143 and 148 are within the catchment. Two stream crossings are proposed at

- HU446558: Burn of Quoys tributary between T143 and T131 and
- HU448560: Burn of Quoys between T143 & T140.

Habitat and survey sites

With the exception of the bottom 200m, the lower 0.7km of the Burn of Quoys runs through gorge-like habitat with bedrock and boulder substrates. The presence of boulder cover creates adequate habitat for trout parr in these reaches, but spawning substrate is lacking. Habitat quality improves further upstream, with gravel areas on bends providing some spawning opportunities and run/pool sequences creating mixed habitat for juvenile salmonids. Undercut peat banks provide additional cover. The western tributary is about 1m wide in its lower reaches and at low flows it will be much smaller. Much of this stream is peat-based with very few opportunities for spawning. Little pools filled with *Potamogeton sp*. are present in the low gradient sections. Three sites were surveyed (Table 18).

Table 18. *Burn of Quoys, survey sites.*

Site Code	Stream	NGR	Survey type	Description
QOY1	Unnamed western tributary	HU4449 5538	SQ	Pools and runs in small stream. Mainly peat substrate. Trout confined to pools.
QOY2	Burn of Quoys	HU4473 5535	SQ	Run and glide with boulder, cobble and pebble substrate.
QOY3	Burn of Quoys	HU4439 5436	FQ	Shallow riffle/run and shallow glide. Cobble and pebble. 150m up from sea.

Fish populations

Trout and eels were present at all sites (Table 19). Flounders were present at the lowest site, which was situated around 150m up from the sea.

Table 19. *Trout abundance and number of other fish species, Burn of Quoys.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
QOY1	0.0	2.6	0.0	3.3	Eels (1)
QOY2	1.1	6.0	1.3	7.6	Eels (2)
QOY3	1.3	10.8	*3.4*	*12.1*	Eels (49), Flounder (11)
All sites mean	***0.8***	***6.4***	***1.6***	***7.6***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

Average trout fry and parr densities were 1.6 and 7.6 fish.100m^{-2} respectively. Parr were more abundant than fry at all sites, suggesting a weak 2008 trout year class. Average fry and parr densities were poor and fair respectively.

Small eels, mainly 10-15cm in length, were abundant at the lower site.

3.4 Kergord

3.4.1 Burn of Kirkhouse

Description and proposed wind farm developments

The Burn of Kirkhouse flows from south into the eastern end of Olna Firth, at the village of Voe (Figure 3). It has one large tributary; Patrick's Burn which joint from the east at HU400612. The smaller Burn of Forse converges from the west. The catchment is potentially impacted by developments in the Kergord quadrant. None of the proposed turbines is fully located within the catchment. However turbines 65 and 69 lie on the Mid-Kame ridge, on the watershed between the Kirkhouse and Sandwater catchments. A single stream crossing over Burn of Forse, is proposed at HU390613 on the proposed access track to T72.

Habitat and survey sites

Stream habitats were examined from the estuary to around 200m upstream from the Burn of Forse confluence. In the upstream part of the survey area the burn is meandering and deep, flowing in a channel incised through peat. Downstream from the confluence there are short sections where substrates are dominated be cobble and the banks are lower and less steep. However, much of the cobble is set into peat, providing poor cover for young fish and likely to support a low abundance of invertebrate food. Habitat quality for salmonids is further reduced by the presence of large areas of bedrock. Deep pools are present, likely to hold trout parr and adults.

A fish pass has been installed at the bridge apron where the stream flows below the B9071 (HU402627). Unfortunately the drop from the lower pool of the fish pass is onto shallow rock, with no suitable pool from which fish can make the jump to the pass. Access would be improved by deepening the pool below the fish pass.

***Table 20**. Burn of Kirkhouse, survey sites.*

Site Code	Stream	NGR	Survey type	Description
KIR1	Burn of Kirkhouse	HU3996 6152	SQ	Small peaty channel with a few patches of gravel. Mainly glide with lots of undercut banks.
KIR2	Burn of Forse	HU3979 6156	SQ	Small peaty channel with little hard substrate. Lots of undercut banks.
KIR3	Burn of Kirkhouse	HU4002 6203	FQ	Cobbles & boulders embedded in peat. Much bedrock. Typical of area.

Three sites were surveyed (Table 20): one a short distance upstream from the Burn of Forse confluence (KIR1), one on the lower Burn of Forse (KIR2) and one downstream from the confluence (KIR3).

***Table 21**. Trout abundance and number of other fish species, Burn of Kirkhouse.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
KIR1	3.3	2.2	4.1	2.8	-
KIR2	2.7	8.0	3.3	10.2	-
KIR3	20.2	4.0	*25.6*	*6.7*	Eels (1)
All sites mean	***8.7***	***4.8***	***11.0***	***6.6***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

Fish populations

Two species were present at electric fishing sites, trout and eels. Only one eel was counted during the survey, a single specimen around 15cm in length at site KIR3. Trout

were present at all sites with mean densities of fry and parr of 11.0 fish.100m^{-2} and 6.6 fish.100m^{-2} respectively. Fry were scarce at sites KIR1 and KIR2 but the density at KIR3 was good.

3.4.2 Burn of Sandwater

Description and proposed wind farm developments

This large stream drains north to south, flowing into the sea at Loch of Strom, HU406506. It is some 10km in length with two lochs along its course, the Petta Water (HU4159) and Sand Water (HU4154). Between these two lochs, the watercourse is known as the Burn of Pettawater. There are no major tributaries. The catchment is potentially impacted by developments in the Nesting quadrant. Proposed turbine T68 lies within the catchment. In addition, the turbines along Mid Kame lie on the watershed between the Sandwater and the Weisdale and Kirkhouse catchments. No stream crossings are proposed within the Sandwater catchment.

Habitat and survey sites

No surveys took place downstream of Sand Water. The Burn of Pettawater was inspected from upstream from Petta Water at HU597415 to the Sand Water inflow at HU415552. The inflow streams to Petta Water are little more than shallow channels through peat, lacking in hard substrates. Sea trout and salmon have been recorded in Petta Water, but it seems likely that they must drop back downstream to spawn as no suitable habitat is present upstream from the loch. Immediately below the loch the watercourse consists of a steep-sided channel incised through peat. Substrate is largely peat, covered with a thin layer of coarse sand. Few larger substrates are present, limiting spawning opportunities for salmonids. In the middle reaches there are long sections where big stable cobbles and boulders are set into the peat. These are surrounded by sand and gravel. The stable bed supports growth of various macrophytes; these and undercut banks provide good cover for fish. As the stream continues south, the proportion of medium sized substrates such as gravel, pebble and cobble increases. Run and pool sequences are present and the stream opens out, with lower banks and greater light penetration. In places the larger substrates are compacted in the underlying peat, but spawning habitat is present on some bends and in pools tails. The lower 0.4km immediately upstream from Sand Water is deep, slow flowing and canal-like with some macrophyte growth – suited mainly to trout parr and adults.

No obstacles to upstream migration were identified on the Petta Water. Sea trout and salmon are believed to have access into the Petta Water, although members of the SAA expressed concerns regarding the design of the fish pass in the lower catchment at HU408511. Nevertheless, Burn of Petta Water is considered an important sea trout stream (SAA 2006) and salmon have been recorded. The Shetland Anglers Association stocked trout fry into the Petta Water during 2007 (4000 fry) and 2008 (1200 fry).

***Table 22**. Burn of Sandwater catchment, survey sites.*

Site Code	Stream	NGR	Survey type	Description
PW1	Burn of Petta Water	HU4173 5846	SQ	Peat channel with a thin layer of sand - very poor salmonid habitat but typical of area.
PW2	Burn of Petta Water	HU4172 5715	SQ	Runs and pools with stable boulder and peat. Cover mainly in macrophytes and along undercut banks.
PW3	Burn of Petta Water	HU4159 5553	FQ	Weed covered cobble and boulder set in peat and surrounded by coarse sand.

Fish populations

Three species were recorded in the Burn of Pettawater, eels, trout and three-spined stickleback. Three-spined sticklebacks were recorded at all three sites while eels and trout were present only at the lower two sites.

Mean density of trout fry and parr was 23.8 fish.100m^{-2} (good) and 4.3 fish.100m^{-2} (fair-poor) respectively. The relative paucity of trout parr may suggest that many drop down into Sand Water, although this is conjectural. Only three fry were identifiable as stocked, these having typical fin deformities. However, the quality of fry stocked into the stream is thought to be good with little fin damage (D. Pottinger, SAA, pers. comm..) and so the contribution of stocked trout to measured densities at survey sites cannot be assessed.

Table 23. *Trout abundance and number of other fish species, Burn of Sandwater catchment.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
PW1	0.0	0.0	0.0	0.0	3 sp. stickleback (>100)
PW2	18.1	4.3	22.5	5.5	Eels (2), 3 sp. stickleback (1)
PW3	41.4	7.5	*48.8*	*7.5*	Eels (15), 3 sp. stickleback (1)
All sites mean	***19.8***	***3.9***	***23.8***	***4.3***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

3.4.3 Burn of Weisdale

Description and proposed wind farm developments

The Burn of Weisdale runs north to south, draining the Valley of Kergord and entering the sea at the head of Weisdale Voe (HU393523). In its upper reaches it is known as the Burn of Kergord. There are no lochs in the catchment and only one major tributary, the Burn of Droswall, entering the main channel at South Setter (HU401548). The catchment is potentially impacted by developments in the Nesting quadrant. Turbines T72, 78, 85, 91, 111, 122 and 136 lie within the catchment. In addition, the turbines along Mid Kame lie on the watershed between the Weisdale catchment and the catchments to the east. A single stream crossing is proposed, on the access track off the B9075 at HU400557 (Burn of Droswall).

Habitat and survey sites

The middle reaches of the stream were inspected from HU405568 (1km north of upper Kergord) downstream to the old dam at HU400542. The whole of this section provides good quality juvenile salmonid habitat. Substrates are stable cobble and boulder with some weed growth. Additional cover is present along the banks, mainly in undercuts. Spawning gravels are present. The gradient is moderate throughout and there are no natural waterfalls or other obstructions to fish passage. The dam shown on the Ordnance Survey Explorer sheet 467 at HU400542 has been removed.

The weir at Weisdale Mill HU396531 was inspected. This weir backs up a considerable pond, providing the water supply for the fish hatchery at the same location. The weir was originally constructed to provide waterpower for Weisdale Mill. There are two possible routes for fish to ascend the weir, one toward the left bank and one toward the right. Both are channels with flow controlled by gates. The largest flow is to the right banks and this offers the best access. However, as the tailrace from this channel is some 20m downstream from the face of the weir fish may have difficulty finding it. The right channel carries less water, but fish do ascend it especially during periods of elevated flow (Paul Featherstone, Shetland Sea Trout, Weisdale, pers. comm.). It is

clear that the weir is not an insurmountable barrier to upstream migration. Nevertheless it seems likely that it could be improved and a full assessment is desirable.

The Burn of Kergord and Burn of Weisdale are considered to be important sea trout spawning streams. Three sites on the Burn of Weisdale were surveyed (Table 24).

***Table 24**. Burn of Weisdale, survey sites.*

Site Code	Stream	NGR	Survey type	Description
WEI1	Burn of Weisdale	HU4053 5779	SQ	Slow flowing. Small glides with weed cover.
WEI2	Burn of Weisdale	HU4051 5672	SQ	Bank very eroded. Unstable stream bed with only a few big boulders.
WEI3	Burn of Weisdale	HU4013 5421	FQ	Very stable weed covered rocks.

Fish populations

Two species were identified at the survey sites, trout and eels. Trout were present at three sites and eels at two (Table 25).

***Table 25**. Trout abundance and number of other fish species, Burn of Weisdale.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
WEI1	26.2	14.5	32.4	18.5	-
WEI2	14.8	5.9	18.4	7.5	Eels (1)
WEI3	1.6	23.6	*3.1*	*34.6*	Eels (16)
All sites mean	***14.2***	***14.7***	***18.0***	***20.2***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

Trout fry were most abundant at the uppermost sites, WEI1 and WEI2 where good densities were present. Trout fry were less abundant at site 3 where the density was poor, nevertheless the average density of 18.0 trout fry.100m^{-2} is good by national standards. In contrast, trout parr were most abundant at site WEI3, which carried an excellent density. As with fry, average trout parr density was classified as good. Eels were plentiful at the lower site, mainly in the length range 10-20cm.

3.4.4 Burrafirth

This sprawling, complex catchment drains westward into Aith Voe at HU366577. There are two main sub-catchments, the South Burn of Burrafirth and the Burn of Lunklet. The South Burn of Burrafirth drains Maa Water and Truggles Water via the Burn of Truggles Water. The Burn of Atlascord joins this burn from the south, forming the South Burn of Burrafirth. The Burn of Lunklet drains Loch of Lunklet. The burn has two large tributaries, the Burn of Marrofield Water from the north and the Burn of Lambawater from the south. The Burn of Lunklet and South Burn of Burrafirth converge at HU367574, some 400m upstream from the sea.

Thirty-one of the proposed Kergord quadrant turbines lie within the catchment. Nine stream crossings are proposed, six of which are small feeder stream of lochs within the catchment:

- HU368544: Burn of Truggles Water between T157 & T159;
- HU375544: unnamed inflow to Truggles Water between T156 & T160;
- HU379533: Burn of Atlascord T165 & T168;

- HU380546: unnamed inflow to Maa Water between T154 & T156;
- HU380547: unnamed inflow to Maa Water between T154 & T156;
- HU381548: unnamed inflow to Maa Water between T154 & T153;
- HU384554: unnamed inflow burn to Lamba Water between T146 & T153;
- HU388556: unnamed inflow to Lamba Water between T146 & 136 and
- HU385555: unnamed inflow to Lamba Water between T146 & T153.

Habitat and survey sites

South Burn of Burrafirth provides large areas of good quality juvenile salmon and trout habitat. Gradient is moderate and substrates are a mix of cobble, pebble and boulder. The stream is moderately stable and spawning areas are present throughout. Between the Truggles Water confluence and its confluence with the Burn of Lunklet, the South Burn of Burrafirth is between 2 and 4m in width and spawning habitat is suitable for both trout and salmon. Good quality habitat continues upstream into the Burn of Atlascord and spawning sites remain plentiful, but suited more to trout than to salmon. The Burn of Atlascord was inspected only as far upstream as HU364543. Judged by gradient, it is probable that suitable juvenile salmonid habitat extends a further 1.5 to 2km upstream.

The Burn of Truggles Water is a small stream, around 1.2m wet width. It provides some areas of good quality juvenile habitat, particularly in its meandering lower reaches, but spawning opportunities appear limited. Further upstream the gradient is steep, and there is an awkward obstacle at HU36825443 where a small waterfall with a choke stone makes upstream access difficult.

The small stream flowing into Truggles Water from the east is tiny (~30cm wet width). Even immediately upstream from the loch, parts of it flow beneath the peat. No spawning substrate was noted and the base of the burn is mainly peat. A waterfall 150m upstream from the loch may be impassable. The main inflow to Truggles Water is from Maa Water. The stream between these two lochs is around 0.7m in width. The gradient is moderate and substrates consist of stable cobble and pebble covered in algae and peat deposits. Spawning substrates appear scarce but the stream is well suited to juvenile trout with plentiful cover in little pools and along undercut banks draped in heather. The main inflow stream to Maa Water is at the southeast corner of the loch. Average width in the lower reaches is 1m and substrates are mainly cobbles set into peat. No spawning habitat was noted in the lower reaches, although the presence of fry suggests some may be present further upstream.

No obstacles of note are present on the South Burn of Burrafirth and migratory fish have clear access at least as far as Burn of Atlascord. Accessibility on Burn of Atlascord was not assessed upstream from HU364543.

Access for migratory salmonids into the Burn of Lunklet side of the catchment is restricted to the lower 300m above the confluence with South Burn of Burrafirth by an impassable waterfall at HU370573. The lower reaches of Burn of Lunklet and Burn of Marrofield Water were inspected during electric fishing surveys. The Burn of Lamba Water was inspected throughout its length. Burn of Vats-houll, the main inflow stream to Lamba Water, was inspected in its lower 500m.

Upstream from the waterfall the Burn of Lunklet provides suitable habitat for juvenile trout, with moderate flows over cobble, pebble and boulder substrates. The banks are quite heavily grazed, but undercuts provide some cover. Upstream from HU375574 the gradient is steeper and substrate includes a high proportion of bedrock, providing poor fish habitat.

The lower reaches of the Burn of Marrofield Water are quite steep and unstable, with several reaches that are dominated by bedrock. This habitat is adequate for trout parr but poor for fry and spawning opportunities are limited. The gradient eases further upstream, towards Marrofield Water.

Burn of Lambawater is an attractive little trout stream with a moderate gradient. The meandering course comprises riffle, run pool sequences providing diverse habitats for trout fry and parr. Spawning substrate is widespread, but in places is slightly unstable.

Burn of Vats-houll is a dark peaty stream, with a channel incised through blanket peat. Substrate in the lower reaches is scattered boulders set into peat. No spawning habitat was noted.

Survey sites in the catchment (n=15) are listed in Table 26.

Table 26. *Burn of Burrafirth, survey sites.*

Site Code	Stream	NGR	Survey type	Description
MAA1	Maa Water inflow.	HU3797 5492	SQ	Peat channel with a few boulders. No obvious spawning habitat present.
TRU1	Between Truggles Water & Maa Water	HU3726 5490	SQ	Little pools and runs with stable cobble and pebble covered in algae. Bank cover in undercuts.
TRU2	Truggles Water inflow	HU3722 5443	Q	Tiny stream with mainly peat substrate. No spawning habitat seen. Poor juvenile habitat.
TRU3	Truggles Water outflow	HU3661 5451	SQ	Decent habitat for trout with patches of spawning.
ATL1	Burn of Atlascord	HU3644 5431	SQ	Nice little trout stream typical of lower reaches of B. of Atlascord.
SBF1	S. Burn of Burrafirth	HU3648 5473	SQ	Mixed habitat of runs, riffles and pools. Undercut banks.
SBF2	S. Burn of Burrafirth	HU3640 5559	SQ	Loose gravel, pebble and angular rather unstable cobble. Run, riffle and glide.
SBF3	S. Burn of Burrafirth	HU3670 5689	FQ	Stable boulder and cobble filled round with less stable sand and gravel. Mainly run.
SBF4	Burrafirth	HU3668 5750	FQ	Typical of river below Lunklet confluence. Good cover but lacks spawning.
LAM1	Burn of Vats-houll - Lamba Water inflow	HU3844 5589	Q	Peat and boulder with few or no smaller substrates. Very poor fish habitat.
LAM2	Burn of Lamba Water	HU3749 5681	SQ	Good juvenile habitat with mixed flows and depths.
LAM3	Burn of Lamba Water	HU3743 5710	SQ	Good fry habitat at top end and pools for parr.
LUN1	Burn of Lunklet	HU3744 5732	SQ	Gentle gradient with good instream cover.
LUN2	Burn of Lunklet	HU3731 5731	FQ	Some bedrock, especially in lower part of section. Top is decent habitat. Two pools and some fast riffles.
MAR1	Marrofield Water	HU3746 5802	SQ	Mainly parr habitat. Poor for fry. Fair bit of bedrock but good bouldery pools.

Fish populations

Five species were recorded. The most widely distributed was trout, present at 14 of 15 survey sites followed by eels (9 sites), salmon (3 sites), three-spined sticklebacks (2 sites) and flounders (1 site).

Average trout fry abundance for the catchment was 21.8 fish.100m^{-2}, good by national standards. There was little difference in mean fry densities between the Lunklett side of the catchment (inaccessible to migratory stocks) and the south Burrafirth side (accessible), with mean fry densities of 23.2 and 19.5 fish.100m^{-2} respectively. Mean

trout parr abundance for the catchment was 9.4 fish.100m^{-2} (fair) with densities of 10.4 and 7.8 fish.100m^{-2} for the Lunklet and South Burrafirth sub-catchments respectively.

***Table 27a**. Trout abundance and number of other fish species, Burn of Burrafirth.*

Site Code	TROUT DENSITY (fish.100m^{-2})				Other fish species (number caught)
	Single run		Absolute		
	0+	*1++*	*0+*	*1++*	
MAA1	22.2	0.0	27.6	0.0	3 sp. stickleback (1)
TRU1	51.7	5.7	64.1	7.3	3 sp. stickleback (1)
TRU2	present	absent	present	absent	-
TRU3	13.9	12.8	17.2	16.3	Eels (11)
ATL1	29.5	11.3	36.6	14.4	Eels (6)
SBF1	6.5	13.0	8.1	16.5	Eels (18)
SBF2	15.2	9.8	18.8	12.5	Eels (7)
SBF3	8.0	4.5	*9.8*	*8*	Eels (5)
SBF4	3.1	4.9	*3.6*	*8.5*	Eels (43), Flounder 92)
VH1	absent	absent	absent	absent	-
LAM1	23.8	2.2	29.5	2.7	-
LAM2	25.9	3.0	32.1	3.8	Eels (1)
LUN1	18.4	9.2	22.8	11.7	Eels (1)
LUN2	10.9	5.5	*13.1*	*8.7*	Eels (3)
MAR1	0.0	9.5	0.0	12.1	-
All sites mean	***17.6***	***7.0***	***21.8***	***9.4***	

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

***Table 27b**. Salmon abundance and number of other fish species, Burn of Burrafirth.*

Site Code	SALMON DENSITY (fish.100m^{-2})			
	Single run		Absolute	
	0+	*1++*	*0+*	*1++*
MAA1	0.0	0.0	0.0	0.0
TRU1	0.0	0.0	0.0	0.0
TRU2	absent	absent	absent	absent
TRU3	0.0	0.0	0.0	0.0
ATL1	0.0	0.0	0.0	0.0
SBF1	0.0	0.0	0.0	0.0
SBF2	0.0	1.5	0.0	2.0
SBF3	0.0	3.6	*0.0*	*3.6*
SBF4	0.0	3.6	*0.0*	*5.8*
VH1	absent	absent	absent	absent
LAM1	0.0	0.0	0.0	0.0
LAM2	0.0	0.0	0.0	0.0
LUN1	0.0	0.0	0.0	0.0
LUN2	0.0	0.0	*0.0*	*0.0*
MAR1	0.0	0.0	0.0	0.0
All sites mean	***0.0***	***0.7***	***0.0***	***0.9***

Note: Absolute density figures in italics are Zippin estimates. All other absolute densities were calculated using correction factors given in Figure 4.

On the South Burrafirth sub-catchment, trout densities were generally highest at the upper sites, including Burn of Truggles Water and Burn of Atlascord. In the Lunklet sub-

catchment trout fry densities were good in the Burn of Lamba Water and the upper site on Burn of Lunklet (LUN1). Fry were absent at the survey site on Burn of Marrofield Water; however parr density at this site was good and the lack of fry is likely to reflect the nature habitat in the lower parts of this stream.

Salmon were found at only three sites and densities at all of these were poor. The fry year class was absent at all sites and all the parr caught (n=19) were aged 1+ i.e. from spawning of winter 2006-07. These data suggest that successful salmon spawning in the catchment is sporadic.

4 DISCUSSION

4.1 Fish populations

The survey streams sustain a rather limited array of species (Table 27), as would be predicted from published accounts of freshwater fish distribution in the Northern Isles. Brown trout were widely distributed, present in all survey streams and at the great majority of sites. Eels were similarly widespread, but occurred at fewer sites. Other species encountered species were three-spined stickleback, which occurred in three catchments, salmon, and flounder, both of which occurred in two.

***Table 27**. Species occurrence by catchment.*

Catchment	Eel	Trout	Salmon	3-spined stickleback	Flounder
Laxobigging	X	X			
Skella Dale		X			
Wester Filla		X			
Laxo	X	X	X	X	
Grunnafirth	X	X			
Crookadale	X	X			
Quoys	X	X			X
Kirkhouse		X			
Sandwater	X	X		X	
Weisdale	X	X			
Burrafirth	X	X	X	X	X

Given that only a small number of sites were surveyed in each catchment, it is possible that some species may have been missed. However, it is very unlikely that any species not listed in Table 27 is present in any of the streams. The most likely species to have been overlooked would be eels, three-spined stickleback and flounder. Eels occurred at low densities at most sites and their absence from survey sites in the Skelladale, Wester Filla and Kirkhouse catchments cannot be assumed to indicate their complete absence from these systems. Similarly, occasional flounders and three-spined sticklebacks may occur in the lower reaches of any of the streams, as these species occupy saltwater as well as freshwater habitats.

Based on data recorded in the NBN Gateway, salmon have previously been recorded in the Burn of Weisdale, Burn of Sandwater, Burn of Kirkhouse, Laxo Burn, Burn of Grunnafirth and Burrafirth catchments. The lower reaches of the Burns of Weisdale and Sandwater were not included in the present survey, due to their distance from any proposed wind farm development. The potential presence of small numbers of salmon in the lower reaches of these two streams cannot be discounted. In contrast, it is probable that the survey would have identified the presence of salmon in the Kirkhouse and Grunnafirth catchments were they present. Salmon may have been extirpated from these streams or may always have been only sporadically present. Furthermore it has not been possible to ascertain whether salmon were stocked into any of the streams in the past either deliberately, for instance using excess farmed fry or accidentally through escapes of farmed salmon. In the two systems where salmon were recorded in the present survey, the Laxo and Burrafirth, their numbers were very low and in the case of the Burrafirth system there appeared to have been no successful spawning during winter 2007-08. While it cannot be determined on the basis of available information that these two populations are truly wild (i.e. not the progeny of farmed escapes), this should be assumed to be the case and they are must be considered of regional importance.

Trout are very widespread in Shetland and where they have access to the sea it is probable that a proportion of the population will exist as migratory sea trout. The genetic

basis for migration is the subject of ongoing research (reviewed by Ferguson 2006), but it is clear that there is considerable flexibility in trout life history strategy (Walker 2006) and that sea and brown trout may freely interbreed. Homing in sea trout has traditionally been considered to be less well developed than in salmon. However recent genetic evidence suggests considerable variation in sea trout populations in different rivers. Hansen and Mensberg (1998) showed that populations within rivers tended to be more closely related to each other than to populations from other nearby rivers. Levels of genetic difference were related to geographic distance, suggesting some localised gene flow. This pattern is not universal however, and other studies show no correlation between genetic and geographic distance (Ferguson 2006). What is largely consistent across studies is that sea trout show considerable genetic differentiation among populations. This differentiation can only be sustained by a relatively high degree of fidelity to river of origin and a low degree of straying. The genetic structure of Shetland's sea trout populations is not known. On the basis of current knowledge of stock structure, it is probable that the trout stocks of each stream should be considered of local importance. The stocks within the four wind farm quadrants when taken together would be of considerable regional importance, both in terms of the likely genetic diversity they represent (both in migratory and non-migratory form) and for their value as a recreational resource.

4.2 Survey limitations

The present survey described fish populations at 66 sites and provides a broad baseline against which future change may be assessed. Two main weaknesses exist: (i) a single survey may be inadequate as a baseline against which to assess future change (ii) data were collected from a small number of sites in each catchment.

The use of a single survey as a baseline may lead to incorrect conclusions relating to trends in fish populations pre- and post-construction. Additional pre-construction survey will be required in order to assess 'natural' annual variation in fish abundance.

The number of sites surveyed on each catchment is likely to be adequate to give a broad indication of the density and distribution of trout and salmon, the main target species. However, it is clear from the data that juvenile trout abundance is highly variable, even over a relatively small spatial scale. This variability inevitably means that unless a large number of sites are surveyed, the magnitude of any change in population would have to be considerable before a statistically significant difference could be shown with any reasonable degree of confidence[1]. Given that the species present in most of the watercourses exclude those covered by Habitats Directive and other conservation regulations, this may be acceptable. However, the trout resource on Shetland is of value as an angling resource and increased survey effort should be targeted at the following areas in any follow-up survey:

- Grunnafirth: additional qualitative sites on upper Burn of Forse to confirm absence of trout above waterfalls;
- Burn of Crookadale: additional fully quantitative site below confluence of Gil Burn and Burn of Flamister;
- South Burn of Burrafirth: additional site in Burn of Atlascord, potentially an important rearing area for sea trout;
- Burn of Weisdale and Burn of Sandwater: additional downstream survey sites to determine to determine current status of salmon and increase precision of baseline assessment.

[1] Bohlin *et al* (1990) provide details of how to calculate the number of survey sites required to measure populations to a known level of precision.

4.3 Recommendations

4.3.1 Construction and operation of wind farm

The scale of the proposed wind farm is very large and both turbine construction and the construction of access tracks will result in the exposure or large quantities of soil. The potential exists for widespread siltation of streams, which could cause damage to fish habitats and direct mortality to fish and ova. Similar or greater impacts may be expected in the event of any peat slide resulting from the development. Should the scheme proceed, the management of silt and suspended solids will undoubtedly present a major challenge. Mitigation measures are beyond the scope of this report, but will clearly have to be carefully planned, robust and enforceable. Contingency planning will be required for e.g. storms and heavy rain, which may increase the rate of sediment transport or the risk of localised peat slide.

Numerous stream crossings are proposed as part of the wind farm scheme. This study has shown that trout are present in the upper reaches of many of the survey streams, indeed some of the highest trout densities recorded during the present survey were in small, headwater areas and these habitats are important to the maintenance of healthy trout populations. Both migratory and non-migratory trout undergo spawning migrations and access to spawning areas must not be restricted. Although their movements may be of lesser magnitude than those of sea trout, artificial barriers that restrict movements can damage brown trout through population fragmentation leading to loss of genetic diversity and reduction in fitness (Antunes *et al* 1999).

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4.3.2 Habitat and species management

Trout habitats

While no formal or detailed habitat surveys were carried out during the study, it is apparent that riparian habitats have been significantly affected by centuries of grazing, mainly by sheep. In the few fenced areas where livestock are completely excluded e.g. the exclosures in lower reaches of Burn of Lunklet and Burn of Crookadale, the regeneration of riparian trees, shrubs and herbs is striking. Regeneration of riparian vegetation may be of benefit to trout populations through provision of cover in the form of draped vegetation, roots and debris. Stream productivity including invertebrate abundance may also increase through inputs of organic material originating from trees and shrubs. Furthermore, terrestrial food may be of importance to trout in streams where aquatic invertebrate abundance is low, as it is in the study streams (Aquaterra 2008) and terrestrial invertebrate abundance may be enhanced where structural and species diversity in the riparian strip is high.

There is a strong relationship between bank-side cover such as undercuts, roots or draped vegetation and high trout abundance (e.g. Wesche *et al*, 1987, Summers *et al* 2005). Regeneration of the riparian strip may be of greatest benefit to trout in the lower reaches of Shetland's streams, since cover in upper reaches is generally plentiful in the form of undercut peat turf. In contrast, the lower reaches of stream such as the Burn of Grunnafirth, South Burn of Burrafirth, Laxo, Seggie and Laxobigging are rather open and lacking in both cover and shade. Consultation with landowners and tenants may identify areas where the promotion of riparian regeneration, mainly be stock exclusion, might benefit fish populations.

While the greatest local impact on fish numbers may be expected in the lower reaches of streams, improving the structure and diversity of riparian vegetation in middle and upper reaches may also be beneficial. Allochthonous nutrient input in the form of leaf litter potentially increases both in stream and terrestrial invertebrate diversity and abundance.

Stocking and fisheries data

At present, the main direct ongoing management of Shetland's sea trout and brown trout fisheries is through stocking. Due to lack of resources, stocking is guided primarily by local knowledge, but without objective data relating e.g. to juvenile abundance or habitat quality in receiving waters that would help guide strategy to ensure maximum benefit. A review of the stocking programme, in partnership with the Shetland Anglers Association would be useful and may help identify strategic projects and data needs that might be subject to external funding. Such a review might include sources of broodstock, life stages for stocking, identification of target areas for stocking, methods of stocking and assessment of associated benefits and risks.

Specific recommendations

Two man made barriers were identified during the survey, the easing of which would aid fish passage.

The dam on the Burn of Laxobigging at HU417727 apparently serves no purpose. Its removal, or the installation of a fish pass, would open up approximately 1km of habitat upstream, most of which is good juvenile habitat with spawning potential. Should the waterfalls at HU411720 be passable by sea trout, the removal of the dam would permit access all the way into the upper reaches of the catchment.

The fish pass on the lower Kirkhouse Burn where the stream flows below the B9071 (HU402627) should be modified. The drop from the lower pool of the fish pass is onto shallow rock, with no suitable pool from which fish can make the jump to the pass. Access would be improved by deepening the pool below the fish pass.

A further man-made obstacle, the weir at Weisdale Mill (HU396531) should be fully assessed. While the weir is passable, it clearly impedes fish passage at certain flows and fish trapped below the weir may be vulnerable to predation. Indeed, this was a favoured poaching area in past years and had to be closely watched (Paul Featherstone, pers. comm.). The weir is an integral part of the hatchery operation at Weisdale. Any modification to water flows or to the structure of the weir should be with the full consultation and co-operation of all stakeholders.

The fish pass on the lower Sandwater (HU408511) was not inspected during the current survey. However concerns were expressed by members of the SAA, who felt that its efficacy should be assessed.

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Appendix 1. Electric fishing survey site dimensions and locations.

Code	Catchment	Stream	NGR	Length	Width	Area	Location
LBG1	Burn of Laxobigging	Burn of Laxobigging	HU3975 7059	59.2	1.4	82.9	Downstream: bedrock sticking out from right bank at top of pool. Upstream: sharp S-bend with bedrock sricking out from right bank.
LBG2	Burn of Laxobigging	Burn of Laxobigging	HU4025 7073	48.5	1.6	77.6	Upstream: 10m down from Oxnabool confluence.
LBG3	Burn of Laxobigging	Burn of Laxobigging	HU4082 7118	58.2	2.7	157.1	Downstream: tail of pool above bedrock fall.
LBG4	Burn of Laxobigging	Burn of Laxobigging	HU4171 7271	42.0	3.4	142.8	Downstream: 50m high drop at left bend. Upstream: line of stones across stream 3m up from top of pool.
LBG5	Burn of Laxobigging	Burn of Laxobigging	HU4114 7311	43.0	2.9	124.7	Upstream: 10m upstream from wooden rails and straining post on left bank.
STN1	Burn of Laxobigging	Stenswall Burn	HU4292 7296	61.0	0.6	38.4	Downstream: road bridge. Upstream: small waterfall above shallow pool.
MOF1	Burn of Laxobigging	Burn of Moorfield	HU4257 7276	47.0	0.8	37.6	Downstream: road bridge. Upstream: large boulders both banks and wee torrent.
NB1	Burn of Laxobigging	North Burn	HU4188 7337	70.0	1.0	72.8	Downstream: 4m up from broken stone footbridge.
SK1	Burn of Skelladale	unnamed tributary	HU3851 6726	74.0	0.7	51.8	Downstream: 60m up from confluence.
SK2	Burn of Skelladale	Burn of Skelladale	HU3856 6741	54.0	1.5	81.0	Downstream: 18m upstream from confluence. Upstream: 30m high bedrock shelf.
SK3	Burn of Skelladale	Burn of Skelladale	HU3820 6747	50.0	2.0	100.0	Downstream: pointed bedrock. Upstream: well defined riffle.
SK4	Burn of Skelladale	Burn of Skelladale	HU3679 6721	42.0	2.9	121.8	Downstream: huge flat boulder jutting from right bank. Upsream: bottom end of riffle (ledge).
WF1	Wester Filla	Wester Filla Burn	HU4153 6113	60.5	1.4	84.7	Downstream: boulder midstream. Upstream: deep pool where stream narrows (peat cliff left bank).
WF2	Wester Filla	Wester Filla Burn	HU4153 6236	52.0	1.1	57.2	Downstream: first gravel bar up from old road. Upstream: Tiny tributary running through grass, left bank.
EF1	Laxo	Easter Filla Burn	HU4240 6154	NA	NA	NA	Series of small pools 50m down from confluence.
EF2	Laxo	Easter Filla Burn	HU4242 6180	64.5	1.0	64.5	Downstream: boulder projecting from right bank. Upstream: top of pool with undercut left bank.
EF3	Laxo	Easter Filla Burn	HU4242 6233	59.0	2.6	153.4	Downstream: 4m up from hairpin bend that is immediately up from fence.
TJB1	Laxo	Thomas Jamieson's B.	HU4316 6251	NA	NA	NA	Approximately 100m upstream from confluence.
GOS1	Laxo	Burn of Dale	HU4349 5996	83.0	1.2	99.6	Upstream grid ref HU43467 59878 (no physical distinguishing features)
GOS2	Laxo	Corgill Burn	HU4353 6022	18.4	0.9	16.6	Bottom of site is approximately 5m downstream from sharp left bend.
GOS3	Laxo	Gossawater Burn	HU4370 6254	44.0	2.3	101.2	Downstream: apex of U bend.
SEG1	Laxo	Seggie Burn	HU4253 6556	34.0	1.1	37.4	Upstream: top of junction pool at confluence.
SEG2	Laxo	Seggie Burn	HU4265 6500	88.0	1.4	123.2	Downstream: sharp S bend 10m up from break in peat bank (rb). Upstream: well defined run on right bend.

contd.

Appendix 1 contd. Electric fishing survey site dimensions and locations.

Code	Catchment	Stream	NGR	Length	Width	Area	Location
SEG3	Laxo	Seggie Burn	HU4354 6486	55.5	3.1	172.1	Downstream: tail of glide 13.5m down from fence at Kingshouse. Upstream: line of huge boulders below left bend.
SEG4	Laxo	Seggie Burn	HU4395 6377	33.0	3.6	118.8	Downstream: line of 4 large boulders extending out from right bank. Upstream: 1m up from block of stone set in righ tbank, above apex of left bend.
LAX1	Laxo	Laxo Burn	HU4372 6277	30.0	4.5	135.0	Upstream: confluence of Gossawater Burn.
LAX2	Laxo	Laxo Burn	HU4416 6343	39.0	6.9	269.1	Downstream: large, round green-topped midstream boulder. Upstream: 6m upstream from big stone block set in right bank.
FOR1	Burn of Grunnafirth	Burn of Forse	HU4362 5798	56.5	1.4	79.1	Downstream: immediately above sharp left bend. Upstream: confluence.
FOR2	Burn of Grunnafirth	Burn of Forse	HU4423 5799	57.0	1.8	102.6	Downstream: riffle at right bend above glide. Upstream: left bend 8m down from high peat face (left bank).
FOR3	Burn of Grunnafirth	Burn of Grunnafirth	HU4519 5802	42.0	2.1	88.2	Downstream: large boulder near right bank (7m d.s. from huge stone block by l.b.).
GRU1	Burn of Grunnafirth	Burn of Grunnafirth	HU4574 5885	49.0	3.1	151.9	Downstream: 2 large boulders by right bank above sharp left bend. Upstream: bottom of glide by walled platform.
GRU2	Burn of Grunnafirth	Burn of Grunnafirth	HU4606 5946	45.0	3.9	175.5	Downstream: pipe marked by concrete marker right bank. Upstream: 1m down from prominent bedrock emerging midstream.
CRK1	Burn of Crookadale	Burn of Crookadale	HU4255 5584	NA	NA	NA	Approximately 100m upstream from proposed crossing point.
CRK2	Burn of Crookadale	Burn of Crookadale	HU4243 5548	60.0	1.0	60.0	Downstream: at grid ref HU4243 5548
CRK3	Burn of Crookadale	Burn of Crookadale	HU4253 5429	80.5	0.7	56.4	Downstream: bottom end of sharp left bend.
CRK4	Burn of Crookadale	Burn of Crookadale	HU4339 5391	36.5	2.1	76.7	Downstream: tail of riffle above pool. Upstream: tail of long pool
FLAM 1	Burn of Crookadale	Burn of Flamister	HU4379 5504	71.5	1.2	85.8	Downstream: boulder set into left bank. Upstream: water gate.
GIL1	Burn of Crookadale	Gill Burn	HU4343 5484	87.0	1.0	87.0	Downstream: start in pool above bedrock fall. Upstream: top of pool where burn turns right.
QOY1	Burn of Quoys	Burn of Quoys	HU4449 5538	90.0	1.3	117.0	Downstream: pool at sharp left bend. Upstream: top of deep pool.
QOY2	Burn of Quoys	Burn of Quoys	HU4473 5535	80.0	2.3	184.0	Upstream: fence line
QOY3	Burn of Quoys	Burn of Quoys	HU4439 5436	42.5	3.5	148.8	Downstream: 3m down from mature willow left bank (2m up from cliff right bank). Upstream: run into shallow glide/pool.
KIRK1	Burn of Kirkhouse	Burn of Kirkhouse	HU3996 6152	90.0	1.0	90.0	Downstream: end of sharp left bend. Upstream: sharp bend.

contd

Appendix 1 contd. Electric fishing survey site dimensions and locations.

Code	Catchment	Stream	NGR	Length	Width	Area	Location
KIRK2	Burn of Kirkhouse	Burn of Kirkhouse	HU3979 6156	53.5	0.7	37.5	Downstream: pool 30m up from confluence. Upstream: tiny waterfall.
KIRK3	Burn of Kirkhouse	Burn of Kirkhouse	HU4002 6203	28.5	2.6	74.1	Downstream: top of glide above sharp right bend. Upstream: line of bedrock at downstream end of glide.
PW1	Sand Water	Burn of Petta Water	HU4173 5846	95.0	0.8	76.0	Downstream: peat bridge where stream flows underground.
PW2	Sand Water	Burn of Petta Water	HU4172 5715	69.0	2.0	138.0	Downstream: 1m upstream from tiny tributary at left bank (marked by big grey mossy boulder in right bank).
PW3	Sand Water	Burn of Petta Water	HU4159 5553	67.0	2.2	147.4	Downstream: left bend at bottom of first stony run upstream from footbridge.
WEI1	Burn of Weisdale	Burn of Weisdale	HU4053 5779	86.0	1.2	103.2	Downstream: bottom of glide where tributary joins at right bank. Upstream: narrow small torrent.
WEI2	Burn of Weisdale	Burn of Weisdale	HU4051 5672	43.5	3.1	134.9	Downstream: 10m down from tributary on right bank. Upstream: riffle at tail of long glide.
WEI3	Burn of Weisdale	Burn of Weisdale	HU4013 5421	38.5	3.3	127.1	Downstream: riffle above ditch. Upstream: eroded left bank at riffle above dried out back channel.
MAA1	Burrafirth	Maa Water inflow.	HU3797 5492	40.5	1.0	40.5	Downstream: 15m upstream from loch where peat channel joins right bank.
TRU1	Burrafirth	Between Truggles & Maa Waters	HU3726 5490	29.0	0.6	17.4	Approximately 100m upstream from Truggles Water.
TRU2	Burrafirth	Truggles Water inflow	HU3722 5443	NA	NA	NA	Alongside ruin.
TRU3	Burrafirth	Truggles Water outflow	HU3661 5451	72.0	1.3	93.6	Downstream: apex of sharp meander.
ATL1	Burrafirth	Burn of Atlascord	HU3644 5431	49.0	1.8	88.2	Downstream: 10m below small bedrock cliff/outcrop on right bank (where wet flush comes in at left bank).
SBF1	Burrafirth	S. Burn of Burrafirth	HU3648 5473	44.0	2.1	92.4	Downstream: at rock cliff on right bank (on left bend in stream). Upstream: 4m down from confluence.
SBF2	Burrafirth	S. Burn of Burrafirth	HU3640 5559	40.0	3.3	132.0	Downstream: top end of hairpin bend. Upstream: little cascade over bedrock shelf.
SBF3	Burrafirth	S. Burn of Burrafirth	HU3670 5689	28.0	4.0	112.0	Downstream: huge midstream boulder. Upstream: Large rock set into right bank.
SBF4	Burrafirth	Burrafirth	HU3668 5750	36.5	6.1	222.7	Downstream: point of bedrock approx 30m upstream from bridge.
LAM1	Burrafirth	Burn of Vats-houll	HU3844 5589	NA	NA	NA	Start 20m upstream from loch.
LAM2	Burrafirth	Burn of Lamba Water	HU3749 5681	42.0	1.1	46.2	
LAM3	Burrafirth	Burn of Lamba Water	HU3743 5710	77.2	1.3	100.4	Downstream: midstream boulder below Z-bend. Upstream: large boulder right bank.
LUN1	Burrafirth	Burn of Lunklet	HU3744 5732	50.7	1.5	76.1	Downstream: watergate. Upstream: small drop over 2 boulders (good stopper).
LUN2	Burrafirth	Burn of Lunklet	HU3731 5731	31.6	2.9	91.6	Downstream: top of bedrock run (start at white boulder left bank). Upstream: confluence of three tributaries.
MAR1	Burrafirth	Marrofield Water	HU3746 5802	52.5	2.2	115.5	Downstream: midstream triangular rock. Upstream: confluence of small stream left bank.

Appendix 2. Length (mm) of trout at electric fishing sites.

Laxobigging								Skelladale				W. Filla	
LBG1	LBG2	LBG3	LBG4	LBG5	STN1	MOF1	NB1	SK1	SK2	SK3	SK4	WF1	WF2
57	57	65	53	55	152	53	65	120	42	47	85	34	41
59	62	66	55	59		56	75		42	49	85	40	42
60	63	91	56	60		62	129		45	52	85	41	42
60	67	92	59	62		67	137		50	85	87	45	42
61	98	97	59	66		68	147		56	95	88	45	43
62	98	100	60	67		70	155		58	97	88	49	43
62	100	101	61	67		71	205		58	101	95	49	43
64	100	106	62	68		72			59	102	100	50	44
64	102	107	63	70		109			60	119	100	50	44
65	103	109	66	70		123			91	130	100	50	44
90	103	114	*74*	71		174			91	132	102	52	45
91	103	132	*75*	71					92	140	102	52	45
102	110	133	*77*	72					120	150	105	54	45
104	111	134	*78*	74					130	162	107	54	46
104	115	136	*78*	75					133		107	54	46
107	119	154	*81*	76					138		108	54	46
110	148	158	*81*	76					148		112	55	46
114	153	165	*86*	76					170		113	56	47
130	163	178	*86*	78							114	56	47
132	166		*86*	79							116	57	47
151	188		*86*	79							126	57	48
162			*87*	*85*							131	58	49
165			*88*	*93*							145	58	49
168			*88*	*94*							155	58	50
235			*88*	*100*							174	59	50
			88	*100*								59	50
			89	*100*								60	50
			91	*102*								60	50
			91	103								61	50
			92	106								61	51
			93	*110*								61	51
			94	110								62	51
			100	110								63	51
			101	110								63	53
			103	112								63	54
			107	116								64	54
			107	118								64	55
			110	120								66	56
			115	120								66	56
			120	121								66	57
			127	121								67	57
			133	123								67	58
			136	124								69	58
			140	126								70	59
			155	130								70	60
			163	130								109	61
				133								115	62
				150								119	63
				163								120	63
				164								121	63
				184								137	63
												173	64
												192	65
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													123
													125
													129
													134
													265

Italics indicate fish that appeared to be stocked. NM: fish counted but not measured.

Appendix 2 contd. Length (mm) of trout at electric fishing sites.

Laxo														Grunnafirth				
EF1	EF2	EF3	TJB1	GOS1		GOS2	GOS3	SEG1	SEG2	SEG3	SEG4	LAX1	LAX2	FOR1	FOR2	FOR3	GRU1	GRU2
NM	50	58	NM	35	59	NM	80	NM	52	58	72	73	62			58	57	62
	52	64		38	59		113		54	61	72	77	66			58	58	69
	59	66		39	59		121		55	63	75	78	67			63	62	70
	60	66		39	60		127		57	65	76	81	69			63	68	71
	60	67		39	60		130		57	68	79	85	73			64	70	74
	60	67		39	60		130		61	68	81	110	73			64	70	74
	62	67		40	60		134		61	69	106	110	74			65	88	75
	62	67		40	61		137		62	70	107	115	74			65	93	77
	63	67		40	61		174		62	71	113	116	75			66	99	79
	64	67		40	61		185		63	72	113	119	75			66	100	81
	64	68		40	62		225		64	72	122	122	76			68	100	106
	65	68		41	62				66	72	123	130	76			68	103	115
	65	69		42	63				70	74	128	144	77			69	104	116
	67	69		42	63				72	74	128	155	78			69	105	118
	67	70		43	63				75	74	130	164	78			70	107	120
	68	71		43	64				103	75	133		79			72	110	121
	68	71		44	64				107	77	153		*90*			73	110	126
	69	71		44	64				108	78	156		97			73	118	128
	71	71		44	66				108	80	164		*98*			73	119	142
	72	72		44	67				109	89	164		*99*			92	126	162
	72	72		45	67				110	100	165		*102*			93	130	163
	73	74		45	67				112	105	177		*104*			98	130	171
	74	74		45	68				112	110			104			99	140	180
	74	75		45	69				113	113			105			100	151	206
	75	76		45	70				115	116			106			101	155	
	76	76		45	70				118	118			*107*			102	157	
	77	76		45	70				129	118			*108*			103	181	
	103	76		46	72				132	121			110			105		
	112	76		46	73				133	122			110			105		
	117	77		46	75				136	124			*111*			105		
	155	78		46	79				140	124			111			107		
		78		46	85				141	126			112			113		
		79		48					142	142			113			115		
		80		48					142	146			115			115		
		81		48					144	152			116			115		
		84		48					148	156			117			117		
		84		48					148	158			120			118		
		114		48					151	158			120			121		
		114		48					153	194			121			122		
		116		49					157	205			124			124		
		116		49					158				124			130		
		124		49					160				124			134		
		194		50					164				148			137		
		210		50					168				*157*			138		
				50					173				184			140		
				50					178							170		
				51					189							174		
				51					190							202		
				51					220							232		
				52														
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Italics indicate fish that appeared to be stocked. NM: fish counted but not measured.

Appendix 2 contd. Length (mm) of trout at electric fishing sites.

Crookadale							Quoys			Kirkhouse			Sandwater				Weisdale		
CRK1	CRK2	CRK3	CRK4	FLAM1	GIL1	GIL2	QOY1	QOY2	QOY3	KIRK1	KIRK2	KIRK3	PW1	PW2	PW3		WEI1	WEI2	WEI3
NM	69	129	48	51		NM	115	86	55	64	70	60		58	67	136	40	52	67
	71	152	48	56			131	91	62	66	121	61		61	67	141	45	55	69
	106	187	52	57			165	105	62	72	124	63		62	68	147	51	57	69
	107		52	59				106	65	109	139	63		62	68	147	52	58	70
	114		52	59				112	71	117		65		64	69	148	53	58	89
	116		52	60				115	95			65		66	70	151	54	60	90
	125		54	60				117	96			66		66	70	154	55	62	91
	129		55	62				131	97			66		66	71	177	56	63	92
	154		55	62				134	98			66		66	71	183	58	63	94
			55	65				138	101			67		67	71		60	64	99
			57	66				144	106			69		67	72		60	65	100
			57	66				165	108			70		67	72		61	66	101
			57	67					109			71		67	72		61	66	101
			57	67					110			71		68	72		61	67	101
			58	67					111			73		71	73		61	68	102
			58	69					113			76		71	73		62	68	103
			59	70					113			76		75	74		64	69	105
			60	73					114			76		76	74		66	70	105
			60	73					120			80		77	74		66	70	107
			60	73					124			115		79	76		68	70	109
			60	74					128			117		81	76		68	91	114
			61	75					138			119		82	76		69	93	114
			61	76					140			131		85	77		69	98	115
			64	76								165		86	77		73	104	115
			64	76										125	77		73	110	117
			64	77										136	78		74	116	118
			66	78										137	78		78	122	119
			69	78										140	79		101	158	120
			71	78										145	79		104		120
			85	79										154	79		105		121
			106	79											80		105		121
			107	81											80		107		123
			107	82											80		107		123
			109	82											81		108		124
			114	82											82		116		125
			116	83											82		123		126
			141	84											83		124		128
			162	84											83		126		129
			189	85											84		128		132
				85											84		129		132
				87											84		136		133
				89											84		141		139
				116											84				140
				118											85				142
				122											86				151
				123											86				152
				167											86				181
				191											86				
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															92				
															95				
															97				
															116				
															122				

Italics indicate fish that appeared to be stocked. NM: fish counted but not measured.

Appendix 2 contd. Length (mm) of trout at electric fishing sites.

Burrafirth														
MAA1	TRU1	TRU2	TRU3	ATL1	SBF1	SBF2	SBF3	SBF4	VH1	LAM1	LAM2	LUN1	LUN2	MAR1
NM	NM	NM	66	57	NM	49	49	52		NM	54	55	60	94
			67	58		49	52	57			58	56	63	97
			71	59		53	57	60			62	58	66	97
			72	62		55	60	60			62	61	67	98
			72	63		58	60	61			64	63	69	101
			73	63		58	62	62			64	66	69	106
			74	64		59	62	64			66	67	70	110
			74	65		59	64	69			68	67	72	112
			74	65		59	65	106			69	68	73	115
			75	65		61	66	106			69	68	76	126
			76	65		62	66	108			70	68	80	192
			78	67		62	94	108			70	69	82	
			81	67		62	102	113			72	70	101	
			102	67		65	102	114			72	72	102	
			104	67		66	103	118			73	93	111	
			106	67		67	109	119			74	102	117	
			108	67		68	109	120			74	105	125	
			110	68		71	109	124			76	119	130	
			113	68		73	114	127			76	120	140	
			114	68		73	126	134			76	120	141	
			117	70		95		137			79	151		
			121	70		95		145			79			
			122	70		104		150			80			
			122	72		107		151			80			
			154	72		108		151			80			
				73		110		169			80			
				99		111					122			
				102		116					158			
				104		117					176			
				105		121								
				107		122								
				108		149								
				111		167								
				118										
				122										
				158										

Appendix 3. Length (mm) of salmon at electric fishing sites.

Laxo			Burrafirth		
GOS3	SEG3	LAX1	SBF2	SBF3	SBF4
83	110	77	112	96	95
125	123	79	122	102	96
129	131	84		105	98
142		85		110	99
		91			100
					100
					102
					102
					109
					110
					112
					112
					113

Note: only sites with salmon present are shown.

Appendix 4 Survey equipment and conditions.

All sites surveyed using Electracatch backpack units model WFC911 with 40cm anode ring and 3 - 5m long braided copper cathodes.

Catchment	Code	Survey date	Volts	Conductivity $\mu.cm^{-1}$	Temperature ^{o}C	Water Level
Burn of Laxobigging	LBG1	04/09/2008	200	110	11.9	moderate
Burn of Laxobigging	LBG2	04/09/2008	190	114	12.4	low-moderate
Burn of Laxobigging	LBG3	04/09/2008	190	115	14.9	low-moderate
Burn of Laxobigging	LBG4	07/09/2008	200	155	11	low-moderate
Burn of Laxobigging	LBG5	07/09/2008	180			low-moderate
Burn of Laxobigging	STN1	04/09/2008	190	148	11.6	low-moderate
Burn of Laxobigging	MOF1	04/09/2008	190	131	12.4	low-moderate
Burn of Laxobigging	NB1	07/09/2008	150	198	11	low-moderate
Burn of Skelladale	SK1	30/08/2008	240			low
Burn of Skelladale	SK2	30/08/2008	280			low
Burn of Skelladale	SK3	30/08/2008	250			low
Burn of Skelladale	SK4	30/08/2008	250			low
Wester Filla	WF1	02/09/2008	160	182		moderate
Wester Filla	WF2	02/09/2008	210	155		moderate
Laxo	EF1	01/09/2008				moderate-high
Laxo	EF2	02/09/2008	210	135	13.9	moderate
Laxo	EF3	01/09/2008	220	117	14	moderate
Laxo	TJB1	07/09/2008				low
Laxo	GOS1	06/09/2008	180	150	13	low
Laxo	GOS2	06/09/2008				
Laxo	GOS3	06/09/2008	200	200	13.1	low
Laxo	SEG1	31/08/2008	160	279	12.2	low
Laxo	SEG2	31/08/2008	160			low
Laxo	SEG3	31/08/2008	180	260	13	low
Laxo	SEG4	31/08/2008	180	280	13	low
Laxo	LAX1	07/09/2008	160	174	11	low-moderate
Laxo	LAX2	29/08/2008	180	232	13	low
Burn of Grunnafirth	FOR1	31/08/2008	250			low
Burn of Grunnafirth	FOR2	31/08/2008	220	183		low
Burn of Grunnafirth	FOR3	31/08/2008	220	172		low
Burn of Grunnafirth	GRU1	31/08/2008	220	175		low
Burn of Grunnafirth	GRU2	02/09/2008	220	130	12	low
Burn of Crookadale	CRK1	07/09/2008	160			low
Burn of Crookadale	CRK2	07/09/2008	160			low
Burn of Crookadale	CRK3	03/09/2008	160	143	14.3	low
Burn of Crookadale	CRK4	03/09/2008		158	13.4	moderate
Burn of Crookadale	FLAM1	03/09/2008	200	132	11.8	low
Burn of Crookadale	GIL1	03/09/2008	180	144	12.9	low
Burn of Crookadale	GIL2	03/09/2008				low
Burn of Quoys	QOY1	01/09/2008	220	124		high
Burn of Quoys	QOY2	01/09/2008	220	107		high
Burn of Quoys	QOY3	02/09/2008	220	150	12.5	moderate
Burn of Kirkhouse	KIRK1	02/09/2008	180	111	13.5	moderate
Burn of Kirkhouse	KIRK2	02/09/2008	190	114	13.5	moderate
Burn of Kirkhouse	KIRK3	02/09/2008	190			moderate
Sand Water	PW1	30/08/2008	160			low
Sand Water	PW2	30/08/2008	160	260	1.2	low
Sand Water	PW3	30/08/2008	160	290	13.9	low

Catchment	Code	Survey date	Volts	Conductivity $\mu.cm^{-1}$	Temperature $^{\circ}C$	Water Level
Burn of Weisdale	WEI1	03/09/2008	200	125	13.3	low
Burn of Weisdale	WEI2	03/09/2008	210	155	13.7	low
Burn of Weisdale	WEI3	05/09/2008	170	166	13.7	low
Burrafirth	MAA1	28/08/2008	200	145	14	low
Burrafirth	TRU1	28/08/2008				
Burrafirth	TRU2	28/08/2008				
Burrafirth	TRU3	28/08/2008	200	155	14	low
Burrafirth	ATL1	28/08/2008	200	185	13	low
Burrafirth	SBF1	28/08/2008				low
Burrafirth	SBF2	28/08/2008	200			low
Burrafirth	SBF3	28/08/2008	220	160		low
Burrafirth	SBF4	29/08/2008				
Burrafirth	VH1	09/09/2008				low
Burrafirth	LAM1	09/09/2008				low
Burrafirth	LAM2	05/09/2008	210	113	14.1	low
Burrafirth	LUN1	05/09/2008	210	116	13	low
Burrafirth	LUN2	05/09/2008	210	118	13.1	low-moderate
Burrafirth	MAR1	05/09/2008	210	106	12.1	low