SURVEY REPORT

Isle of Mull Rivers Project: Summary of 2010 Fish Populations, Habitat Surveys and Potential Habitat Management Initiatives

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For further information on this report please contact;
Argyll Fisheries Trust,
Cherry Park,
Inveraray,
Argyll, PA32 8XE

SURVEY REPORT

Summary

Isle of Mull Rivers Project: Summary of 2010 Fish Populations, Habitat Surveys 2010 and Potential Habitat Improvement Initiatives.

Background

Argyll Fisheries Trust undertook electrofishing and habitat surveys of eight river catchments on the Isle of Mull in 2010. The aim of the surveys was to assess fish species distribution and their relative abundance compared to a previous survey conducted in 2003. New data were collected on fish habitats.

This report has two main purposes:

1. To enable land managers and landowners to identify riparian improvement works that will enhance biodiversity and the fishery resource. Potential sources of grant aid to fund improvement work are highlighted in section 5.2 of this document.

2. To provide a baseline survey so that future comparison studies can assess the health of the fisheries and the benefits secured from any habitat works.

This report summarises the findings of the survey and provides management advice for fisheries and habitat improvement. Catchment specific reports of the study provide detailed information and management prescriptions.

Main findings

Electrofishing surveys undertaken at 68 sites found five native species; Atlantic salmon (*Salmo salar*), Brown trout (*Salmo trutta fario*), European eel (*Anguilla anguilla*), flounder (*Platichthys flesus*) and three-spine stickleback (*Gasterosteus aculeatus*). Lamprey (*Lampetra spp.*) are also likely to be present but were not found during this survey. One translocated species; minnow (*Phoxinus phoxinus*) was also found in two of the eight catchments surveyed.

Juvenile Atlantic salmon and brown trout were sampled in all eight catchments surveyed. Salmon fry were sampled at 66% of sites and salmon parr were sampled in 60% of sites. Trout fry were sampled at 63% of sites and trout parr were sampled at 47% of sites. Salmon were found at only one survey site on the Bunessan catchment.

Where present the relative abundance of juvenile salmonids was variable between survey

sites in each catchment, ranging from a relatively low to very high abundance when compared to a classification scheme for rivers on the west of Scotland. Comparisons with the juvenile salmonid fish abundance found in 2003 indicate that salmon abundance was lower in three catchments on the east of the island; Aros, Forsa and Lussa in 2010. The relative abundance of juvenile salmon was higher in the north and west catchments in 2010 compared to 2003. Comparisons of juvenile trout abundance between 2003 and 2010 were variable.

Habitat surveys were undertaken on 67 km of main channels in eight catchments. The location and assessment of 99 obstacles to fish passage and size and condition of 219 significant adult holding pools and 334 spawning sites was recorded.

The connectivity of habitats to fish from the sea were influenced by naturally occurring high gradient features such as waterfalls and cascades, but there is a rudimentary fish pass on the Mingary catchment at the dam on Loch an Torr. It was not possible to assess the passage of fish at the dam from the fish data collected as part of this study.

The condition of juvenile salmonid fish habitat was mostly of moderate status, but was poor in the Bunessan, and some reaches of the Bellart, Forsa and Ba catchments due to changes to river morphology. The condition of riparian habitat was generally poor due to land use influences; forestry and grazing of livestock. The most abundant type of juvenile habitat found was suited a range of age classes (mixed), with habitat specific to fry (young of the year) present in all catchments. Deep juvenile habitat (specific to older parr and sub-adults) were also present in abundance in the lower Bellart catchment.

The factors affecting productivity of juvenile habitats were identified for in-stream conditions, which included sections of bedrock, compaction of riverbed sediments, channel modification and lack of large woody debris. Widespread factors affecting riparian habitats included lack of shading of the stream channel and lack of bank cover (vegetation) for fish. Japanese Knotweed (*Fallopia japonica*) at one location in the Aros catchment and Rhododendron (*R. ponticum*) was found at five locations in three catchments; the Ba, Forsa and Lussa.

The following conclusions were reached:

Much of the habitat management and improvement actions may be accomplished by land and fishery managers and owners. Guidance and sources of funding for this work can be found in the catchment specific reports generated as part of this study.

The distribution of juvenile salmon and trout was relatively wide in all eight catchments surveyed, but salmon were most commonly found in main river channels, compared to trout that were frequently found in smaller tributary streams.

A poor distribution and relatively low abundance of juvenile salmon were found in the Bunessan and there were also some sites in the Coladoir and Lussa catchments where juvenile salmon were not present, but suitable habitat were available. The highly variable abundance of juvenile salmon indicate localised areas are relatively well utilised for recruitment of salmon in a number of catchments, while other areas are less well populated. Patchy distribution and variable abundance of juvenile salmon is likely to be primarily a consequence of low numbers of adult sea returns and subsequent egg deposition. The relatively small salmon population in the Bunessan may be vulnerable to localised habitat disturbance.

The poor distribution and relatively low abundance of juvenile trout found in the main river habitats of catchments may be an artefact of the trout preference for smaller tributary streams for recruitment. Relatively high densities at some sites indicate that they are likely to be derived from the migratory form, sea trout. Similarly to salmon, the principle factors affecting productivity of migratory trout are likely to occur in the marine phase of their life-cycle at this time. However, the habitat survey identified a number of factors affecting the productivity of freshwater habitats that are likely to be a mixture of natural channel features and a consequence of land use.

The data collected on fish indicate that salmon and trout populations are not likely to support exploitation by fisheries at this time. Operating fisheries on conservation-minded principles will be essential to maximise spawning escapement of sea run adult fish and stimulate restoration of the fishery resource. Management and regulation of the use of local marine resources, principally aquaculture and future development of marine renewable are likely to have a significant influence on the health and survival of migratory species during the marine phase of their life-cycle.

The restoration of natural river morphology in significant reaches of the lower Bellart, Bunessan and Mingary are likely to have significant long-term benefits for fish populations and wider biodiversity. However, there are significant resources, technical and land use considerations to be better understood and overcome if ecological status is to be improved.

Modification of habitat for angling amenity (weirs for pool creation) on the Forsa and Ba are likely to have localised affects on recruitment and habitat availability for both adult and juvenile salmonids. A detailed geomorphological study of how such structures affect fish habitat at the reach scale may be necessary to assess suitability and possible improvements.

Agriculture is the most significant land use affecting riparian habitats, which are mostly open to grazing. Localised fencing of stream banks affected by grazing may improve the diversity

of riparian vegetation, but a more significant scale of broadleaf tree planting and protective fencing are required in the Lussa, Ba, Bellart and upper Forsa to improve the diversity of vegetation. Additional control of deer numbers may also be required to reduce significant grazing pressure on stream banks. An integrated approach to control of grazing and restoration of stream morphology is likely to be required to achieve widespread and significant improvement as measures to regenerate bank vegetation may prevent or impair natural recovery of morphology where river channels have been modified. The planting or regeneration of existing native trees in riparian zones in combination with effective fencing is likely to have longer-term benefit for management of water temperature, which may be a limiting factor for salmonid fish in the future depending on the localised effects of global warming.

Forestation of the Mingary Burn catchment has a significant influence on riparian habitat, which in places will require re-structuring to achieve standards outlined in the Forest and Water Guidelines.

Timely measure for control and eradication of Japanese Knotweed on the upper reaches of the Aros catchment are likely to prevent further spread. Measures for prevention of introduction and spread of all priority invasive non-native species on the Island such as knotweed, *R. ponticum* and American mink are likely to have longer-term benefits in protecting against new threats to biodiversity. The minnows found in three catchments may be more widespread, but further translocation must be avoided to prevent competition and biosecurity risks to native fish.

Biosecurity and other threats to native fish resources are also posed by aquaculture activity in freshwater catchments; the Ba and the Aros. Due to the relatively small size of local salmon populations, they may be vulnerable to potential competition and inter-breeding with escapee farm salmon from freshwater and marine rearing facilities. Analysis of genetic samples collected during this survey may inform management of wild fish resources, particularly where stocking is being undertaken or where fish farm escapes has been recorded.

Acknowledgements

Argyll Fisheries Trust thanks the project partners for their support; Scottish Natural Heritage (SNH), all fishery owners and Forestry Commission and other land owners for permission to access survey sites. Additional thanks are given to all those that helped with the survey work and to Marine Science Scotland for providing fishery catch data.

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1 INTRODUCTION

Argyll Fisheries Trust undertook electrofishing surveys of fish population and habitat on eight catchments on the Isle of Mull in 2010 (Figure 1.1). The aim of the surveys was to collect information on fish species distribution; their relative abundance and the quality of habitats to establish the status of the freshwater resource. Additionally, guidance for habitat management and improvement initiatives are provided to enable land managers and landowners to identify riparian improvement works that will restore and enhance biodiversity and the fishery resource. Potential sources of grant aid to fund improvement work are highlighted in section 5.2 of this document.

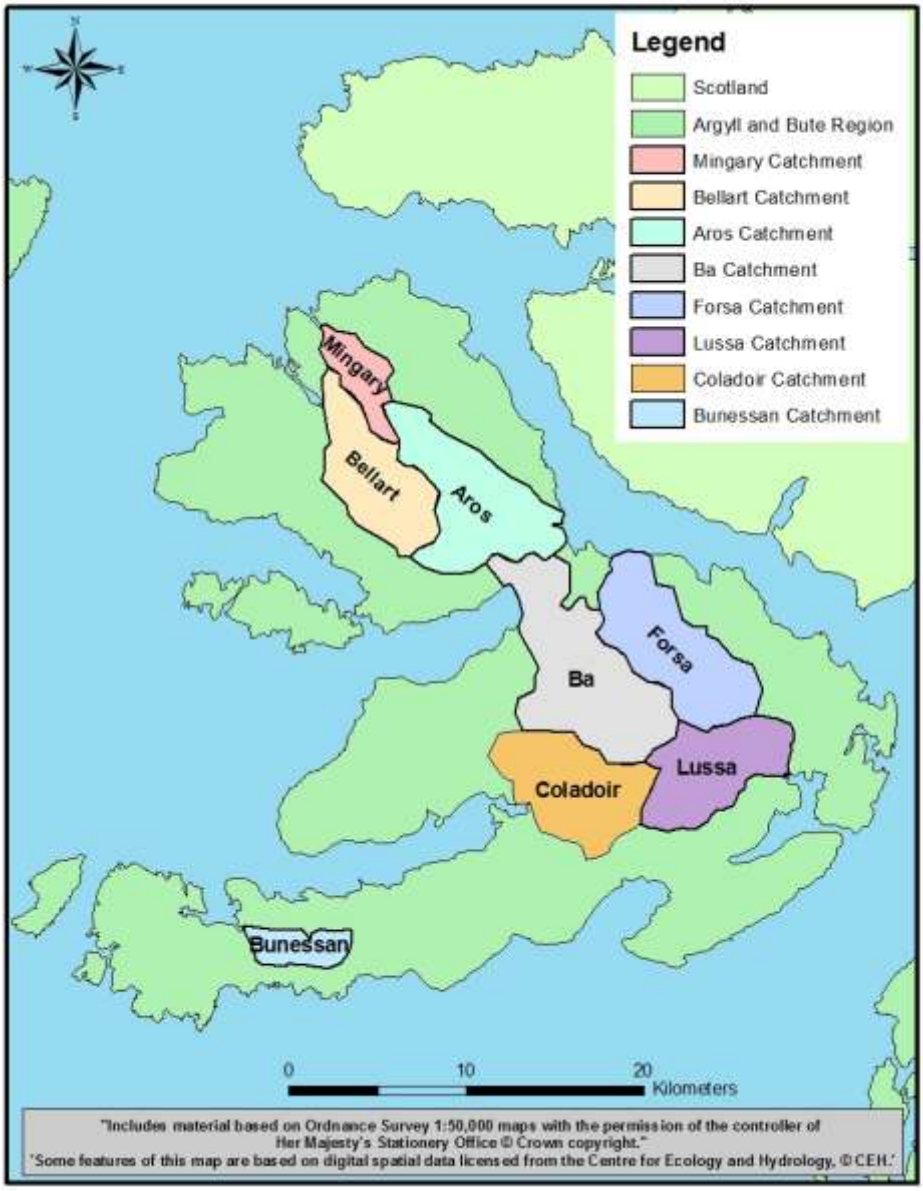

Figure 1.1 Mull catchments surveyed in 2010

This report summarises the findings of the surveys undertaken in 2010 and makes comparison to fish data collected in 2003 using the same protocol. This report has two main purposes.

Firstly it will enable land managers and landowners to identify riparian works which will enhance biodiversity and fishery productivity and give guidance on potential sources of grant aid to help fund improvement work. Secondly, in addition to the 2003 data, this survey provides further baseline data on fish populations which may contribute to time-series information so that future comparison studies can assess the health of the fisheries over time and quantify any benefits delivered by habitat improvement works in the future.

In addition to the survey findings, the implication for management is discussed and management actions that are likely to be beneficial to fish will also improve the aquatic environment and protect wider biodiversity. Potentially beneficial initiatives are linked to environmental measures in the Scottish Rural Development Programme (SRDP) in Appendix II and III, which may be a useful resource for informing habitat improvements and identifying sources of funding to deliver improvement work. Catchment specific reports that provide more detailed information on the study findings are provided separately

Surveyed Catchments

There are aspects of geology, topography and anthropogenic pressures that influence the productivity of freshwater habitats and status of fish populations. It is important to consider these characteristics when interpreting survey results.

1.1.1 Geology and use of land and water resources

The catchments surveyed on the Isle of Mull are primarily influenced by base geology (Figure 1.2) which consists of a mix of igneous extrusive and intrusive rock types. Overlaying superficial deposits of till and peat soils are also present (Figure 1.3).

The combination of slow weathering hard rock types and poorer soils indicate that base productivity for most of the island is relatively low. There is a varied use of land resources, including farming livestock, forestry and infrastructure development, that have a potential to effect ecological status and fish habitat. Further pressure is exerted on Mulls freshwater resources by demand for potable water supply and aquaculture production of salmon smolt that could potentially escape and interact directly with and affect the health status of wild fish.

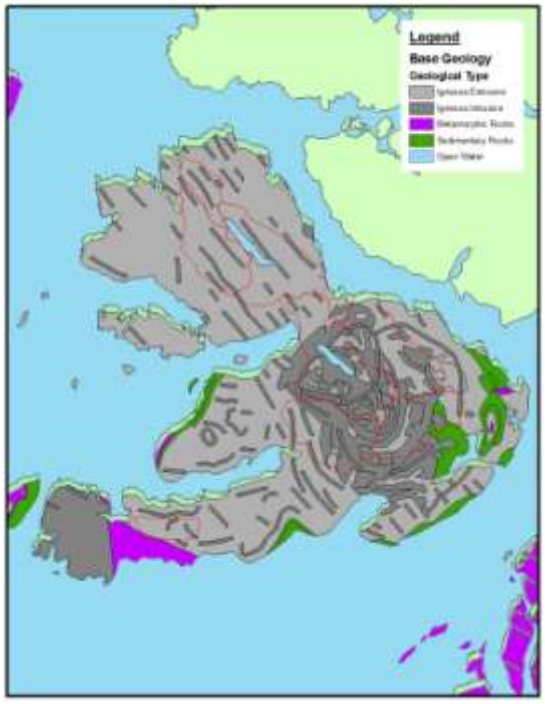

Fig.1.2 Base geology of the Isle of Mull

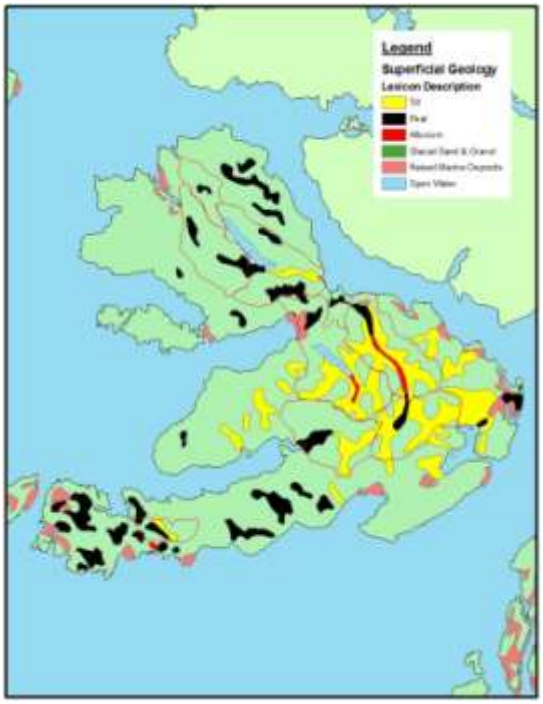

Fig. 1.3 Superficial geology of the Isle of Mull

1.1.2 Ecological status of freshwater catchments

The 2010 survey included eight catchments which have been assessed by the Scottish Environment Protection Agency (SEPA) as part of the Argyll and Lochaber River Basin Plan (http://www.sepa.org.uk/water/river_basin_planning/area_advisory_groups/argyll.aspx). As part of this process, the ecological status of all catchments have been categorised (Table 1.1).

Table 1.1 Ecological status of catchments surveyed in (SEPA) 2010

Catchment	Waterbody	ID	Ecological status	Identified pressure	Other
North					
Mingary	Mingary (main)	10340	Good	None	
Bellart	Bellart (main)	10339	Good	None	
West					
Ba	Ba river	10335	Good	None	Aquaculture
	Loch Ba	100241	Moderate	Diffuse pollution	Aquaculture
	Clachaig	10335	Moderate	Acidification	
	Glencannel	10336	Moderate	Low productivity	
Coladoir	Coladoir (main)	10332	Good	None	
Bunessan	Bunessan (main)	10328	Poor	Flow regulation	Abstraction
	Loch Assapol	100253	HMWB (Bad EP)		
East					
Aros	Aros River	10343	Good	None	
	Loch Frisa	100229	Good	None	Aquaculture
Forsa	Forsa River	10337	Good	None	
Lussa	Lussa River	10333	Good	None	

The ecological status of the freshwater catchments within the survey area varies from bad ecological potential in the heavily modified water body (HMWB) of Loch Assapol and poor status of the out-flowing river in the Bunessan catchment to moderate in much of the Ba catchment and good in all others.

1.1.3 Ecological status of coastal waters

Migratory fish also utilise inshore marine habitats that have also been assessed as part of the River Basin Plan. The Bellart and Mingary catchments flow north, but only the estuarine waters of the Bellart have been assessed, where Loch a Chumhainn was classified as having good ecological status and is also a shellfish protected area. The west flowing catchments of the Bunessan and the Coladoir flow into Loch Scridain which is currently of good ecological status and is a shellfish protected growing area. There has historically been a salmon fish farm site in Loch Scridain, but this is not currently used.

Table 1.2 Ecological status of coastal water bodies (SEPA) 2010

Catchment	Waterbody	ID	Ecological status	Identified pressure	Other
North					
Mingary	Loch Mingary		None	None	
Bellart	Loch a Chumhainn	200350	Good	None	
West					
Ba	Loch Na Keal	200071	Good	None	Aquaculture
Coladoir	Loch Scridain	200064	Good	None	Aquaculture*
Bunessan	Loch Scridain	200065	Good	Flow regulation	Aquaculture*
East					
Aros	Sound of mull	200464	Moderate	Benthic invertebrates	Aquaculture
Forsa	Sound of mull	200464	Moderate	Benthic invertebrates	Aquaculture
Lussa	Loch Spelve	200065	Good	Diffuse pollution	Aquaculture

Note no site currently in use*

The east flowing catchments of the Aros and Forsa flow directly into the sound of Mull which classified to be of moderate ecological status. The Lussa catchment flows into Loch Spelve which is of good status, but does not currently meet shellfish growing water guidelines. Both the sound of Mull and Loch Spelve have significant development of fish farms for Atlantic salmon.

1.2 Fish populations and fisheries

The freshwater habitats of the Isle of Mull consist of a number of moderate-sized river catchments, small coastal streams and a number of lochs. Fish fauna is dominated by species that migrate between freshwater and marine habitats such as Atlantic salmon (*Salmo salar*) and the migratory form of brown trout; the sea trout (*Salmo trutta*). Other native fish species that can typically be found to utilise freshwater ecosystems on the west coast region of Scotland during their life-cycle are understood to be European eel (*Anguilla anguilla*), river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*), three spine stickleback (*Gasterosteus aculeatus*) and flounder (*Platichthys flesus*). Brook lamprey (*Lampetra planeri*) and some genetically distinct brown trout populations may spend their entire life in freshwater. This study was mainly focused on salmonid fish, but also collected data on other species present in samples at survey sites.

1.2.1 Salmonid fish life-cycle

Typically migratory adult salmonid fish return to freshwater in the summer months before reproducing during the late autumn and early winter period. Fertilised eggs are incubated

within the substrates of the river bed before emerging as fry (young of the year) in spring. Subsequently, free-swimming stages of juvenile salmonid fish inhabit freshwater rivers for a period of one (as fry), two or three years (as parr) or sometimes longer. Juveniles then migrate to sea as smolts where they complete over 90% of their growth phase before maturation and eventual return to their natal rivers. Unlike salmon, a proportion of the trout population (usually a high percentage of males) remain in freshwater as a resident form of brown trout where they may or may not interbreed with sea run morphs. This report will evaluate the current status of juvenile salmonid fish in their fry and parr stages prior to emigration and provide information on distribution, relative abundance and assess the quality and availability of salmonid habitat.

1.2.2 Fisheries for salmon and trout

Mull's fishery resource supports rod & line fisheries for Atlantic salmon and sea trout in most of the catchments surveyed. These recreational fisheries have an important benefit to rural economies. Previously, this resource has been managed by the Mull District Salmon Fishery Board, but the Board has not been in operation in recent years. The stocking of salmon has been undertaken on the Ba and Forsa catchments in recent years with the aim of enhancement of the fishery. Some stocking was also known to have been undertaken on the River Aros prior to 2004.

Historically, fishery catch data has been collected for three fishery districts on Mull. The Ba district on the west also includes the Coladoir, Bunessan (Loch Assapol), Mingary (Loch an Torr) and Bellart fisheries. The Ba catchment reports the largest fishery catch on the Island. The Pennygown district on the east includes the Aros (and Loch Frisa) and the Forsa river fisheries and the Lussa district, which is for the Lussa River only. Fishery catch and stocking records are given in Appendix I.

2 METHODS

To assess the status of fish populations and the condition of their habitat, two survey methods were employed; sampling of fish by electrofishing and assessment of habitats by walk-over survey.

2.1 Electrofishing surveys

The electrofishing technique is used to temporarily stun fish in the close vicinity of the operator, allowing fish to be retained and processed prior to release.

2.1.1 Salmonid fish

The surveys are designed to investigate relatively shallow areas of flowing water (< 1m depth) in which juvenile salmonid fish frequently inhabit. Juvenile life stages of salmonid fish are targeted by such surveys as, unlike adult fish, they are generally present throughout the year and provide a history of which species have spawned in the vicinity of the survey site in recent years. Survey site locations were chosen to represent the likely distribution of migratory fish and typical habitat condition within each catchment.

Fish surveys were conducted during low-to-medium flow conditions with backpack electric fishing equipment, using smooth direct current between 200 and 350 volts. The voltage was varied depending on the conductivity, depth and flow of the water at each site. All surveys (see below) were undertaken in accordance with the Scottish Fisheries Co-ordination Centre (SFCC) protocols (SFCC, 2007). An assessment of the in-stream and riparian habitat characteristics were undertaken at each site. Digital photographs were taken of each site to aid identification during future surveys.

It is preferable to undertake fully-quantitative sampling (i.e. each site fished three times over a known area) to provide accurate estimates of fish abundance with known confidence limits. However, the broad requirement of the survey and limited resources available dictated that a lower resolution of information was collected at a higher frequency of sampling sites. Therefore, semi-quantitative sampling (i.e. each site fished once over a known area) were utilised to estimate the minimum density of fish present within the site at the time of the survey. Captured fish were anaesthetised prior to being identified to species level and measured for length. Scale samples were removed from a number of salmonid fish at each site to provide age information to allow estimates of fry (< 1 year old) and parr (> 1 year old) abundance to be calculated. Genetic samples were also taken from a number of salmon parr for later analysis as part of the Focusing Atlantic Salmon Management on Populations (FASMOP) project.

2.1.2 Other fish

The electrofishing technique used to capture salmon and trout is also effective at capturing non-salmonid fish species. However, physiological differences between species means that the electrical output settings used to capture salmonids do not initiate the same level of response in other species. Additionally, the shallow water habitats targeted during salmon and trout surveys may not reflect the ecological requirements of other species due to seasonal or ontogenetic habitat preferences. Non-salmonid fish data is therefore less accurate and allows only for qualitative assessment of their distribution to be made.

2.1.3 Classification of salmonid fish abundance

Densities of fish were calculated separately for fry (young of the year) and parr (juveniles that have spent at least one winter in freshwater but have not yet been to sea) for salmon and trout. Estimates of minimum density were calculated by dividing the number of fish caught by the area of stream surveyed. In order to provide a guide to the relative abundance of salmonid fish sampled during the survey, minimum density estimates were classified according to the SFCC classification scheme (Godfrey, 2005) (Table 2.1).

The SFCC classification scheme is based on statistical analysis of data from 185 sites in the west coast region of Scotland and places abundance into six quintile ranges (Class A to F) depending on stream width at a given survey site. Classes A (high) through to E (low) are assigned to abundance placed within a given quintile range, while Class F represents an absence of fish. The 100th percentile represents the highest density found at any one of the 185 sites compared.

Table 2.1 Quintile ranges for juvenile salmonid fish density (West region)

	Stream width Class				
Min. Percentile	**<4m**	**4-6m**	**6-9m**	**>9m**	**Class**
Salmon fry (0+)					
0th	1.3	1.6	0.8	0.6	E
20th	2.4	3.5	1.6	2.7	D
40th	5.3	6.0	10.4	8.1	C
60th	10.7	14.0	14.0	15.9	B
80th	17.2	35.5	21.1	45.1	A
100th	60.0	27.3	44.7	29.4	
Salmon parr (1++)	**<4m**	**4-6m**	**6-9m**	**>9m**	**Class**
0th	1.4	0.8	0.5	0.5	E
20th	2.3	2.0	1.9	1.7	D
40th	3.3	5.0	4.4	3.2	C
60th	6.9	6.6	5.9	4.2	B
80th	12.2	10.8	10.9	6.6	A
100th	30.9	40.4	22.0	24.0	
Trout fry (0+)	**<4m**	**4-6m**	**6-9m**	**>9m**	**Class**
0th	1.4	0.7	0.5	0.2	E
20th	9.9	3.0	1.1	0.8	D
40th	28.5	5.0	1.8	1.5	C
60th	44.7	12.4	2.7	2.6	B
80th	74.4	19.0	5.3	4.0	A
100th	181.3	103.5	94.6	9.8	
Trout parr (1++)	**<4m**	**4-6m**	**6-9m**	**>9m**	**Class**
0th	0.9	0.9	0.8	0.5	E
20th	3.9	2.3	1.5	0.7	D
40th	5.6	3.3	2.1	0.9	C
60th	7.6	5.4	3.2	1.5	B
80th	12.1	8.4	4.9	1.8	A
100th	66.7	30.3	10.8	6.0	

2.1.4 Survey sites

A total of 68 fish survey sites covering an area of 8,069 m² of habitat were sampled across the eight catchments (Table 2.2, and Figure 2.1). The wet width of survey sites ranged from

1.1m to 34.0 m and water conductivity ranged between 8 and 83 (μs^{-1}). Water temperatures during the survey ranged from 8.8 to 19.6 °C and survey water conditions were clear with either low or medium height of flow.

Table 2.2 Mull electrofishing survey site summary

Catchment	Catchment Size (km²)	No. of sites	Width range (m)	Total area (m²)	Conductivity (μScm^{-1})	Water Temp. (°C)
North						
Mingary	32	7	1.1 - 4.6	702	40 to71	10.3-16.4
Bellart	25	9	1.1 - 6.1	726	41 to 83	8.8-10.8
Total	*57*	*16*		*1,428*		
West						
Ba	52	12	2.7 - 16.2	1,680	08 to 20	14.1-19.6
Coladoir	36	8	2.6 - 16.8	1,302	13 to 22	10.4-13.8
Bunessan	13	5	1.0 - 3.7	344	61 to 85	13.1-17.2
Total	*101*	*25*		*3,326*		
East						
Aros	45	8	1.3 - 13.87	924	36 to 42	13.4 - 16.7
Forsa	45	10	2.4 - 15.6	1,307	10 to 23	13.0 - 16.5
Lussa	31	9	1.43 - 34.0	1,085	11 to 13	10.1 - 12.5
Total	*121*	*27*		*3,316*		
Total	**279**	**68**		**8,069**		

2.1.4 Comparative electrofishing data

Comparisons of data collected by the SFCC standard electrofishing survey technique are possible for 2003, 2008 (Mingary only) and the data collected by this survey in 2010. Discrepancies in results (when compared between years) may be linked to the environmental conditions at the time of survey; water flow, turbidity and temperature which may affect sampling efficiency. The conditions during the 2003, 2008 and 2010 studies were undertaken in low-to-moderate and clear flow conditions which are unlikely to significantly influence the efficiency surveys. By comparing the class of abundance, rather than minimum density values, broad comparison of population status can be made. Localised changes at one or two survey sites may be expected as a part of natural variation, but widespread differences in abundance of a species or age class at a catchment or regional level may provide more reliable information.

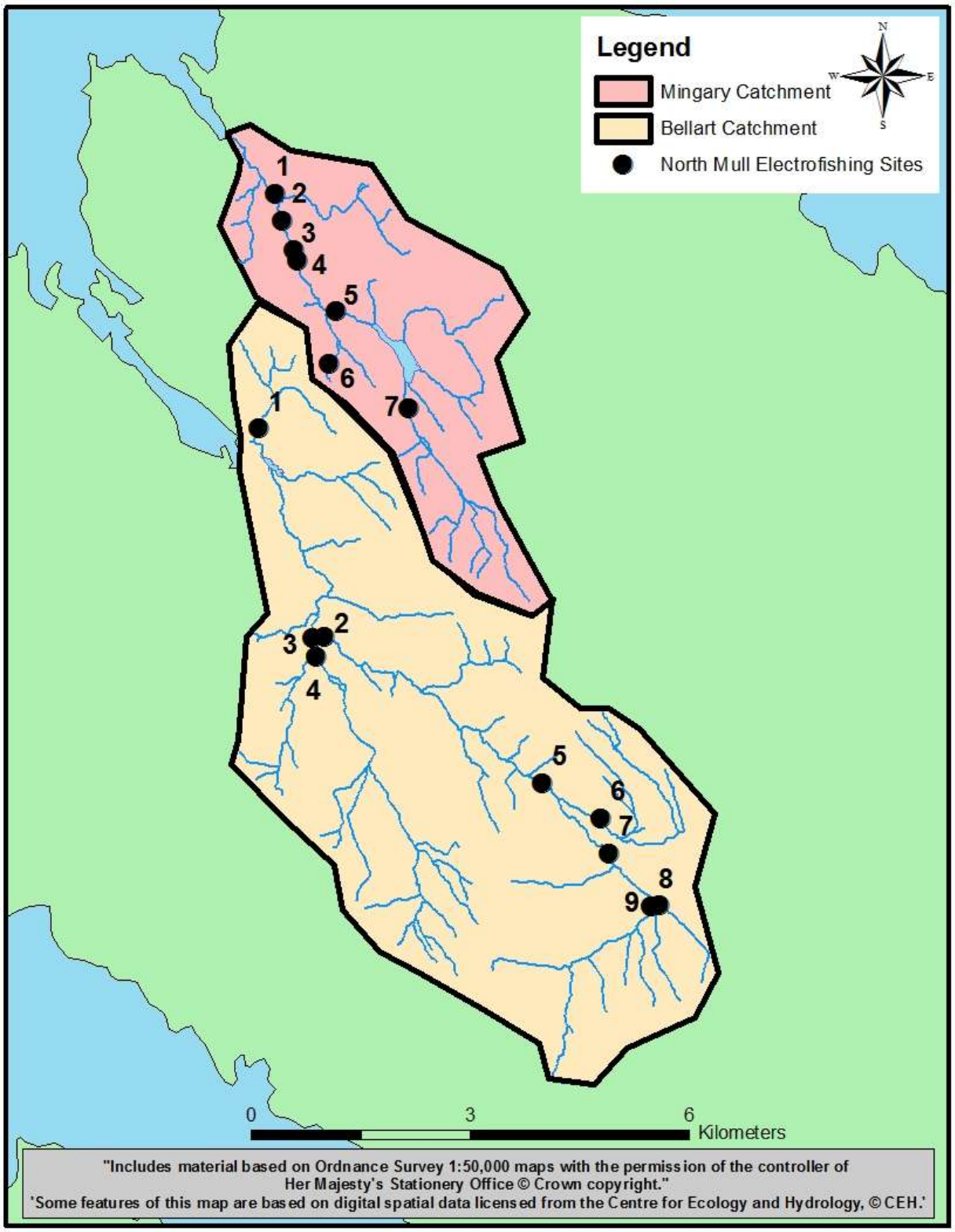

Figure 2.1 North Mull electrofishing survey locations

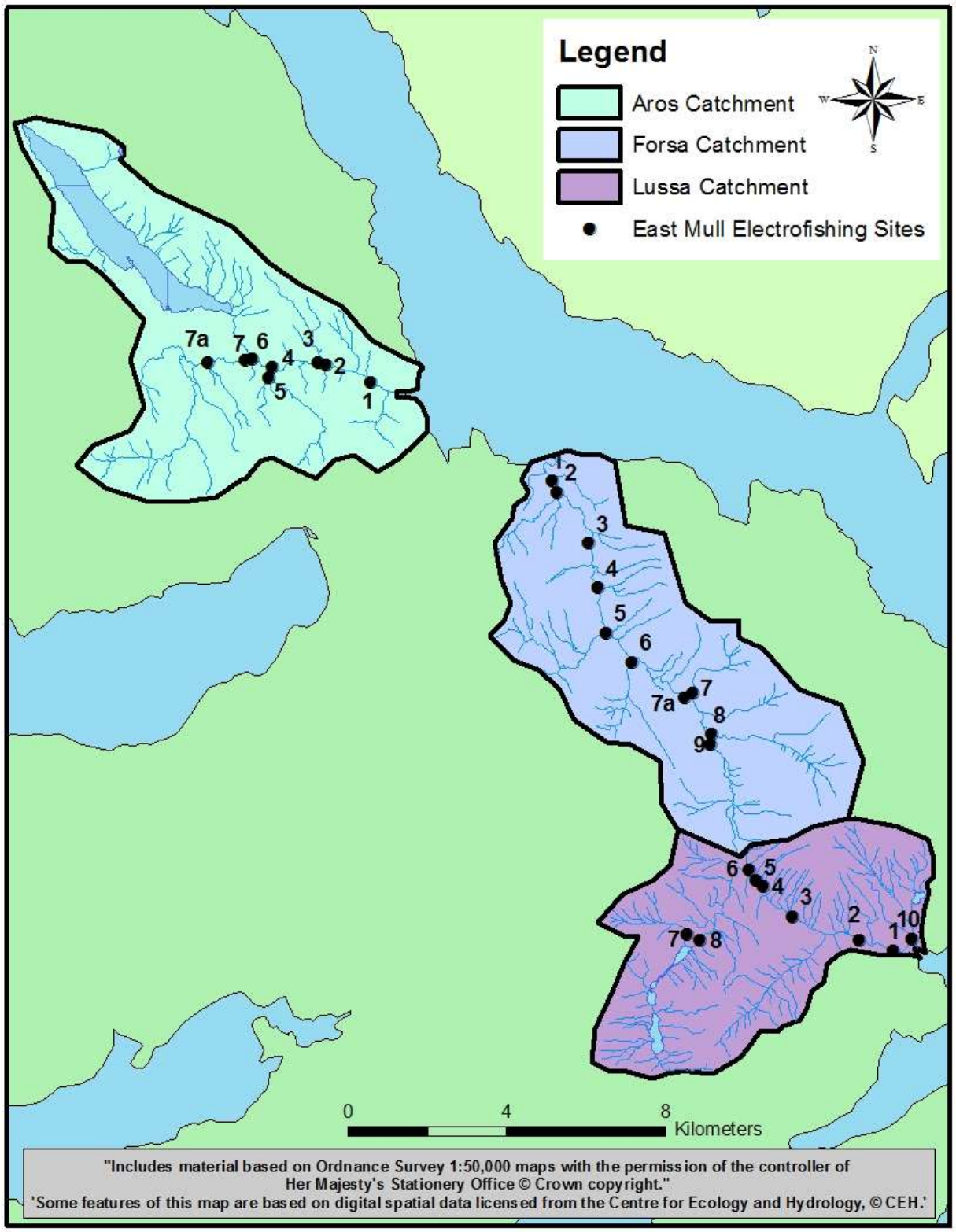

Figure 2.2 East Mull electrofishing survey locations

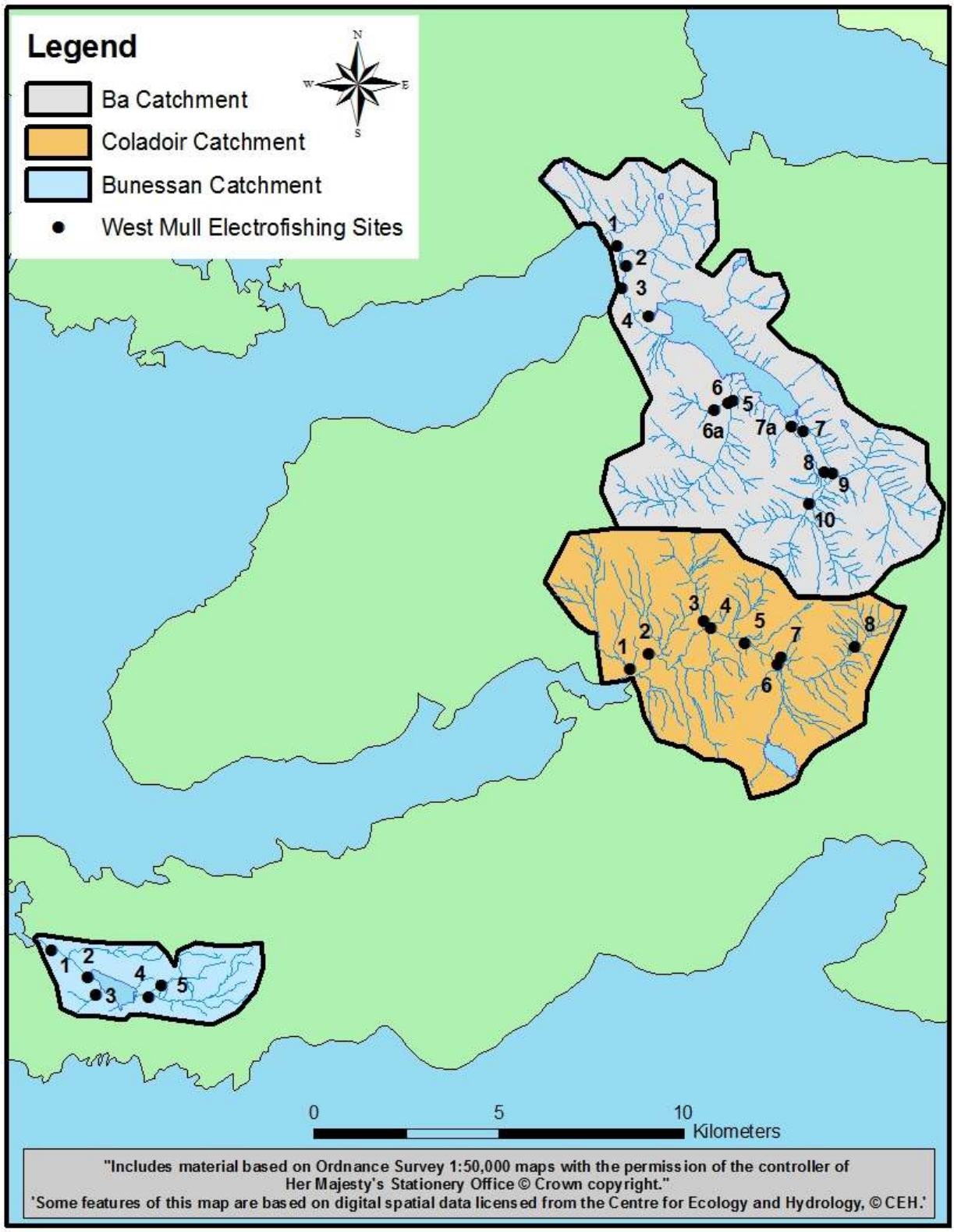

Figure 2.3 West Mull electrofishing survey locations

2.2 Habitat surveys

A walkover habitat survey was undertaken on main channels of eight catchments with the aim of quantifying and evaluating the condition of freshwater habitats utilised for recruitment by salmonid fish. Additionally, the habitat data collected at electrofishing sites was also assessed to provide information of a higher resolution.

The survey technique was founded on the basic elements of the SFCC habitat survey protocols (SFCC, 2007) and undertaken by walking upstream during low and clear flow conditions. The survey was divided up into 500m sections and location of survey start and end points were recorded using a six figure grid reference by hand-held GPS. During the course of the survey photographs were taken of the general characteristics of the watercourse, including significant features to provide a spatial view of the catchment in a systematic manner. Information on habitat characteristics which are associated with salmonid fish was recorded for survey sections that were potentially accessible to migratory fish. The distribution and quality of the main in-stream and bankside habitat characteristics were recorded with the left and right banks orientation viewed downstream.

2.2.1 River channel characteristics

The type of river channel present in each survey section was categorized in relation to the fluvial geomorphological character as described by Rosgen (1996), summarised in Table 2.3.

Table 2.3 River channel types and associated characteristics (after Rosgen, 1996)

Type	Channel	Bed	Flow	Fish habitat
A	High gradient Straight Constrained	Bedrock, boulder & cobbles	Shallow cascade & plunge pool	Limited. Resident brown trout in lower gradient sections.
B	Moderate gradient Low sinuosity Constrained	Boulder, cobble and pebble	Shallow contiguous riffle/pool sequences	Important spawning and nursery habitats for salmonids.
C	Low gradient Meandering channel. Braided in places	Cobble, pebble and gravels	Sinuous line of defined deep water within the bed Riffle and glide flow sequences	Important habitat for all salmonid life stages and other fish species

2.2.2 Classification of habitat type

Classification of habitat types were undertaken using methods adapted from Hendry and Cragg-Hine (1996), that distinguishes habitat type according to their use by salmonid fish (Table 2.4).

Table 2.4 Juvenile fish habitat type (adapted from Hendry and Cragg-Hine 1996)

Habitat Type	Classification
Fry habitat	Shallow (< 20cm) and fast flowing water with surface turbulence and a substrate dominated by pebbles and cobbles
Mixed juvenile habitat	Generally deeper water than fry habitat (20-40cm) with a pebble, cobble and boulder substrate. Water may be more turbulent than fry habitat. Stream edges often more suited to fry than parr.
Deep juvenile habitat	Water over 40cm deep with pebble, cobble and boulder substrate (generally in main-stem rivers).
Pools (adult habitat)	Optimal; No perceptible flow and usually greater than 1metre deep with cover from canopy or undercut banks Sub optimal; smooth flow with little surface turbulence and generally greater than 30cm deep. Small substrates dominated by cobbles and fine materials.
Bedrock and gorge	Habitat dominated by sheets of bare rock. Depth usually <50cm. Little or no cover and unsuited to juvenile fish. May include different flow types including pools (although larger pools recorded separately).
Spawning	Optimal; stable & not compacted. Mean substrate size up to 80mm. Not silted. Sub optimal; As above with fine sediments (sand & fine gravel <2mm) more than 20%.

Indices were used to indicate the quality of juvenile habitat using a scale of 1 (poor) to 5 (excellent). Scores were attributed depending on the presence of habitat features likely to promote or reduce the productivity for juvenile salmonid fish (Table 2.5).

Table 2.5 Downgrades for fry and older juvenile salmonid habitat

Habitat characteristic	Downgrade features
Substrate	*Presence of*; Bedrock, fine substrates (silt & sand) & substrate size variation
In-stream cover for fish	*Presence of;* fine substrates (silt & sand), compacted substrate matrix *Lack of;* Broken flow type (Run & riffle), depth variation
Bank cover for fish	*Lack of;* Draped vegetation, tree roots & bank undercut
Habitat instability	*Presence of;* Unstable channel & substrates, overly-wide and shallow wetted area
Gradient of fall	*Presence of;* High % of turbulent flow (torrent) in high gradient or glide or pool flow in low gradient
Shading of channel	*Lack of;* Canopy cover & riparian trees *Presence of;* Tunnelling (over-shading), Livestock grazing, conifer plantation, invasive non-native plants in riparian zone
Morphological alteration	*Presence of;* Channel straightening, deepening, bank protection, fords, embankments, culverts, weirs & bridge aprons affecting fish passage / habitat type
Spawning Habitat	*Lack of;* Spawning sites within the survey section
Large woody debris	*Lack of;* Fallen trees and timber in-stream below natural tree-line

2.2.3 Distribution and status of key habitats

The location of obstacles and key habitats for salmonid fish were recorded (six figure grid reference by hand-held GPS) and given site specific identification codes. An assessment of the relative size of the site and its condition was also undertaken to designate the site as optimal or sub-optimal. To assess the distribution of habitats for connectivity and usefulness to fish, key habitats were mapped using Geographic Information System (GIS) software (Arc GIS version 9.2).

2.2.3.1 Obstacles

The location, type and approximate size of significant obstacles to fish migration of was recorded and assessed in relation for potential passage of salmonid fish (Table 2.6).

Table 2.6 Obstacle assessment

Assessment	Selected options
Type of obstacle	*Natural;* Waterfall (WF), Flood debris (FD), Fallen tree (FT), Gravel cone (GC) *Man-made;* Dam (DA), Weir (WE), Culvert (CU), Bridge apron (BR), Fish counter (FC), Water gate (WG)
Passable?	No (Upstream & Downstream), No (Upstream), Yes (Species/flow specific), Yes or Unsure
Vertical?	Yes / No / Not applicable
E-fish requirement?	Yes / No (if unsure of fish passage)
Notes	Other information such as the height of the barrier or the presence of pools below waterfalls

2.2.3.2 Adult holding pools

The location of potential pool habitats for adult salmonid fish was recorded and approximate dimensions assessed. The status of the habitat was assessed in relation to site features that provide cover for fish as optimal or sub-optimal (Table 2.7). Optimal habitats are likely to be long-term holding habitats for adult fish providing a high level of cover. Sub-optimal habitats are likely to be short-term habitats for adult fish during migration or spawning activities.

Table 2.7 Adult pool habitat assessment

Assessment	Selected options
Area (m²)	Approximate estimate of length and width
Cover type	Depth / Canopy cover / Bank cover / Other
Status	*Optimal;* Large size (>50m²), deep (>2m), In-stream boulders, overhanging vegetation *Sub-optimal;* Small size (<50m²), shallow (<2m), Lower availability of in-stream and bank cover
Notes	Other information such as features creating or sustaining the pool habitat

2.2.3.3 Spawning sites

The location of potential spawning habitats for salmonid fish was recorded and approximate dimensions assessed. The status of the habitat was assessed in relation to site features that affect the potential productivity of the site (Table 2.8).

Table 2.8 Spawning site assessment

Assessment	Selected options
Area (m²)	Approximate estimate of length and width
Status	*Optimal;* Protected stable substrate, suitable substrates, Low % fine substrates, adult fish cover nearby, *Sub-optimal;* Exposed or unstable substrate, Large or fine substrates in sites, no or low available cover
Suitability	Trout (gravel / pebble) / Salmon (pebble / cobble) or both (mix)
Situation	Left bank (LB) / Central (C) / Right bank (RB)
Downgrades	Stability, Substrates; fines or boulder, accessibility, de-watering or other
Site features	Pool / braid / Island / Ford / Large woody debris (LWD) or other
Notes	Other information such as accessibility of the habitat

2.2.3.4 Channel and bank modifications

The location of modifications to the bank and channel was recorded and length of channel affected was assessed (Table 2.9). Notes on potential effects likely to impair the productivity of fish habitat were also recorded.

Table 2.9 Habitat modifications

Assessment	Selected options
Area (m)	Approximate estimate of length (and width if applicable)
Location	Left bank / central / right bank
Type	Gabions (GA), Concrete wall (CW), Fishing pool (FP), Croys (CR), Current deflectors (CD), Revetments (RE), Rip rap (RR) or Under construction (UC) or other or none
Notes	Other information that affects fish habitat

2.2.4 Riparian habitats

The relative cover for fish, percentage shading and riparian habitat features were estimated for left and right bank (observed downstream). Predominant land use 50m from the channel and the presence of invasive non-native plants (INNS) were also recorded.

3 RESULTS

3.1 Electrofishing survey

The results of electrofishing sampling of salmonid and other fish species are given separately below. The distribution of species is also compared between results for 2010 and the 2003 survey, with the exception of the Mingary Burn which was previously surveyed in 2008.

3.1.1 Juvenile salmonid fish distribution

Juvenile trout and salmon were sampled in all eight catchments surveyed (Table 3.1, Figures 3.1, 3.2). Salmon fry were found at 68 % of sites in 2010 compared with 64% of sites in 2003 and salmon parr were found at 45 % of sites in 2010 compared with 48% of sites in 2003. Trout fry were found at 38 % of sites in 2010 compared with 43% of sites in 2003, while trout parr were less well distributed than fry at 32% of sites in both 2010 and 2003.

Table 3.1 Distribution of juvenile salmonid fish (no. of sites), 2010 and 2003

Catchment	No. sites		Salmon Fry		Salmon Parr		Trout Fry		Trout Parr	
North	***2010***	***2003***	***2010***	***2003***	***2010***	***2003***	***2010***	***2003***	***2010***	***2003***
Mingary*	7	5	5	5	5	1	5	4	4	1
Bellart	9	9	6	7	5	5	8	7	5	4
West										
Ba	12	10	11	10	9	7	3	1	0	0
Coladoir	8	8	5	3	3	6	8	5	5	6
Bunessan	5	5	1	1	1	1	3	4	5	5
East										
Aros	8	8	4	7	4	6	6	5	6	3
Forsa	10	9	8	9	7	4	6	8	1	6
Lussa	9	10	5	6	7	8	4	4	6	7
No. sites	**68**	**64**	**45**	**48**	**41**	**38**	**43**	**38**	**32**	**32**
% of all sites			66	75	60	59	63	59	47	50
% <3m width	22	19	31	75	38	42	69	75	56	67

Note*; Mingary previously sampled in 2008

Salmon fry and parr were relatively well distributed in all catchments except the Bunessan, where they were found at only one of the five sites surveyed. Additionally, Salmon parr were found at only three of the eight sites surveyed on the Coladoir and fry at four of the

eight sites on the Aros in 2010. Trout fry were relatively well distributed in all catchments except the Ba where they were found at only three of twelve sites surveyed and the Lussa where they were found at four of the nine sites surveyed. Trout parr were relatively well distributed in all catchments except the Ba where no parr were found in either 2010 or 2003. Trout parr were found at one site in 2010 in the River Forsa compared to six sites in 2003.

When accessible sites with a stream width of less than 3m wet width are compared, the 2010 data indicate trout fry were present in 69 % of the 22 sites compared to 75% of the 19 sites surveyed in 2003. Trout parr were found at 56 % of small stream sites in 2010 compared to 67 % in 2003. Salmon fry were found in 31 % of sites surveyed in smaller streams in 2010 compared to 75 % of sites in 2003 and salmon parr were found at 38 % of sites in 2010 compared to 42 % in 2003.

3.1.2 Classification of salmonid fish abundance 2010

The minimum density of juvenile salmon and trout sampled in the 2010 is presented using the classification scheme in Table 3.2. For interpretation, when compared to 185 other sites sampled in the region, grade F represents an absence of fish and classes D and E represent low to very low abundance respectively. Classes C and B represent moderate to high abundance respectively and class A represents very high abundance.

Table 3.2 Classification of salmonid fish abundance 2010

Catchment	Salmon Fry		Salmon Parr		Trout Fry		Trout Parr	
	Min	Max	Min	Max	Min	Max	Min	Max
North								
Mingary	E	A	D	B	E	C	E	A
Bellart	D	A	C	A	E	B	E	B
West								
Ba	E	A	E	A	D	B	F	F
Coladoir	E	B	E	D	E	A	E	A
Bunessan	A	A	C	C	E	C	E	A
East								
Aros	E	A	D	A	E	A	E	C
Forsa	E	A	E	A	E	B	E	B
Lussa	D	C	E	B	E	C	D	A

Where present in the two northern catchments, minimum salmon fry and parr abundances were relatively low (classes E to D) with the exception of parr in the Bellart catchment, where

minimum abundance was moderate (class C). Similar variation was found in western catchments, but with a lower minimum abundance of fry and parr (class E). A relatively lower maximum abundance of parr was found in the Coladoir (class D). Where salmon were present at one site in the Bunessan, abundance was high for salmon fry and moderate for parr. A similar patchiness in salmon fry and parr abundance was found in eastern catchments; the Aros and Forsa and Lussa with the exception of salmon fry abundance in the Lussa catchment, which was classed as low to moderate (Classes D to C).

Where present in the two northern catchments, trout fry and parr abundances were variable (classes E to A), with moderate maximum abundances of fry found in the Mingary catchment (class C). Similar variation was found in western catchments with a relatively low minimum abundance of fry and parr (class D or E) being common to all catchments, while maximum abundance was moderate (class C) in the Bunessan. A pattern in minimum abundance of juvenile trout was found in eastern catchments; the Aros and Forsa and Lussa (classes D and E), while maximum abundance was moderate (class C) for trout fry in the Lussa and for trout parr in the Aros catchment.

3.1.3 Non-salmonid fish

The electrofishing surveys found European eels in 47 % of sites in 2010 compared to 57 % in 2003 in all catchments surveyed (Table 3.3). Flounder were sampled in 2010 and 2003 in the Bellart, Ba and Aros catchments and were present at 7% of all sites. Stickleback was found 4 % of sites in the Ba and Forsa catchments in 2010 compared to 6% of sites in the Bellart and Ba in 2003. European minnow were found at 6 % of sites in the Bellart, Aros and Lussa catchments in 2010 compared to 7% in the same catchments in 2003. Lamprey species are also likely to be present in some catchments, but none were found during this survey.

Table 3.3 Distribution of non-salmonid fish (no. of sites) 2010 and 2003

Catchment	No. sites		European Eel		Flounder		Stickleback		Minnow	
North	**2010**	**2003**	**2010**	**2003**	**2010**	**2003**	**2010**	**2003**	**2010**	**2003**
Mingary*	7	5	2	5	0	0	0	0	0	0
Bellart	9	9	4	2	2	2	0	1	2	2
West										
Ba	12	10	7	9	2	2	1	3	0	0
Coladoir	8	8	4	6	0	0	0	0	0	0
Bunessan	5	5	3	3	0	0	0	0	0	0
East										
Aros	8	8	1	4	1	1	0	0	1	0
Forsa	10	9	7	5	0	0	2	0	0	0
Lussa	9	10	4	5	0	0	0	0	1	3
No. sites	**68**	**64**	**32**	**39**	**5**	**5**	**3**	**4**	**4**	**5**
% of sites			47	57	7	7	4	6	6	7

Note*; Mingary previously sampled in 2008

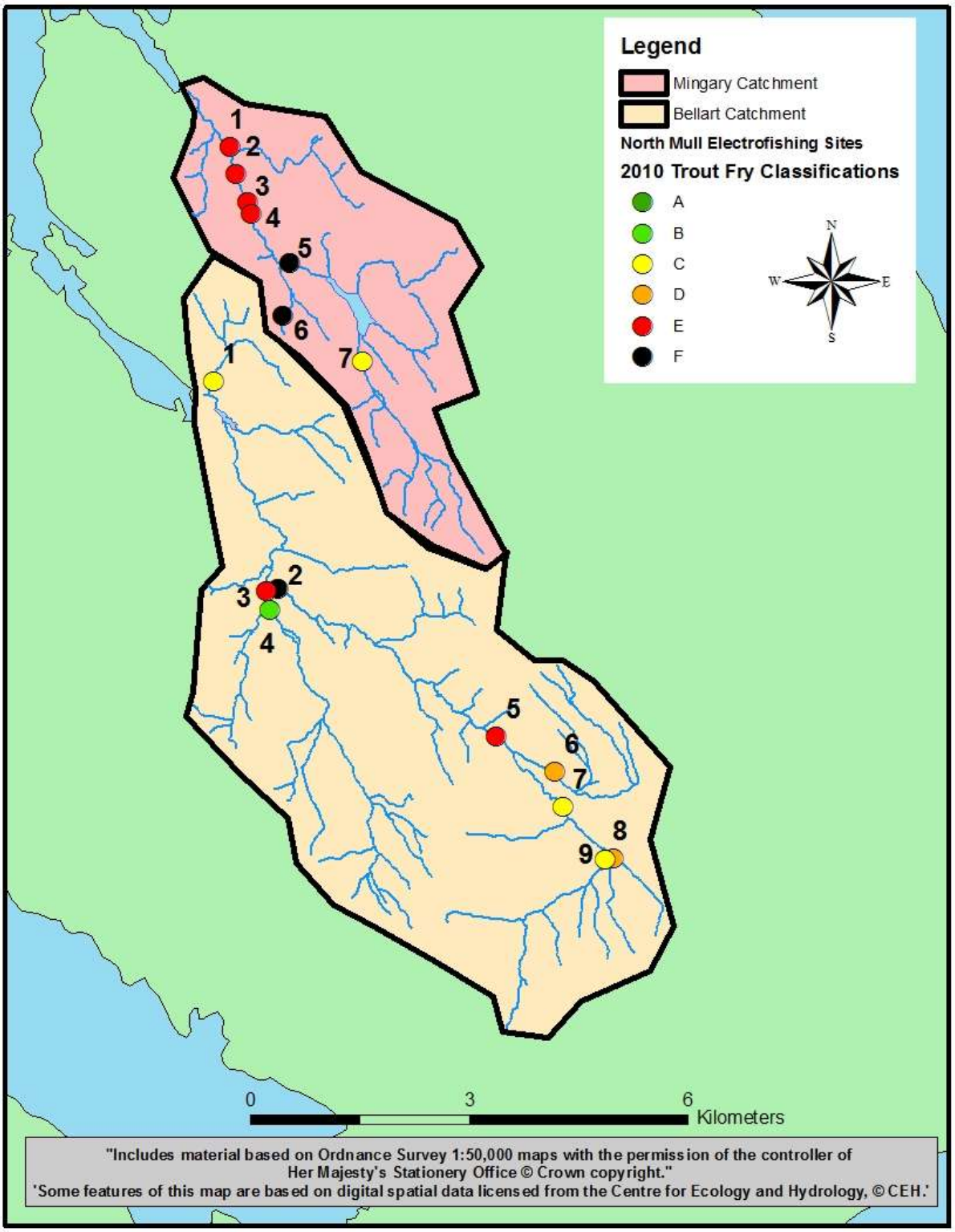

Figure 3.1 Trout fry distribution and relative abundance in North Mull

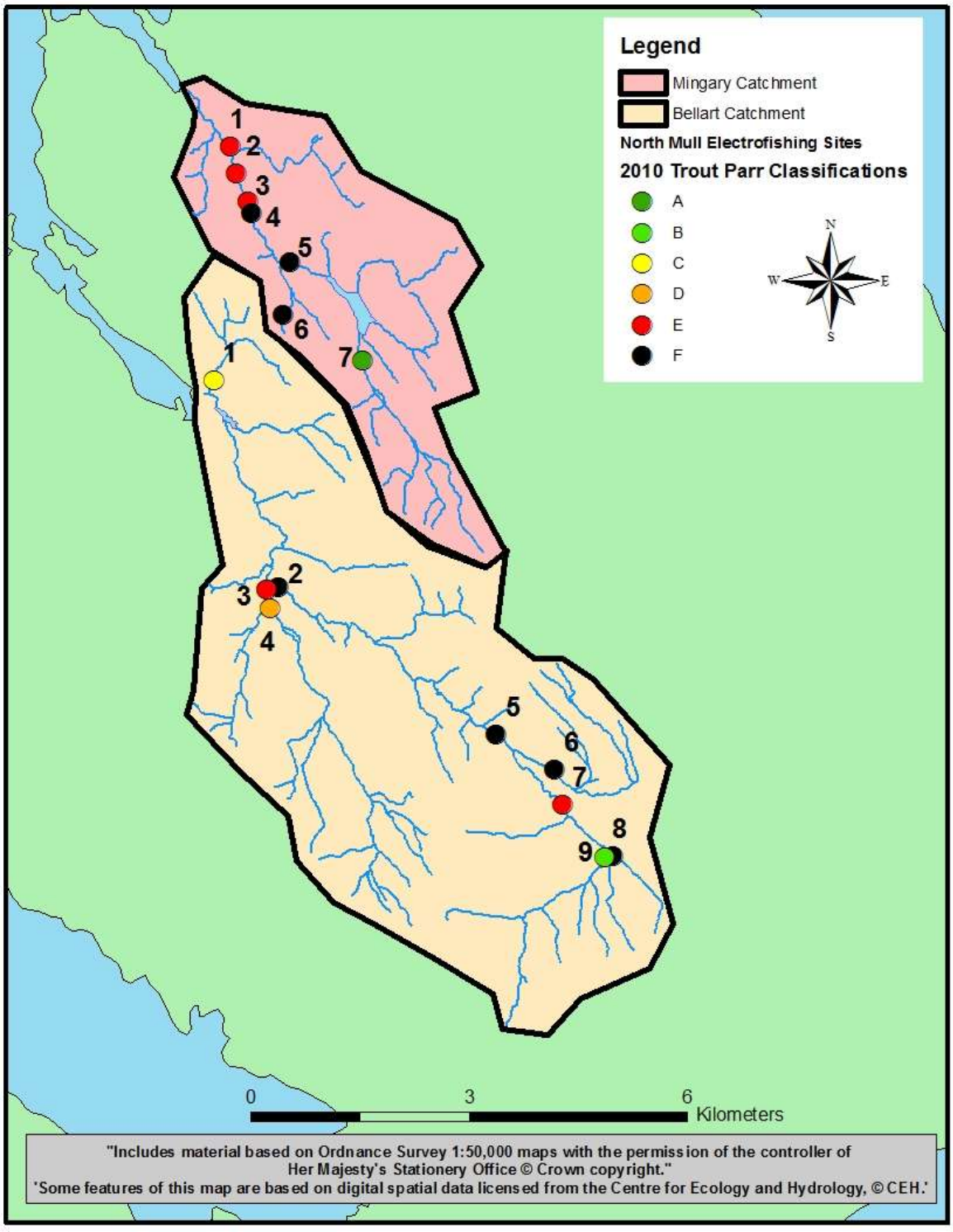

Figure 3.2 Trout parr distribution and relative abundance in North Mull

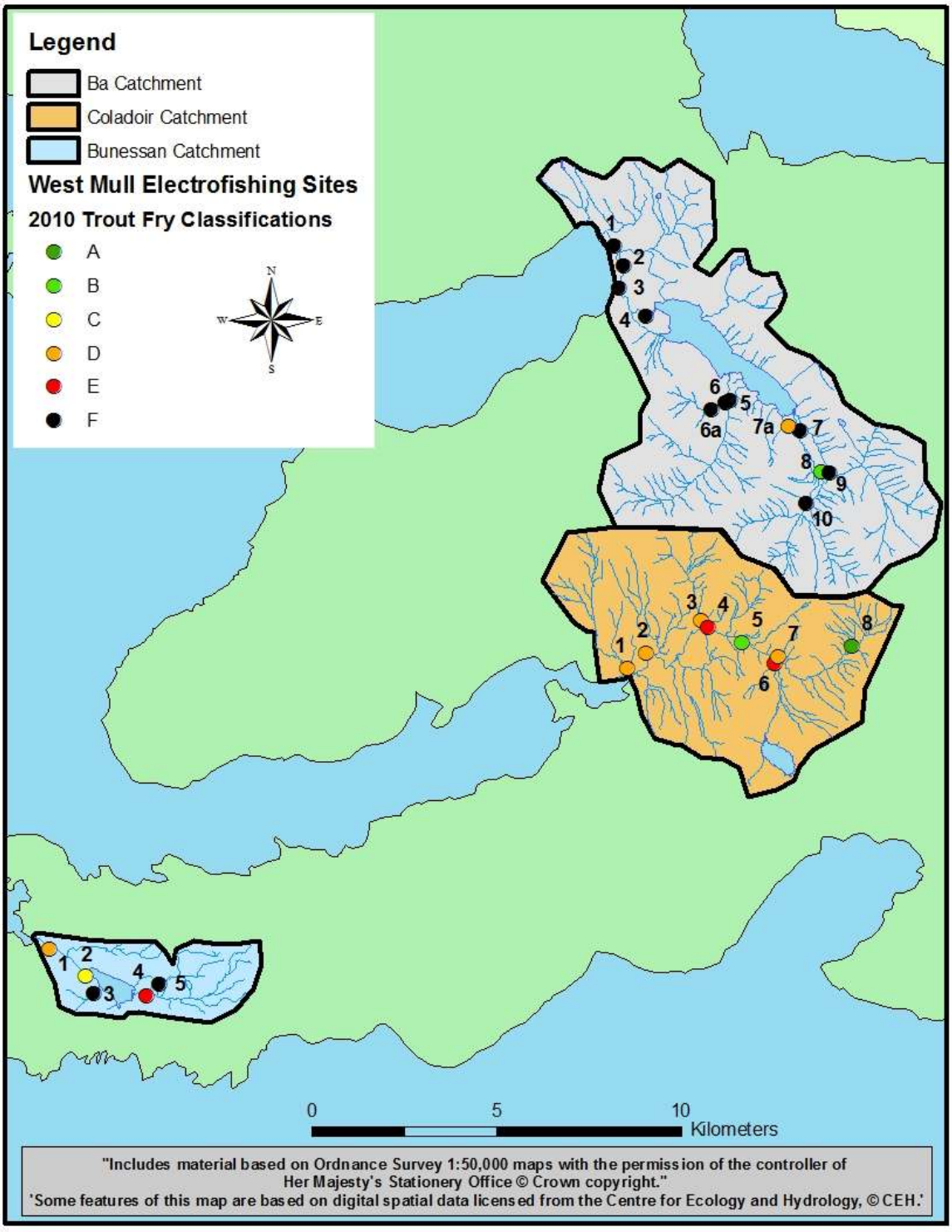

Figure 3.3 Trout fry distribution and relative abundance in West Mull

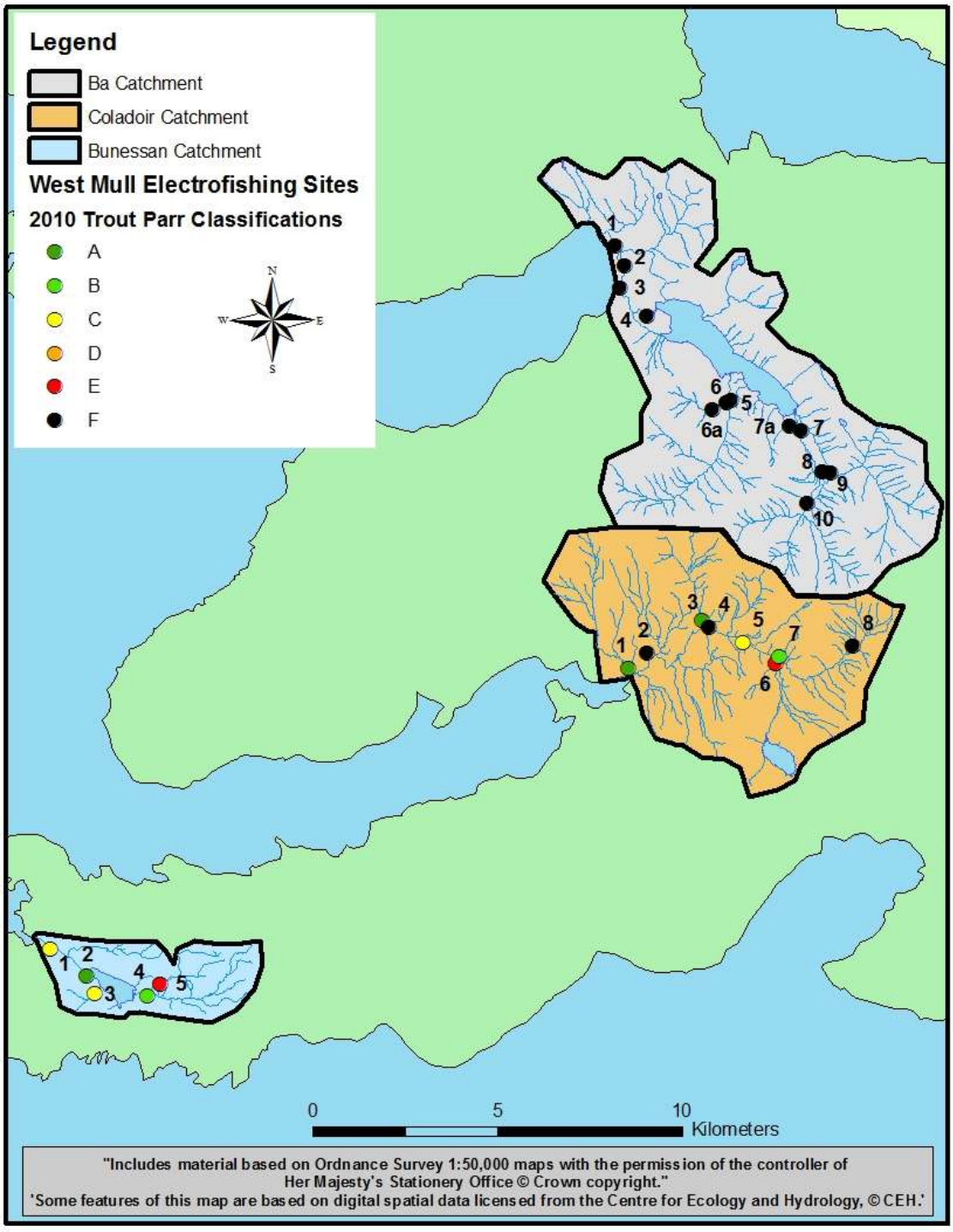

Figure 3.4 Trout parr distribution and relative abundance in West Mull

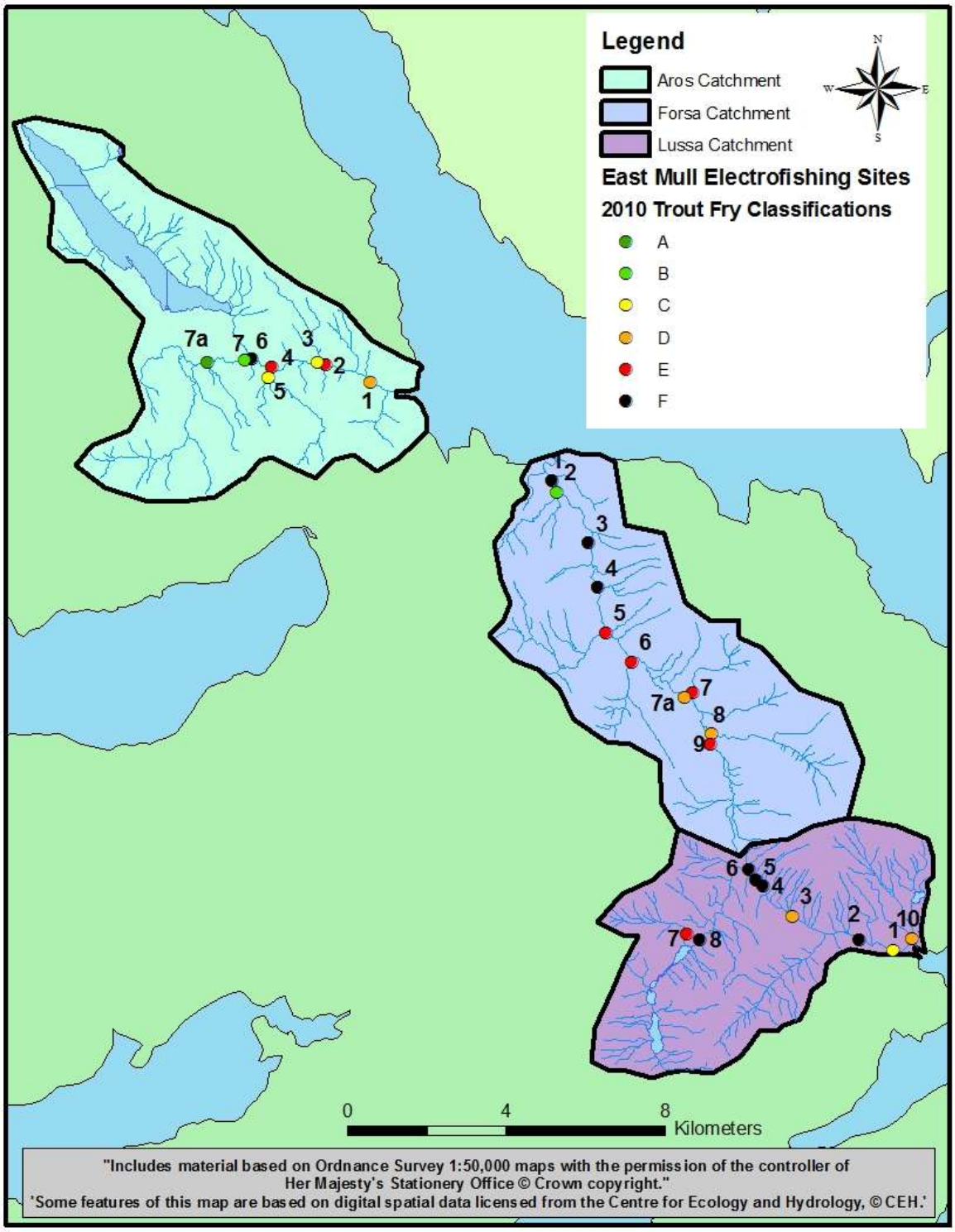

Figure 3.5 Trout fry distribution and relative abundance in East Mull

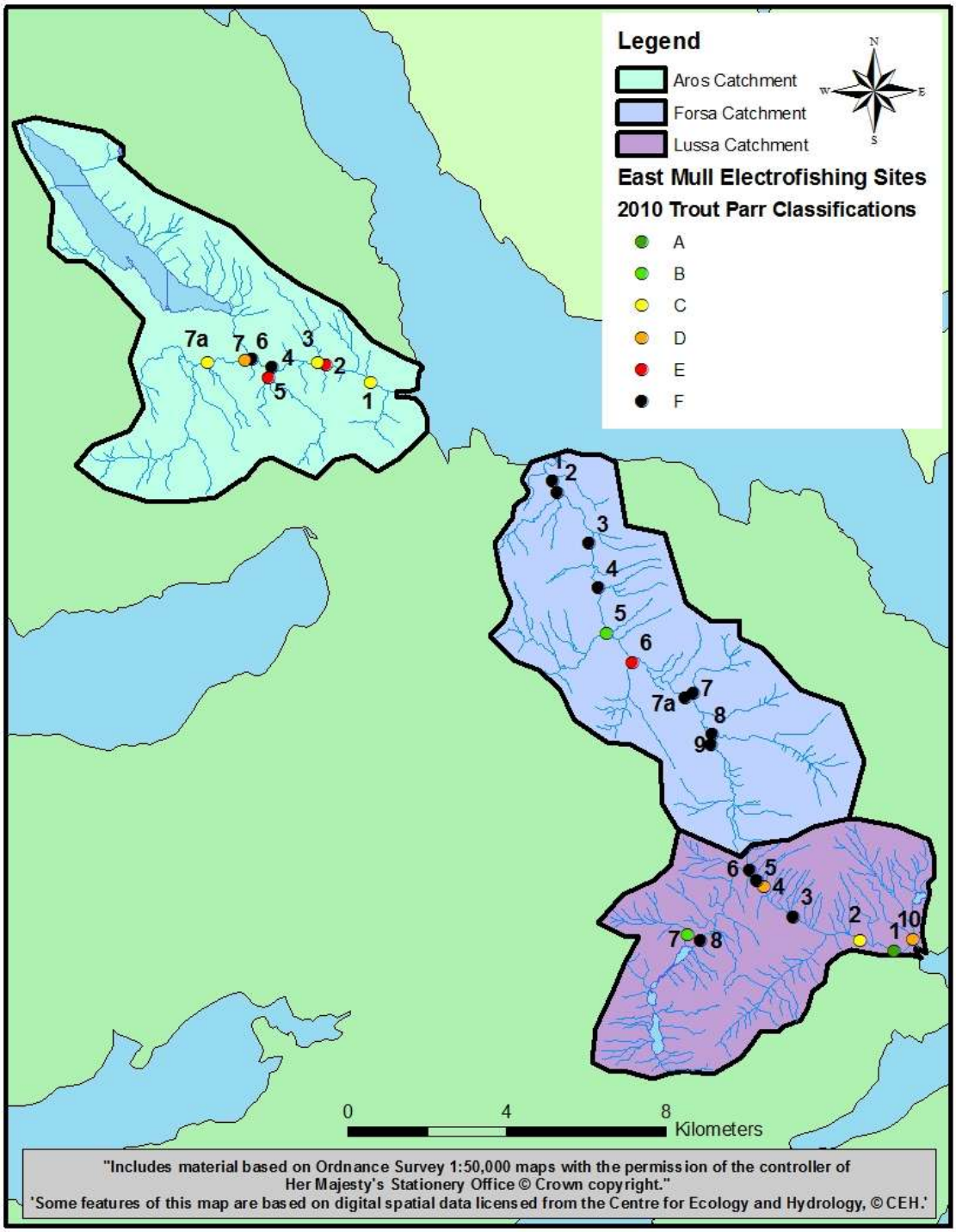

Figure 3.6 Trout parr distribution and relative abundance in East Mull

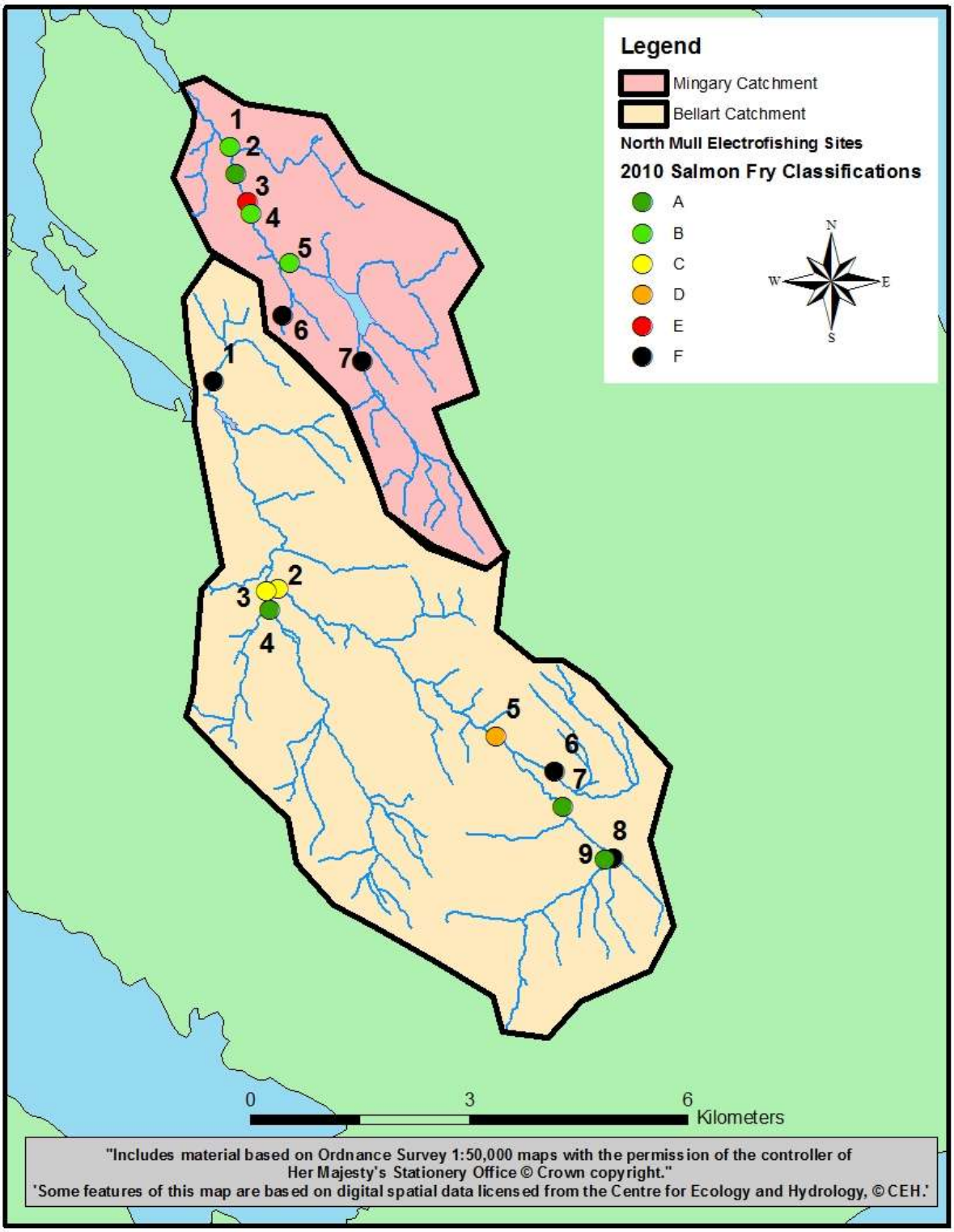

Figure 3.7 Salmon fry distribution and relative abundance in North Mull

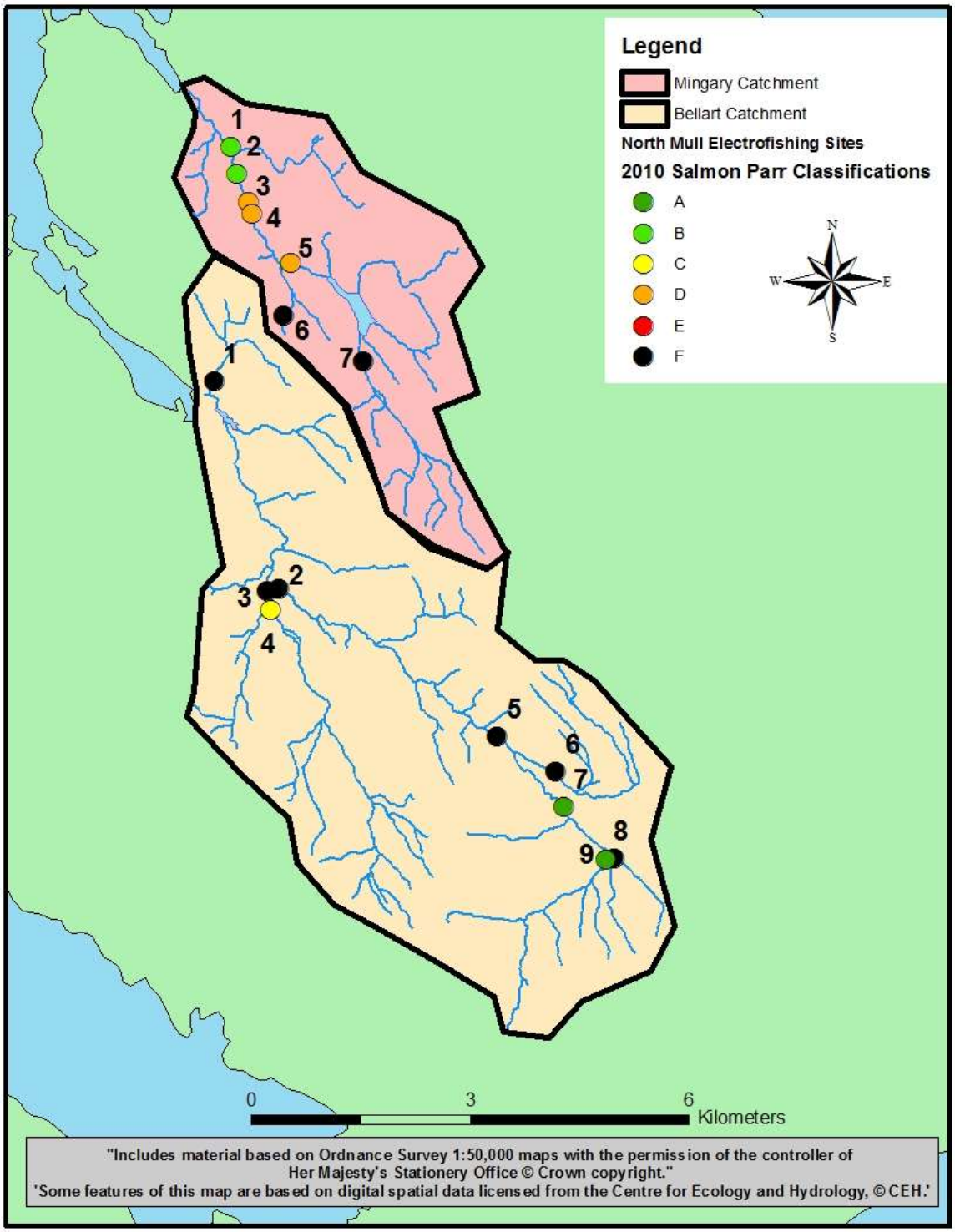

Figure 3.8 Salmon parr distribution and relative abundance in North Mull

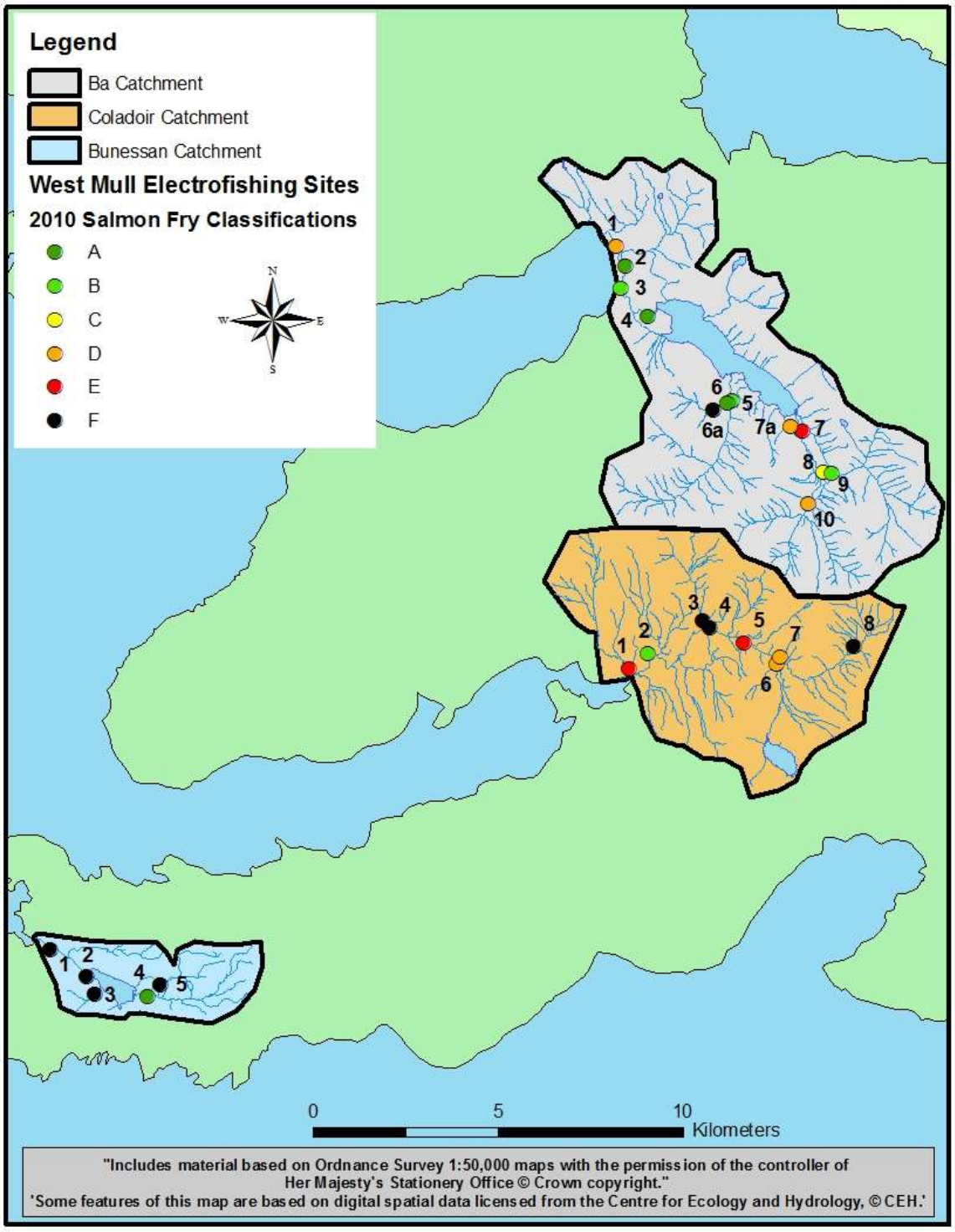

Figure 3.9 Salmon fry distribution and relative abundance in West Mull

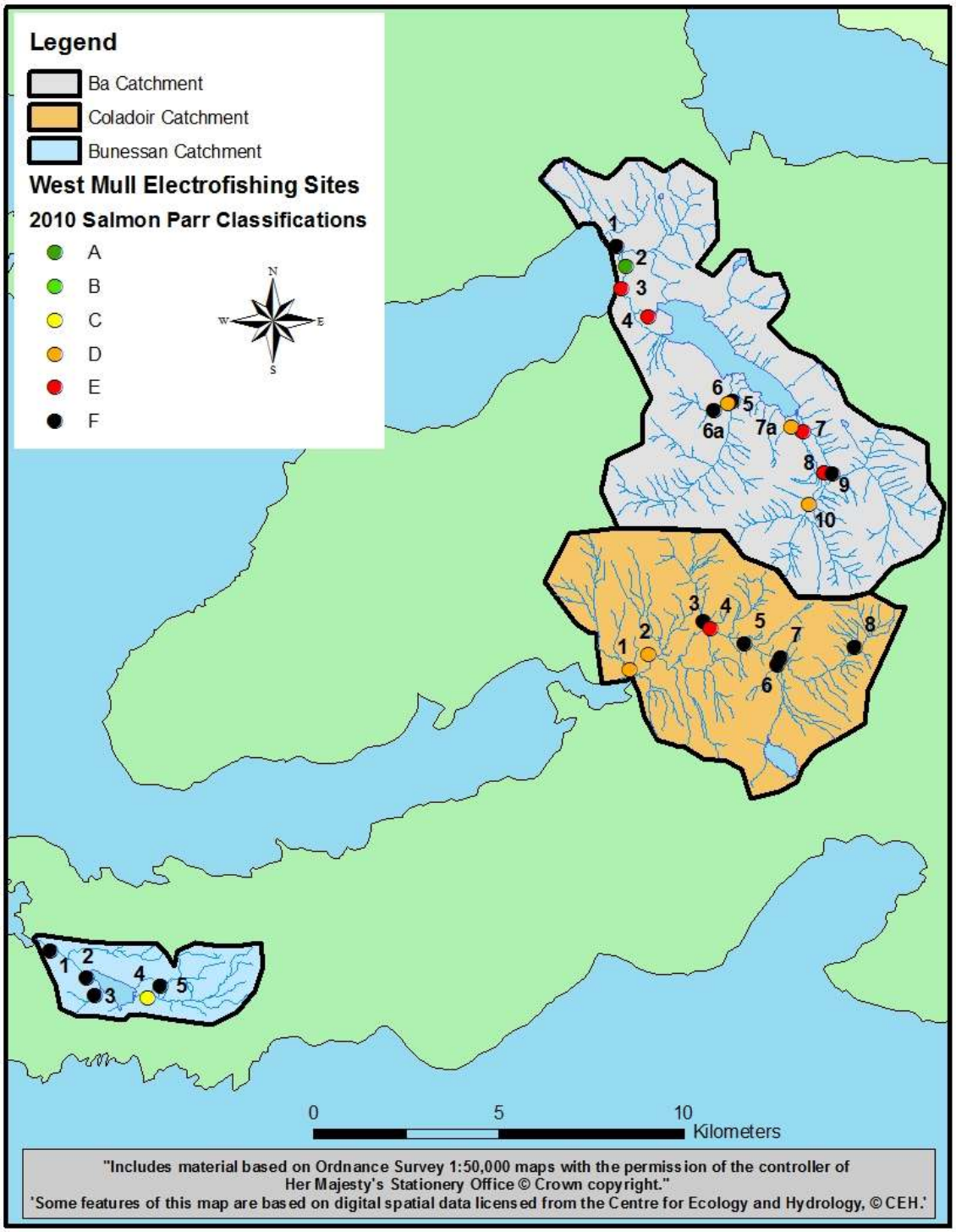

Figure 3.10 Salmon parr distribution and relative abundance in West Mull

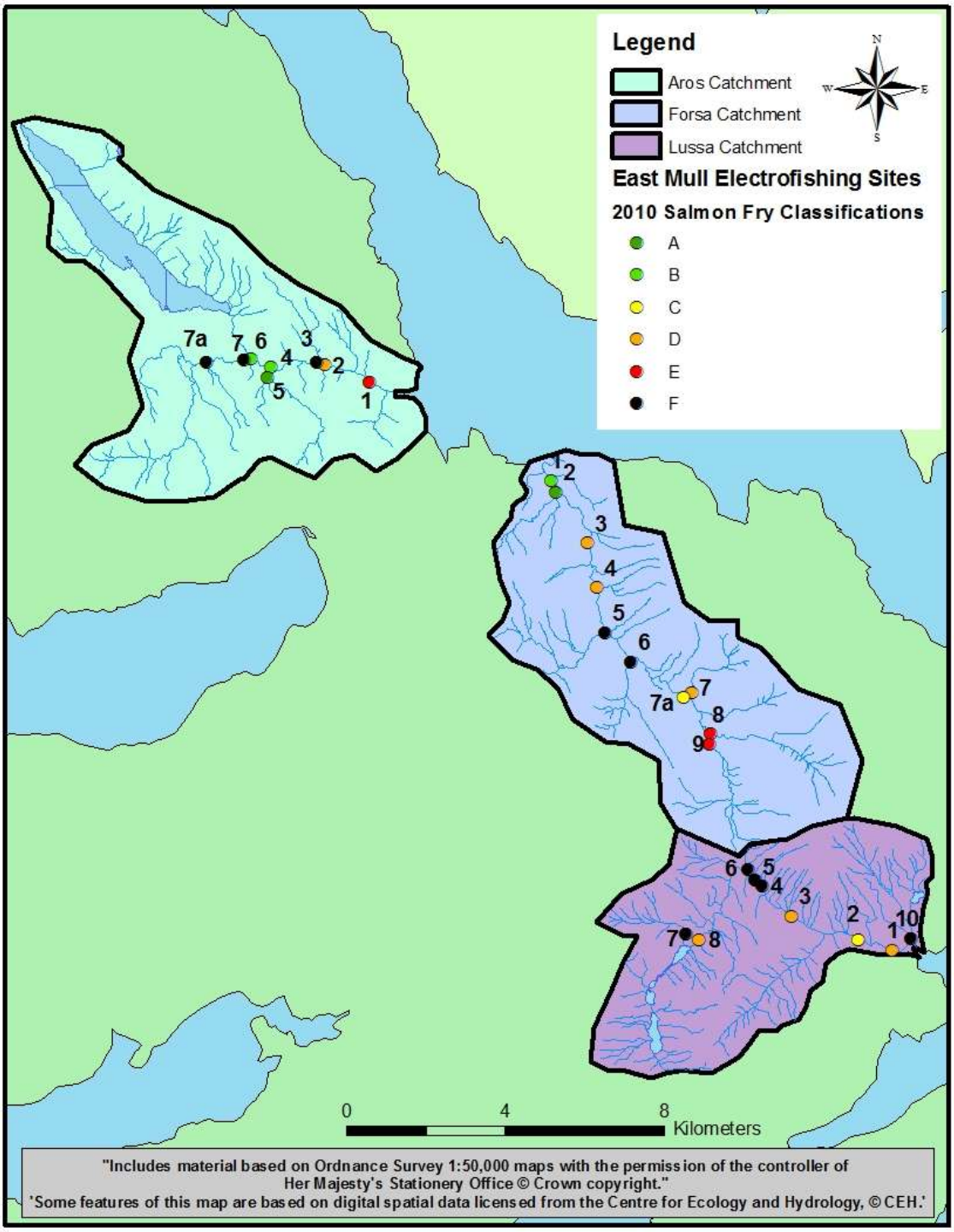

Figure 3.11 Salmon fry distribution and relative abundance in East Mull

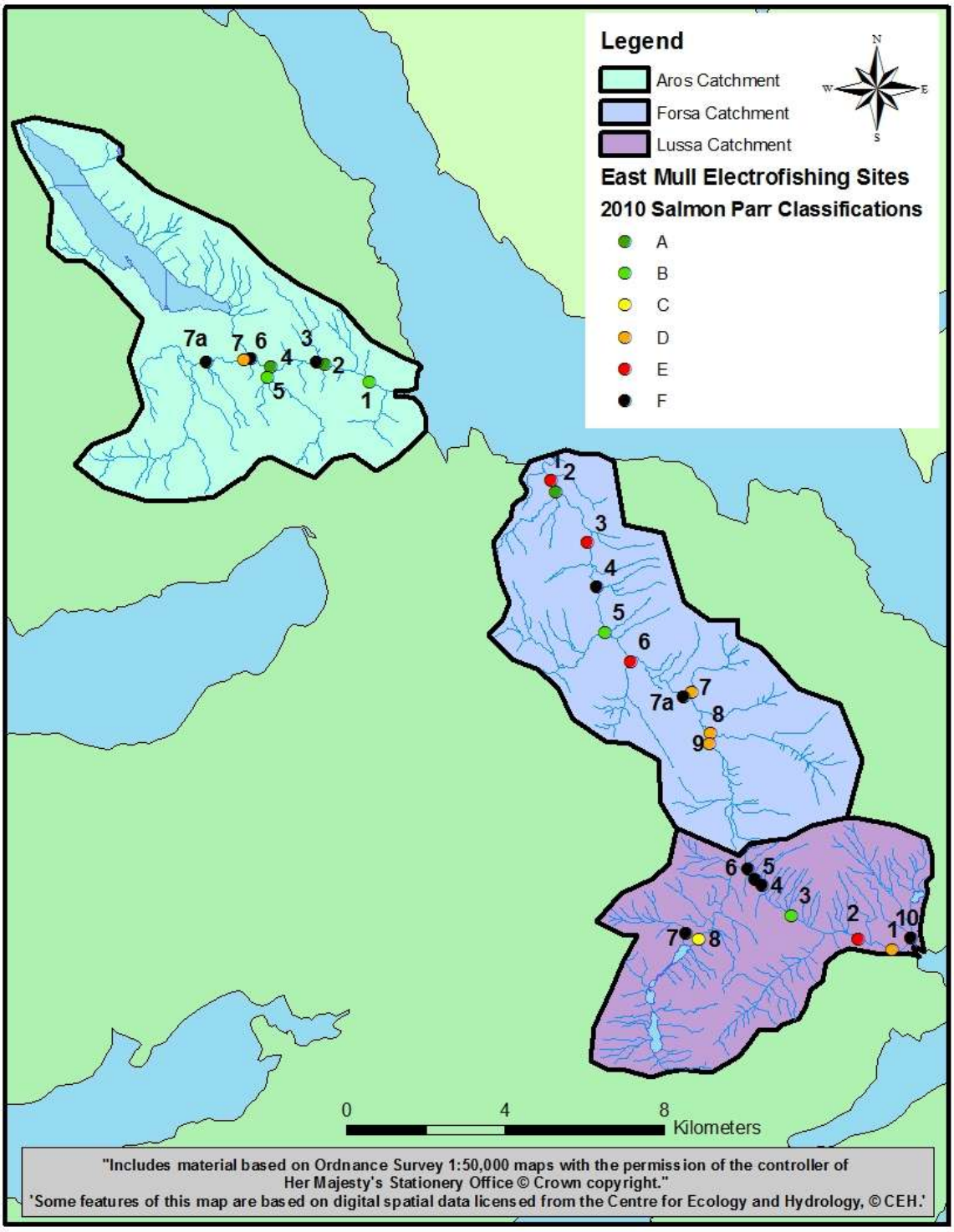

Figure 3.12 Salmon parr distribution and relative abundance in East Mull

3.1.3 Classification of fish abundance 2010 compared to 2003

Comparisons between the results of the 2003 (2008 for the Mingary) survey at 62 sites that were repeated in 2010 are made for salmon fry (Table 3.4), salmon parr (Table 3.5), trout fry (Table 3.6) and trout parr (Table 3.7). The number of sites where each age class of salmon and trout were found in 2003, but not in 2010 (loss), or were found in 2010, but not in 2003 (gain) provide information on changes in distribution. Comparative information of changes in the classification of abundance (increase, decrease or no change) at individual sites between surveys and the average change in class (i.e. a change from class A in 2003 to B in 2010 is equal to -1 class) are also given to describe the relative degree of change.

3.1.3.1 Salmon fry

The distribution of salmon fry (Table 3.4) found in 2010 indicates that fry were not present at a total of seven sites (11 %) where they were found in 2003. The 2010 survey also recorded salmon fry at four sites (6 %) in 2010 where they were not present in 2003. Classification of fry abundance was found to increase at 11 sites (18 %), decrease in 19 sites (31 %) and no change was found at 21 sites (34 %). An average decrease in abundance of 0.41 classes for fry across all sites was found in 2010 compared to 2003.

Table 3.4 Change in distribution, abundance and average class (no. sites) of salmon fry

		Distribution		Abundance (class)			class
Catchment	**No. Repeat sites**	**Loss**	**Gain**	**Increase**	**Decrease**	**No change**	**Avg. change**
North							
Mingary	5	0	0	2	2	1	0.4
Bellart	9	2	1	3	2	1	0.2
Total / Avg.	14	2	1	5	4	2	0.30
West							
Ba	10	0	0	3	3	4	0
Coladoir	8	0	3	2	0	3	0.9
Bunessan	5	0	0	1	0	4	0.4
Total / Avg.	23	0	3	6	3	11	0.43
East							
Aros	7	2	0	0	3	2	-2
Forsa	9	2	0	0	5	2	-2.7
Lussa	9	1	0	0	4	4	-1.2
Total / Avg.	25	5	0	0	12	8	-1.97
Grand Total / Avg.	**62**	**7**	**4**	**11**	**19**	**21**	**-0.41**

Of the 14 sites surveyed in the two catchments in north Mull, the 2010 results indicate an overall loss of distribution of fry by one site (7 % of sites), compared to a gain in fry distribution of three sites (13 %) of the 23 sites surveyed in three catchments in west mull. A more pronounced loss of distribution of fry was found at 5 of the 25 sites surveyed (20 %) in three east Mull catchments.

A slight increase in salmon fry abundance was found in north Mull catchments where abundance class was higher at five sites (36 % of sites), lower in four sites (29 %) and no change at two other sites (14 %) in 2010 compared to 2003 (2008 for the Mingary). Average abundance class was higher at an average of 0.30 of a class per catchment, but was higher in the Mingary (0.4 of a class) compared to the Bellart (0.2 of a class). Similarly to the northern catchments, a general increase in salmon fry abundance class was found in west Mull catchments where abundance was higher in six of the 23 sites surveyed (26 %) and lower in three sites (13 %) in 2010 compared to 2003. Average abundance class was higher at an average of 0.43 of a class per catchment, but was higher in the Coladoir (0.9) compared to the Bunessan (0.4), while there were no recorded change of average fry abundance in the Ba catchment.

In east Mull catchments, a decline in distribution was found in 2010 in combination with a loss of distribution of salmon fry. Abundance class was lower at 12 of the 25 sites (48 %) surveyed in 2010 compared to 2003 at an average of 1.97 classes per catchment, but was most acute in the Forsa (average of -2.7 classes) compared to the Aros (-0.2) and the Lussa (-1.2).

3.1.3.2 Salmon parr

The distribution of salmon parr (Table 3.5) found in 2010 indicates that parr were not present at a total of 12 sites (19 %) where they were found in 2003, but parr were also found at 14 sites (23 %) in 2010 where they were not present in 2003. Classification of parr abundance was found to increase at 7 sites (11 %) and decrease in 10 sites (16 %) and no change were found at 17 sites (27 %). An average increase in parr abundance of 0.24 of a class was found in 2010 across all sites compared to 2003.

Table 3.5 Change in distribution, abundance and average class (no. sites) of salmon parr

		Distribution		Abundance			Class
Catchment	**No. Repeat sites**	**Loss**	**Gain**	**Increase**	**Decrease**	**No change**	**Avg. change**
North							
Mingary	5	0	4	1	0	0	2.6
Bellart	9	2	0	1	1	5	-0.4
Total / Avg.	14	2	4	2	1	5	1.10
West							
Ba	10	2	3	0	3	2	-0.6
Coladoir	8	4	1	1	1	1	-0.6
Bunessan	5	0	1	0	0	4	0.6
Total / Avg.	23	6	5	1	4	7	-0.20
East							
Aros	7	1	0	2	1	3	-0.1
Forsa	9	0	5	1	1	2	0.7
Lussa	9	3	0	1	3	0	-1.1
Total / Avg.	25	4	5	4	5	5	-0.17
Grand Total / Avg.	**62**	**12**	**14**	**7**	**10**	**17**	**0.24**

In the two catchments in north Mull, the 2010 results indicate an overall gain of distribution of parr by two sites (14 % of sites), compared to a loss of parr distribution in three catchments in west mull of one site (7 %). A slight overall gain of one site in parr distribution (4 %) was also found in three east Mull catchments.

A slight increase in salmon parr abundance was found in north Mull catchments where abundance class was higher at two sites (14 % of sites), lower in one sites (7 %) and no change at five other sites (36 %) in 2010 compared to 2003 (2008 for the Mingary). Average abundance class was higher at an average of 1.10 of a class per catchment, but was higher in the Mingary (2.6 classes) compared to the Bellart, which decreased on average (-0.4 of a class). An overall decrease in salmon parr abundance class was found in west Mull catchments where abundance was higher in only one site (4 %) and lower in four sites (16 %) in 2010 compared to 2003. Average abundance class was lower at an average of -0.20 of a class per catchment, but was higher in the Bunessan (0.6 of a class) compared to the Coladoir and the Ba where abundance class fell by a similar value (-0.6 of a class).

In east Mull catchments, abundance class decreased at 5 of the 25 sites (20 %) surveyed in 2010 compared to 2003 and increased at another four sites (16%). On average, abundance decreased by -0.17 of a class per catchment, but increased in the Forsa (0.7 of a class), while decreasing in the Lussa (-1.1 classes) and the Aros (-0.1).

3.1.3.3 Trout fry

The distribution of trout fry (Table 3.6) found in 2010 indicates that fry were not present at a total of seven sites (11 %) where they were present in 2003, but fry were also found at nine sites (15 %) in 2010 where they were not present in 2003. Overall classification of fry abundance was found to increase at eight (13 %) sites and decrease in 13 (21 %) sites and there was no change found at 25 (40 %) sites. An overall average decrease in trout fry abundance class was found in 2010 of -0.13 of a class across all sites compared to 2003.

Table 3.6 Change in distribution, abundance and average class (no. sites) of trout fry

		Distribution		Abundance			Class
Catchment	**No. Repeat sites**	**Loss**	**Gain**	**Increase**	**Decrease**	**No change**	**Avg. change**
North							
Mingary	5	1	1	0	1	2	-0.4
Bellart	9	0	1	3	2	3	0.1
Total / Avg.	14	1	2	3	3	5	-0.15
West							
Ba	10	1	1	0	0	8	-0.1
Coladoir	8	0	3	2	2	1	1
Bunessan	5	1	0	1	1	2	-1
Total / Avg.	23	2	4	3	3	11	-0.03
East							
Aros	7	1	2	0	2	2	0
Forsa	9	2	0	1	4	2	-0.8
Lussa	9	1	1	1	1	5	0.2
Total / Avg.	25	4	3	2	7	9	-0.20
Grand Total / Avg.	**62**	**7**	**9**	**8**	**13**	**25**	**-0.13**

In north Mull, comparisons with the 2003 data, indicate a slight gain in the distribution of fry by one site (7 %) in 2010. Similarly, a gain in distribution was also recorded in west mull by two sites (8 %), while a slight loss in distribution was found in east Mull catchments by one site (4 %).

In north Mull, a general overall increase in trout fry abundance class was found at one site (7 %) in the Bellart catchment in 2010 compared to 2003, while a decrease in abundance was also found at one site in the Mingary when compared to 2008 data. There was no change in abundance class at five other sites (36 %). Average fry abundance class decreased by -0.15 of a class per catchment, but was most acute in the Mingary (-0.4 of a class) compared to an increase in the Bellart (0.1 of a class).

Similarly to the northern catchments, an average decrease in trout fry abundance class was found in west Mull catchments (-0.03 of a class) where abundance was higher in three sites (13 %) and lower at another three sites in 2010 compared to 2003. There were no changes in abundance at 11 sites (48 %). Average abundance class for trout fry was higher in the Coladoir (1.0 class) in 2010 compared to being lower in the Bunessan (-1.0 class) and the Ba catchment (-0.1 of a class). In east Mull, average trout fry abundance class was found to decrease (-0.20 of a class) where abundance was higher in two sites (8 %) and lower at seven sites (28 %) in 2010 compared to 2003. There were no changes in abundance at nine sites (36 %). Average abundance class for trout fry was higher in the Lussa (0.2 of a class) in 2010 compared to being lower in the Forsa (-0.8 of a class), while no change was found in the Ba catchment.

3.1.3.4 Trout parr

The distribution of trout parr (Table 3.7) found in 2010 indicates that parr were not present at a total of nine sites (15 %) where they were present in 2003, but the survey data also indicate that parr were found at eight other sites (13 %) in 2010 where they were not present in 2003. Classification of parr abundance was found to increase at 11 (18%) sites and decrease in 8 (13%) sites and no change were found at 26 (42%) sites. An overall average increase in abundance class was found in 2010 of 0.03 of a class for trout parr across all sites compared to 2003.

In north Mull, comparisons with the 2003 data, indicate a gain in the distribution of parr by three sites (21 %) in 2010. No overall change in distribution was recorded in west mull, while a loss in distribution of trout parr was found in east Mull catchments by four sites (16 %).

In north Mull, a general overall decrease in trout parr abundance class was found at one site (7 %) in the Mingary catchment in 2010 compared to 2008, while there were no change overall in the Bellart when compared to 2003 data. There was no change in abundance class at four sites (29 %). Average fry abundance class increased by 0.25 of a class per catchment, but was more so in the Bellart (0.3 of a class) compared to the Mingary (0.2 of a class).

Table 3.7 Change in distribution, abundance and average class (no. sites) of trout parr

		Distribution		Abundance			Class
Catchment	**No. Repeat sites**	**Loss**	**Gain**	**Increase**	**Decrease**	**No change**	**Avg. change**
North							
Mingary	5	0	2	0	1	2	0.2
Bellart	9	2	3	1	1	2	0.3
Total / Avg.	14	2	5	1	2	4	0.25
West							
Ba	10	0	0	0	0	10	0
Coladoir	8	1	1	4	0	2	0.9
Bunessan	5	0	0	2	2	1	-0.2
Total / Avg.	23	1	1	6	2	13	0.23
East							
Aros	7	0	2	2	0	3	0.9
Forsa	9	4	0	0	1	4	-1.8
Lussa	9	2	0	2	3	2	-0.3
Total / Avg.	25	6	2	4	4	9	-0.40
Grand Total / Avg.	**62**	**9**	**8**	**11**	**8**	**26**	**0.03**

Similarly to the northern catchments, an average increase in trout parr abundance class was found in west Mull catchments (0.23 of a class) where abundance increased in six sites (26 %) and lower at another two sites (9 %) in 2010 compared to 2003. There were no changes in abundance at 13 sites (56 %). Average abundance class for trout fry was higher in the Coladoir (0.9 of a class) in 2010 compared to being lower in the Bunessan (-0.2 of a class). No trout parr were found in the Ba catchment surveys in 2003 or 2010.

In east Mull, average trout parr abundance class was found to decrease (-0.40 of a class) although abundance was higher in four sites (16 %) and lower at another four sites in 2010 compared to 2003. There were no changes in abundance at nine sites (36 %). Average abundance class for trout parr was higher in the Aros (0.9 of a class) in 2010 compared to being lower in the Forsa (-1.8 classes) and the Lussa catchment (-0.3 of a class).

3.2 Habitat survey

An estimated total of 67.15 km of stream were surveyed in 135 survey sections (of approximately 500m length) in eight catchments (Table 3.8).

Table 3.8 Habitat survey coverage

Catchment	No. sections	Survey Length (km)
North		
Mingary	8	3.65
Bellart	21	10.5
West		
Ba	21	10.5
Coladoir	22	11.0
Bunessan	7	3.5
East		
Aros	13	6.5
Forsa	23	11.5
Lussa	20	10.0
Total	**135**	**67.15**

3.2.1 Distribution and status of key habitats

The location and status of 99 significant obstacles, 219 adult fish holding pools and 132 spawning sites recorded in the surveys are described below.

3.2.1.1 Obstacles to fish passage

A total of 99 significant obstacles to fish passage were recorded during the surveys (Table 3.9), 16 of which were in north Mull (Figure 3.14), 30 in west Mull (Figure 3.15) and 53 in east Mull catchments (Figure 3.16). The frequency of obstacles recorded in each catchment averaged from one obstacle every 0.5 per km in the Bellart to 2.7 per km in the Lussa. Natural bedrock waterfalls or cascades were the most common type of the 93 (93%) natural obstacles identified. The surveys also identified 6 (7%) man-made obstacles that were mostly weirs and bridge aprons. A total of 86 (87%) of the obstacles recorded were adjudged to be potentially passable and 9 to be impassable to migratory salmonids. The potential passage of salmonid fish past a further three obstacles by could not be confidently assigned.

Table 3.9 Obstacles to upstream passage of salmonid fish

Catchment	No. of obstacles	Man-Made	Natural	Passable	Unsure	Not Passable	Obstacles per Km
North							
Mingary	11	1	10	10	1	0	3.0
Bellart	5	0	5	5	0	0	0.5
West							
Ba	10	0	10	4	1	5	1.0
Coladoir	16	0	16	14	1	1	1.5
Bunessan	4	1	3	3	0	0	1.1
East							
Aros	14	0	14	13	0	1	2.2
Forsa	12	3	9	11	0	1	1.0
Lussa	27	1	26	26	0	1	2.7
Total	**99**	**6**	**93**	**86**	**3**	**9**	1.5

3.2.1.1 Adult holding pools

A total of 328 significant adult fish holding pools were recorded during the surveys (Table 3.10) with a total area of 113,594 m² of habitat. The proportion of adult holding pool habitat surveyed ranged from 24% of total in the north catchments (Figure 3.17), 25% in west catchments (excluding Loch Ba) (Figure 3.18) and 50% in east catchments (excluding Loch Frisa and upper Lussa lochs) (Figure 3.19). The frequency of pools found in each catchment range from an average of 2.3 per km in the Bunessan to 6.3 per km in the Mingary catchment.

Table 3.10 Adult holding pools results

Catchment	No. Pools	Sub optimal	Optimal	Primary cover	Secondary cover	Pool Area (m²)	No. per Km
North							
Mingary	23	10	13	Depth	Canopy / Bank	2,106	6.3
Bellart	43	21	22	Depth	Bank	25,451	4.1
West							
Ba	57	27	30	Depth	Bank	9,199	5.4
Coladoir	61	31	30	Depth	Bank	18,934	5.5
Bunessan	8	7	1	Depth	Bank	404	2.3
East							
Aros	36	15	21	Depth	Bank	10,535	5.5
Forsa	57	28	29	Depth	Bank	32,275	5.0
Lussa	43	23	20	Depth	Bank	14,690	4.3
Total / avg.	**328**	**162**	**166**			**113,594**	**4.8**

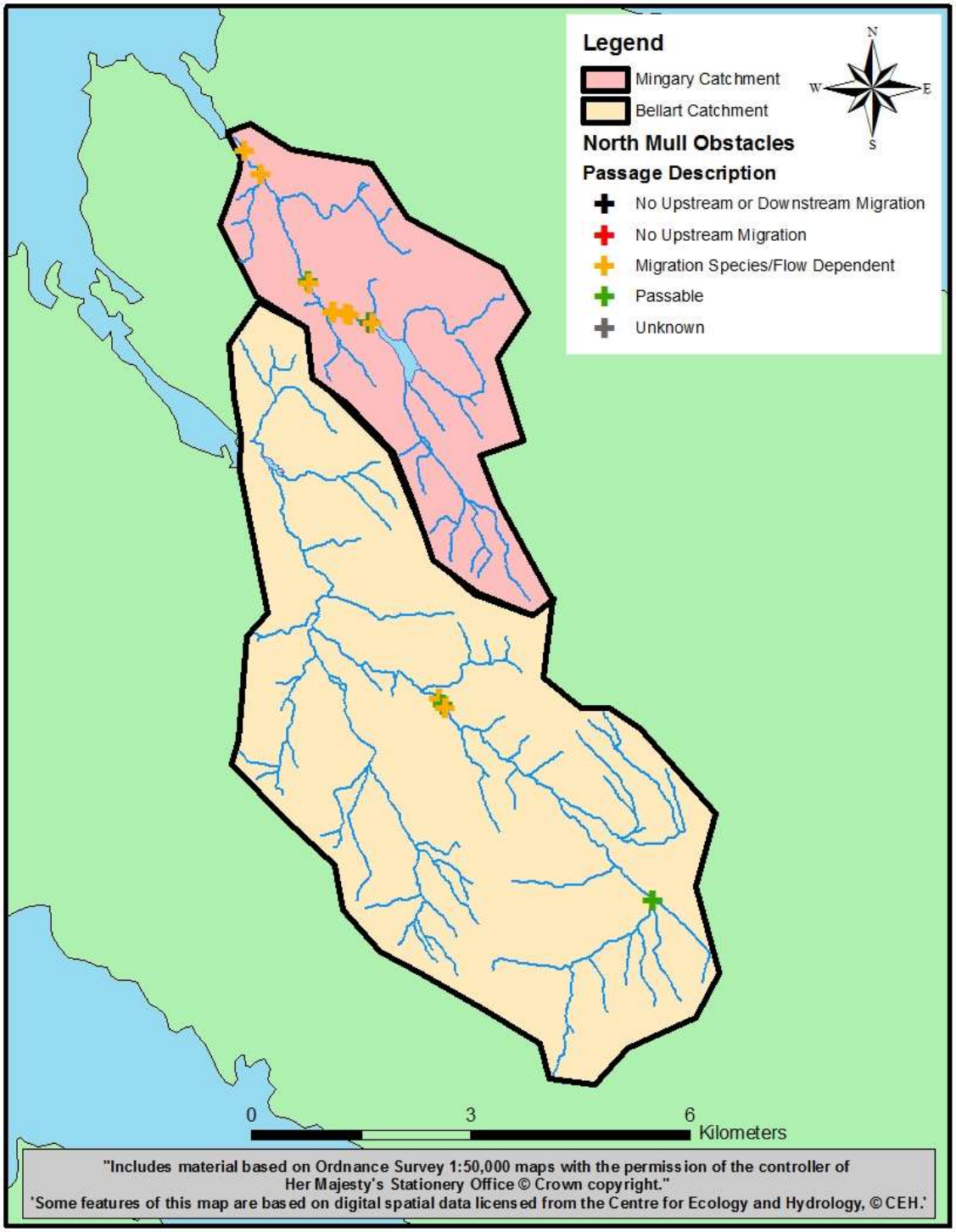

Figure 3.13 Distribution of obstacles to salmonid fish passage in North Mull

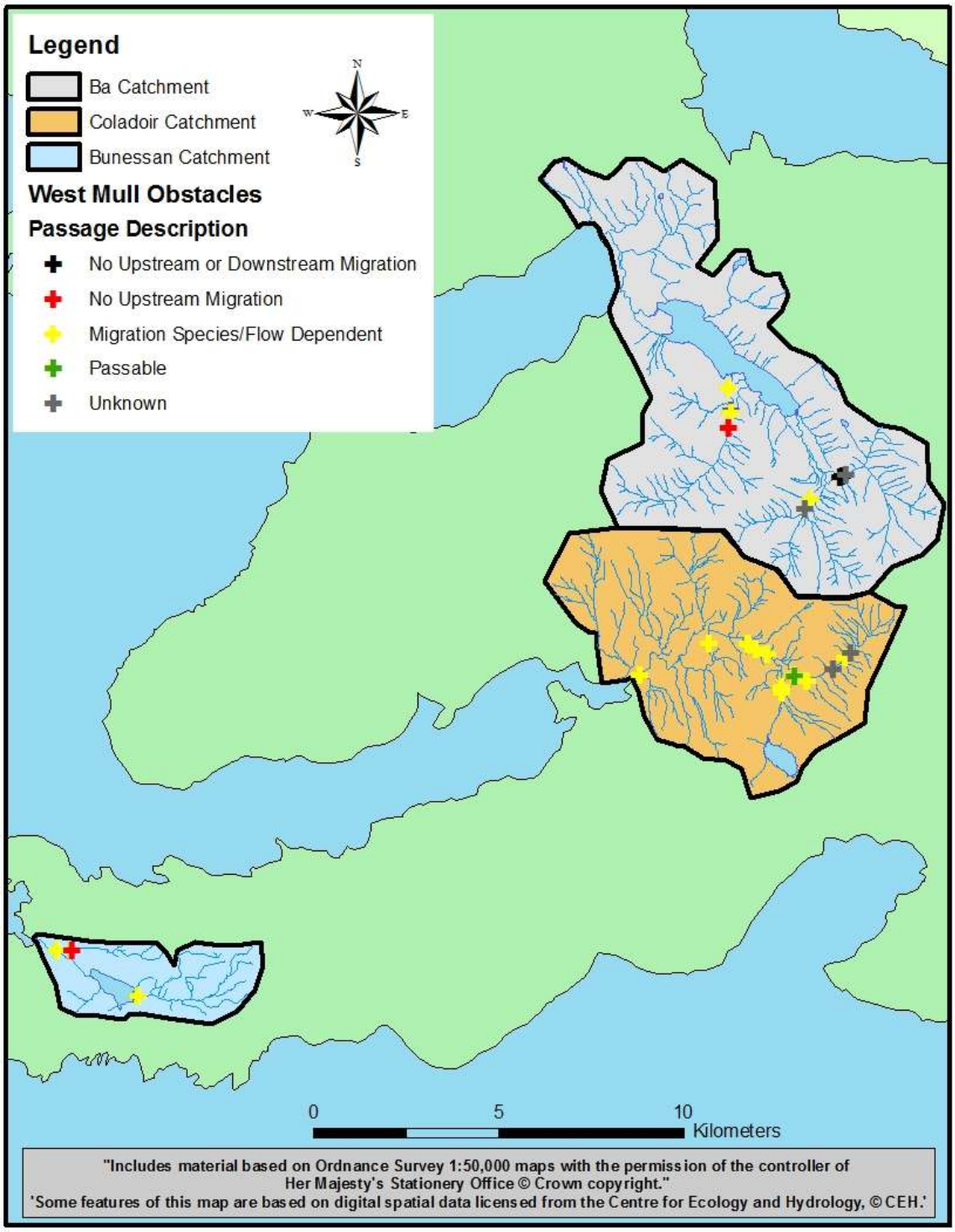

Figure 3.14 Distribution of obstacles to salmonid fish passage in West Mull

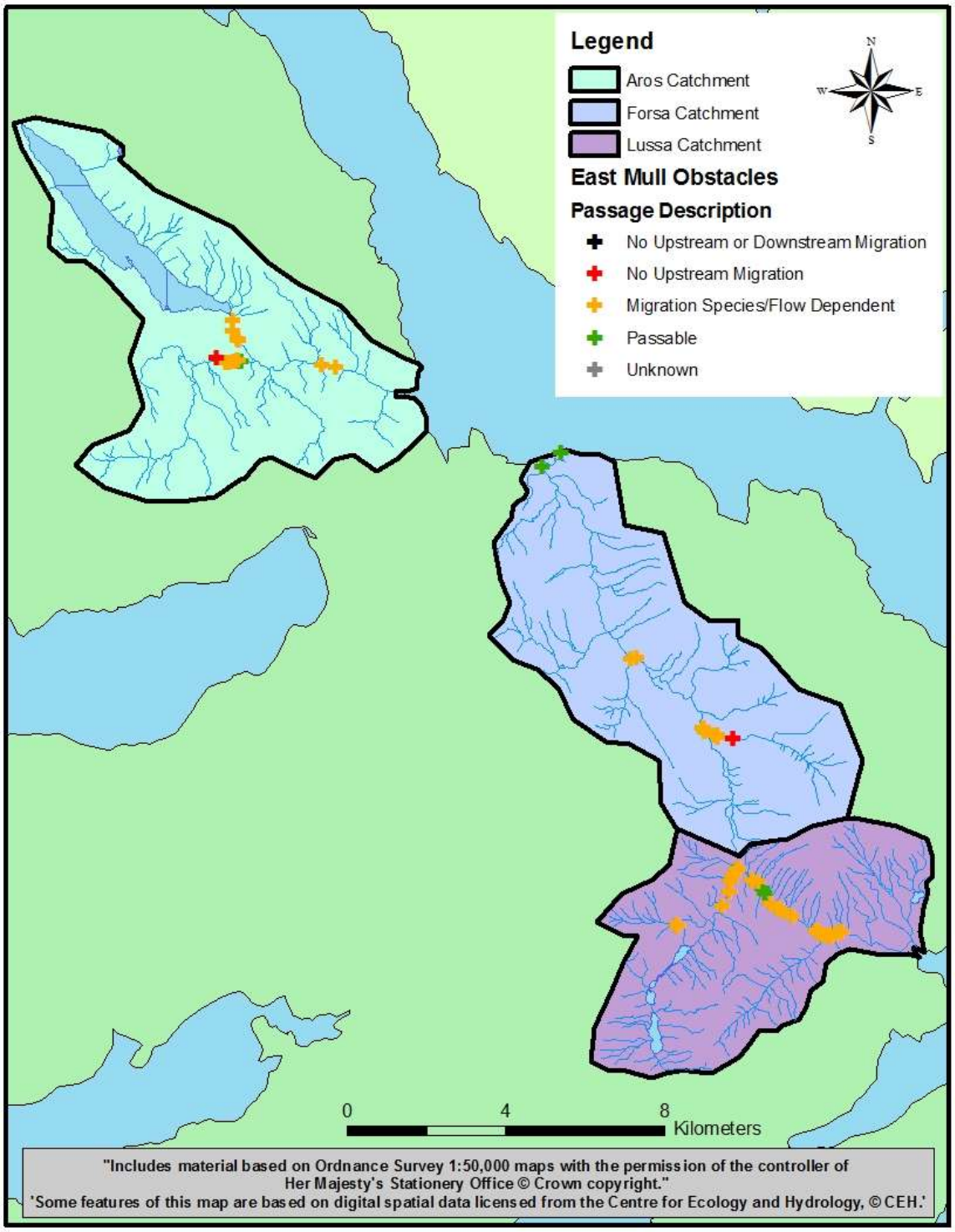

Figure 3.15 Distribution of obstacles to salmonid fish passage in East Mull

The area of pool habitat potentially available ranged from 404m² in the Bunessan (excluding Loch Assapol) to 32,275 in the Forsa. A total of 162 (49%) pools were identified as being sub-optimal due to their relatively small size, which are not likely to provide cover to adult salmonids over low flow periods. The remaining 89 (41%) were assessed as having optimal size and cover for adult salmonids. The predominant type of cover available to fish in pools was the depth of water and from bank undercut or vegetation.

3.2.1.1 Spawning sites

A total of 482 significant salmonid fish spawning sites was recorded at 334 locations during the surveys (Table 3.11). The frequency of sites recorded in each catchment range from 2.2 per km in the Bellart to 6.8 per km in the Aros catchment and averaged 5.0 per km. Of the eight catchments surveyed, only the Bunessan had less than 100m^2 of potential spawning habitat: the greatest areas of potential spawning were found in the Ba catchment, with 7,780m^2. A total of 128 (27%) of sites were identified as being sub-optimal for salmonid spawning, with the remaining 199 (63%) having optimal conditions.

Table 3.11 Spawning habitat survey results

Catchment	No. Locations	No. sites	Total area (m²)	No. Sub-optimal	No. Optimal	site features	No. per Km
North							
Mingary	22	36	189	7	13	bend / island	6.0
Bellart	23	29	445	9	13	Meanders	2.2
West							
Ba	68	133	7,780	22	45	Braid / Island	6.5
Coladoir	68	82	4,581	26	42	Pool / Glide	6.2
Bunessan	13	15	67	9	4	Glides	3.7
East							
Aros	44	64	2,323	18	23	Island / Bend	6.8
Forsa	62	81	6,666	24	38	Braids	5.4
Lussa	34	42	2,136	13	21	Island / Braid	3.4
Total	**334**	**482**	**2,4187**	**128**	**199**		**5.0**

Habitat features associated with spawning sites were mostly morphological features of the river channel including glides at the outflow of pools and other features such as braided channels and islands. The relative distributions of pools to spawning areas are demonstrated in figures 3.17, 3.18 and 3.19.

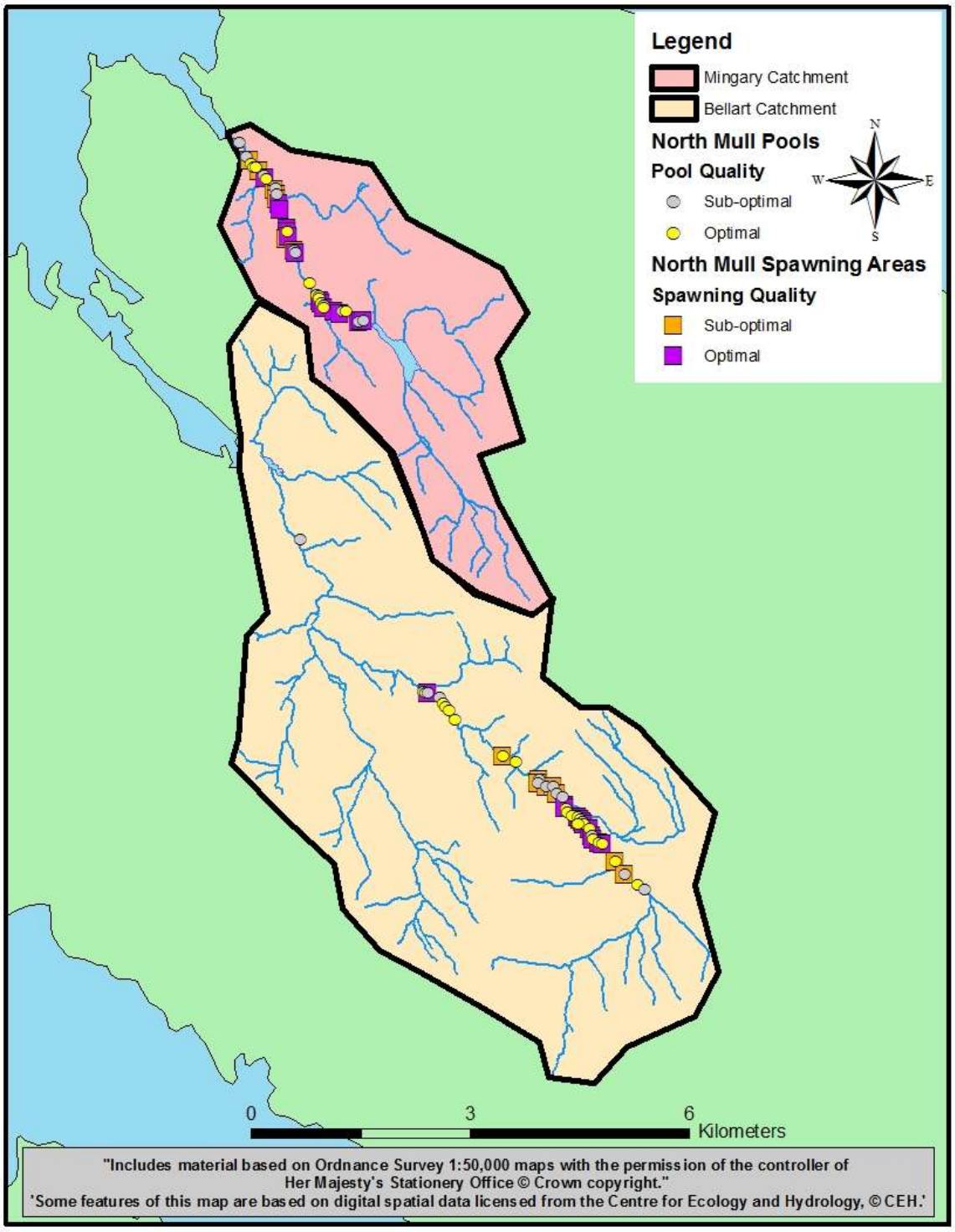

Figure 3.16 Distribution of spawning areas and pools in North Mull

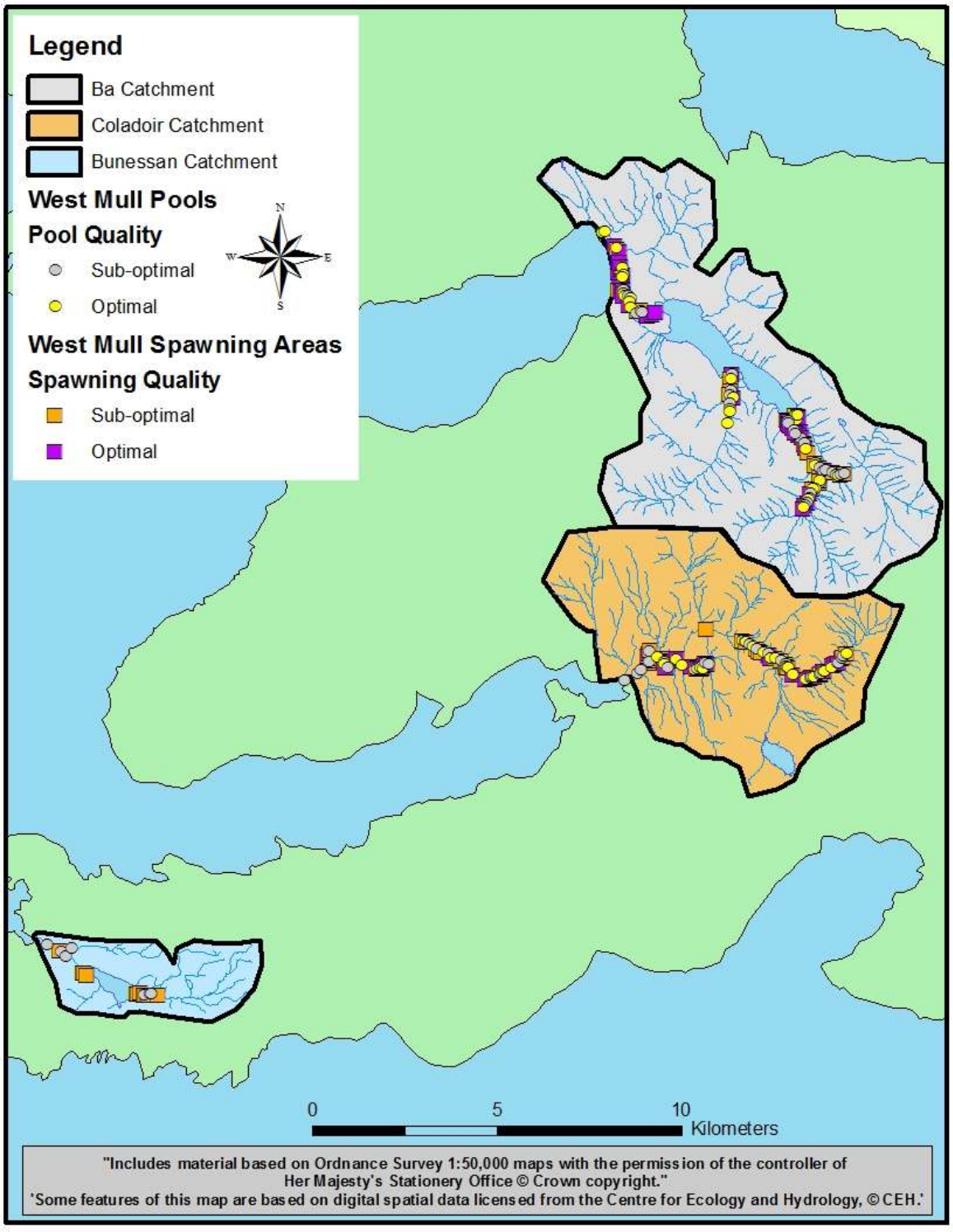

Figure 3.17 Distribution of spawning areas and pools in West Mull

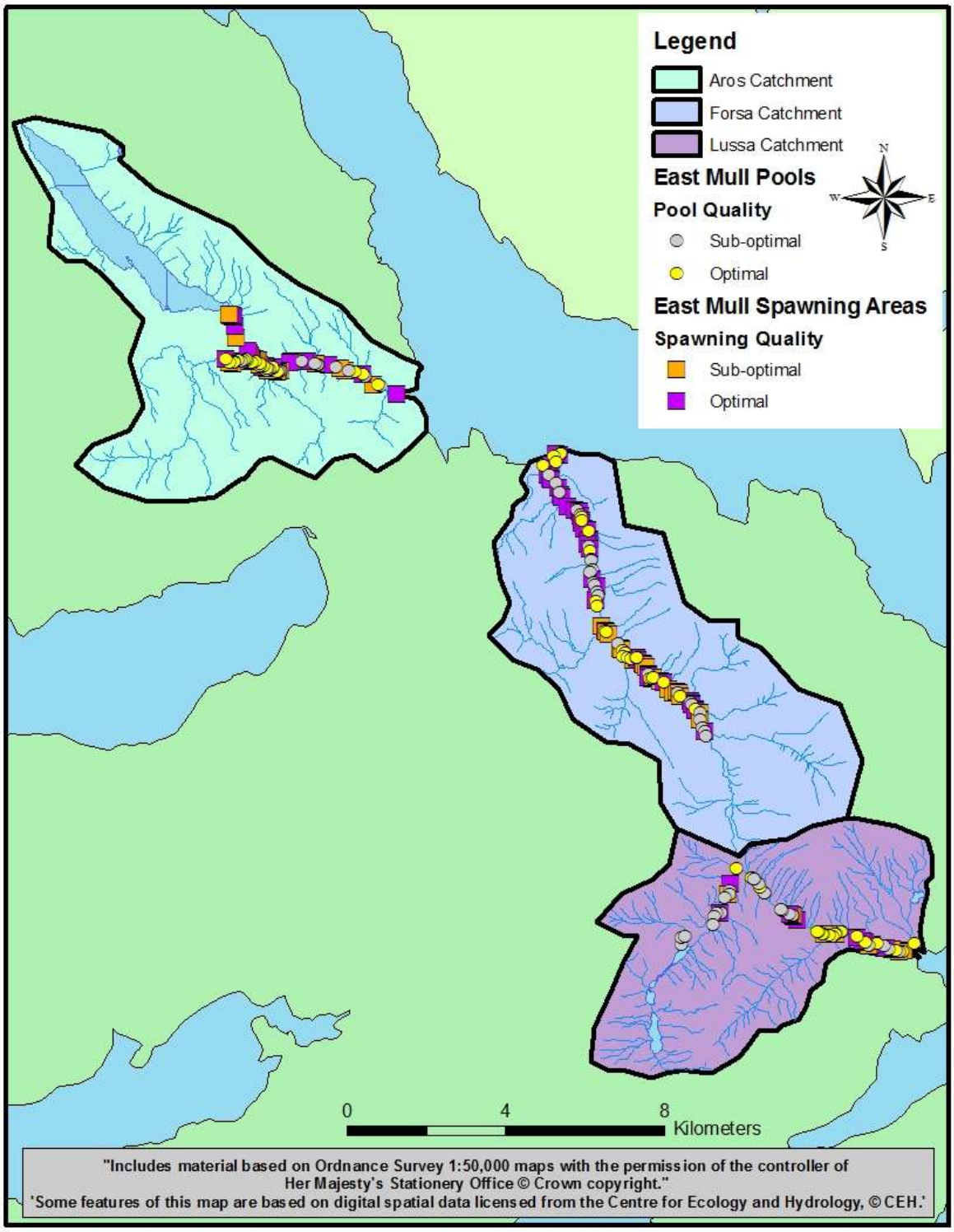

Figure 3.18 Distribution of spawning areas and pools in East Mull

3.2.2 Habitat condition

The relative suitability of the habitat for juvenile salmonid fish and factors potentially affecting productivity that were identified during the survey are described below.

3.2.2.1 Habitat suitability for juvenile salmonid fish

The juvenile salmonid fish habitats recorded (Table 3.12) consisted of shallow, mixed and deep habitats. Large areas of fry habitat were less abundant than mixed or deep juvenile habitats comprising only 8.6% of all sections surveyed, although some fry habitat was present in all catchments. The average scores suitability of fry habitats ranged from 2.0 out of a possible 5.0 in the Bunessan to 4.0 in the Mingary and averaged 2.9 for all sections. Mixed juvenile habitats (which including smaller areas of fry and deep juvenile habitat) were most abundant being recorded in 86% of all sections and present in each catchment. Suitability scores for mixed juvenile habitat ranged from 2.8 in the Bellart to 3.8 in the Bunessan and averaged 3.1 for all sections.

Table 3.12 Habitat abundance and suitability scores for juvenile salmonid fish

Catchment	No. of Survey Sections	Fry		Mixed Juv.		Deep Juv.	
		Sections Present	Score	Sections Present	Score	Sections Present	Score
North							
Mingary	8	1	4.0	8	3.0	5	3.0
Bellart	21	3	2.3	6	2.8	12	3.0
West							
Ba	21	6	3.4	20	3.1	3	3.0
Coladoir	24	6	3.8	20	3.1	8	2.9
Bunessan	7	1	2	5	3.8	1	1.0
East							
Aros	14	1	3	13	3.0	8	3.0
Forsa	23	5	2.6	19	3.0	13	3.8
Lussa	20	4	2.5	18	2.9	12	3.1
Total / avg.	**267**	**23**	**2.9**	**232**	**3.1**	**70**	**2.9**

Deep juvenile habitats were relatively abundant being recorded in 26% of all sections and present in each catchment. Suitability scores for deep juvenile habitat ranged from 1.0 in the Bunessan to 3.8 in the Forsa and averaged 2.9 for all sections.

3.2.2.2 Factors potentially affecting productivity

The main characteristics of habitats potentially affecting productivity of juvenile salmonid fish recruitment were recorded as downgrades for in-stream (Table 3.13) and riparian (Table 3.10) habitats. The total number of in-stream downgrades identified per km of survey varied between 4.0 on the Coladoir to 6.0 on the Bellart and averaged 5.2 per km for all catchments surveyed.

Table 3.13 Downgrades of in-stream habitat condition (No. per km)

Catchment	Total No.	In-stream Cover	Unstable substrates	Gradient	Modification	No spawning	No Large Woody Debris
North							
Mingary	5.8	2.5	0	0.5	1.1	0.3	1.4
Bellart	6.0	1.5	0	0.4	1.0	1.5	1.5
West							
Ba	4.7	0.8	1.0	0.3	0.7	0.3	1.7
Coladoir	4.0	1.1	0.2	0.3	0	0.5	2.0
Bunessan	7.7	4.3	0	0	1.4	0.9	1.1
East							
Aros	4.5	2.5	0	0.3	0	0	2
Forsa	4.2	0.3	0.6	0.2	1.0	0.2	1.9
Lussa	4.7	2.1	0.4	0.2	0.1	0.3	1.6
Average	**5.2**	**1.9**	**0.3**	**0.3**	**0.7**	**0.5**	**1.6**

Downgrades identified during the surveys were mostly attributed to factors related to in-stream cover for young fish (1.9 per km average), such as bedrock substrates or fine sediments in the substrate matrix. Relatively high scores were also given for a lack of large woody debris in the river channel (1.6 per km). More moderate average scores were also recorded for unstable substrates in four of the eight catchments surveyed, high or low gradient (0.3 per km) and lack of spawning sites (0.5 per km).

The number of riparian downgrades identified per km of survey (Table 3.14) varied between 0.3 per km on the Aros to 2.7 on the Ba and averaged 1.7 per km for all catchments surveyed. Downgrades identified during the surveys were mostly attributed to lack of shading of the river channel (1.3 per km), a lack of bank-side cover for fish in five catchments (average 0.4 per km). Over-shading from trees was identified in the Bunessan only (0.1 per km).

Table 3.14 Downgrades of riparian habitat condition (no. per km)

Catchment	Total No.	No Shade	Over Shade	Bank Cover	Predominant Land use
North					
Mingary	0.8	0.8	0	0	Forestry
Bellart	1.5	1.5	0	0	Grazing / Forestry
West					
Ba	2.7	1.8	0	0.9	Grazing
Coladoir	2.5	2.0	0	0.5	Grazing / Forestry
Bunessan	1.1	0.6	0.6	0	Grazing / Forestry
East					
Aros	0.3	0.2	0	0.2	Grazing / Forestry
Forsa	2.3	1.5	0	0.8	Grazing / Forestry
Lussa	2.6	1.8	0	0.8	Grazing / Forestry
Average	**1.7**	**1.3**	**0.1**	**0.4**	

3.2.2.3 Invasive Non-Native Species (INNS)

Invasive non-native plant species were recorded in four catchments during habitat surveys (Table 3.15). Japanese knotweed was found in one location (at Ledmore) on the Aros catchment only. *Rhododendron Ponticum* was identified in three catchments; the Ba (2 sections), the Forsa (2 sections) and the Lussa (one section). Himalayan balsam was not found on any catchment surveyed.

Table 3.15 Distribution of invasive non-native plants in riparian zones.

Catchment	No. of Survey Sections	INNS - no. of sections where present		
		Japanese Knotweed	Rhododendron Ponticum	Himalayan balsam
North				
Mingary	8	0	0	0
Bellart	21	0	0	0
West				
Ba	21	0	2	0
Coladoir	22	0	0	0
Bunessan	7	0	0	0
East				
Aros	13	1	0	0
Forsa	23	0	2	0
Lussa	20	0	1	0
Total	**135**	**1**	**5**	**0**

3.2.2.4 Lamprey habitat

A total of four sites in the Mingary and Aros catchments found in stream habitats to have

suitable habitat characteristics to host lamprey ammocoetes, which consisted of a mixture of organic silt deposits with leaves and small woody debris (Table 3.16). The total area was estimated to be 61 m², most of which was located in the Aros catchment.

Table 3.16 Distribution of lamprey habitat found in stream habitats

Catchment	No. sites	Total area (m²)	Optimal (no.)	Sub-optimal (no.)	Accessible (no.)
North					
Mingary	2	7	1	1	2
Bellart	0				
West					
Ba	0				
Coladoir	0				
Bunessan	0				
East					
Aros	2	54	1	1	2
Forsa	0				
Lussa	0				
Total	**4**	**61**	**2**	**2**	**4**

Two sites were thought to be in optimal condition related to size, stability and depth of silt, while two other were found to be sub-optimal. All sites identified were likely to be accessible to lamprey from the sea.

4 DISCUSSION

The findings of the fish and habitat surveys are discussed below in relation to the status of fish populations, factors potentially affecting their productivity and other influences on the results of the survey.

4.1 Fish distribution and abundance

The habitat and fish surveys indicate that all naturally available habitats for migratory fish appear to be accessible, with natural topographical features such as bedrock waterfalls, cascades or extensive reaches of unsuitable habitat in high gradient, upper catchment reaches currently limiting fish distribution.

4.1.1 Atlantic salmon

The fish data collected indicate that all eight catchments surveyed as part of this study are currently able to support salmon populations even though salmon were not sampled at all survey sites in all catchments. The relatively low distribution (and abundance) found in the Bunessan indicate that there may be a potential threat of local extinction, although more parr were found in 2010 compared with 2003.

Similar surveys in other rivers in Argyll (AFT, 2010a, 2010b) indicate that juvenile salmon are generally more widespread and relatively more abundant in the main river channel in contrast to trout that are generally more widely distributed and more abundant in smaller tributary streams. The distribution of salmon fry in 2010 was found to be similar to that found in 2003 (AFT, 2004) with a loss of distribution at seven of the 62 comparable sites and gains at four others, three of which were in the Coladoir catchment. Losses in salmon fry distribution were mostly from sites in tributary or smaller main river sites (less than 3m wet width) indicating that recruitment may be infrequent in these sites where access of mature adults may vary year-to-year due to flow conditions at the time of spawning. Alternately, the changes in salmon fry distribution found in tributary streams in 2010 may also be an artefact of lower than optimal spawner numbers in the previous autumn.

There was more variation in salmon parr distribution compared to fry with losses found at 12 sites compared to gains at 14 others. Reasons for this may be the increased swimming ability of larger parr compared to smaller fry, which are more likely to remain close to their natal redd sites.

These data also suggest that salmon fry abundance in 2010 was high at one or more locations in all catchments with the exception of the Lussa River only low-to-moderate abundance was found. Similarly, salmon parr was also found to be relatively high at some

locations within each catchment, but with the exception of the Coladoir and the Bunessan where low-to-moderate abundance was found. When compared to 2003 data, the average classifications of abundance of salmon fry in 2010 was found to be lower in all east Mull populations, but were of higher abundance in the north and west Mull populations. Comparisons of parr abundance were more variable with lower classification average in one or more catchments for north, west and east Mull.

The condition of some freshwater habitat may also influence smolt production, but may not be the most significant factor at this time due to low rates of adult returns. However, there may be exceptions to this, particularly in regard to the Bunessan catchment which is classified as a heavily modified water body with bad ecological potential. The productivity of water chemistry may also influence juvenile numbers, particularly where natural base-poor geology may be prevalent, but survey data suggest that there were a high abundance of salmon at some locations where relatively low dissolved minerals were present in the water. Therefore, these data indicate that recruitment of salmon may not be optimal in at all site in all years, possibly as a consequence of relatively low spawner numbers.

The relatively poor abundance of salmon populations found in east Mull catchments; the Aros, Forsa and Lussa, in 2010 indicate that there may a difference in the performance of salmon populations in different areas of the island. Other data also indicate that the performance of salmon populations in the River Aline (Lochaber Fisheries Trust, 2009) on the north shore of the Sound of Mull have also been relatively poor in recent years. Although little is known of inshore movements of salmon and sea trout smolt migration through Scottish west coast inshore waters (Malcolm et. al, 2010), the Sound of Mull is likely to be a major thoroughfare for outward migrating smolts and returning adult salmon from a number of major rivers, including the River Lochy and the River Awe. Rod catch data from the Lochy and Awe (Tripartite Working Group, 2011, in preparation) indicate significant decline in fishery performance during the period 2008 to 2010, which is likely to be an artefact of the low numbers of returning adult fish counted by the Awe Barrage fish counter in these years (Appendix I).

Given the indications of a relatively widespread decline in salmon populations associated with the Sound of Mull, Firth of Lorn and Loch Linnhe from 2008 to 2010, it is therefore possible that smolt production is currently less than optimal, which may subsequently influence the maintenance and recovery of salmon populations given that smolt survival at sea has been variable and often low in recent times.

4.1.2 Brown trout

The fish data collected indicate that all eight catchments surveyed as part of this study are

currently able to support trout populations even though trout were not sampled at all survey sites in all catchments. The relatively low distribution and abundance of trout found in the Ba catchment in 2010 and 2003 indicate that there may be limitations on freshwater habitat suitability in the catchment for this species. Unlike salmon it is not thought likely that there is a potential threat of local extinction as trout are able to complete their life-cycle in freshwater and are therefore not reliant on marine survival of post-smolts to the same degree as are salmon. Additionally, it is possible that trout fry migrate shortly after emergence from nesting sites (redds) into Loch Ba, which was not sampled as part of this survey.

The distribution of trout fry in 2010 was found to be similar to that found in 2003 with a loss of distribution at seven of the 62 comparable sites and gains at nine others. Losses of trout fry distribution in tributary or smaller main river sites (less than 3m wet width) were less common than was found for salmon, factors affecting access of mature adult trout may vary less year-to-year (conditions at the time of spawning) than for salmon depending on flow. Alternately, the changes in salmon fry distribution found in tributary streams in 2010 may also be an artefact of lower than optimal spawner numbers in the previous autumn.

The lower proportion of sites where trout were found compared to salmon in this survey may be an artefact of sampling error, as few small tributaries were surveyed that are more commonly used for trout recruitment compared to main river habitats. Previous surveys of the Ba catchment (2003) also found few or no trout, which may indicate that the habitat surveyed is unsuitable.

These data also suggest that trout fry abundance in 2010 was high at one or more locations in all catchments with the exception of the Mingary, Bunessan and Lussa catchments where only low-to-moderate abundance was found. Similarly, trout parr was also found to be relatively high at some locations within each catchment, but with the exception of the Aros where moderate abundance was found. When compared to 2003 data, the average classifications of abundance of trout fry in 2010 was found to be lower in four catchments; Mingary, Ba, Bunessan and Forsa, but were of higher abundance in the Bellart, Coladoir, Aros and Lussa populations. Comparisons of parr abundance classification average were lower in the Bunessan, Forsa and Lussa catchments.

Similarly to salmon, the patchiness and changes recorded in trout distribution of different age classes also indicates that spawning activity may be infrequent in some populations which may be as a result of poor adult sea returns. The relatively moderate-to-good abundance of trout fry and parr sampled at some sites indicate that they are likely to be, in part, the progeny of sea-run adults. Unlike salmon, sea trout post-smolts tend to remain relatively close in coastal waters, indicating that the local marine survival of sea trout has not improved

significantly since the previous survey in 2003.

4.1.3 Non-salmonid species

Although not sampled in all sites the distribution of European eel was also relatively wide compared to other non-salmonid fish, but was lower in 2010 (47 % of sites) compared to 2003 (57 % of sites). Unlike salmon and sea trout this migratory species utilises freshwaters for their adolescent growth phase and their distribution is an artefact of the relative suitability of available habitats rather than spawning activity in previous years. While there are international concerns over the status of eel populations, their modest distribution recorded in this survey indicate that they remain relatively well established, but there are no data on their density or age class distribution to assess their relative abundance and age class presence.

Flounder were found in the lower reaches of three catchments and are more commonly known to inhabit estuarine and coastal marine habitats (Maitland & Campbell, 1994). Flounder are also capable of spending long periods in freshwater where suitable habitats are accessible from the sea before returning to sea to breed. Hence their distribution may be wider than described here, but may not be present in the Forsa catchment which has a waterfall obstacle near the estuary. Similarly, although three-spine stickleback were found in only three catchments during the study, this may be an artefact of the type of habitat surveyed, which was mostly faster flowing turbulent flow types primarily suited to juvenile salmonid fish.

Although lamprey ammocoetes (*Lampetra spp.)* were not found at any survey sites this may not accurately reflect the distribution of potential lamprey. Lamprey may be present, but habitat preferences for lamprey ammocoetes are likely to be for silt beds and free-swimming transformer life-stage may not be present at the time of sampling. Habitat survey data indicate that potential habitat for juvenile lamprey (ammocoetes) may be limited to a small number of sites in a few catchments, much of which was in shallow loch habitats that could not be surveyed by the electrofishing technique. Therefore, further site specific sampling would be required to establish their distribution.

Minnow are understood to be a translocated species in most Scottish Waters and are unlikely to be native to the Island of Mull. Their current distribution on Mull in the Bellart, Aros and Lussa is likely to be as a result of them being discarded by anglers after they have been used as bait for trout. Consequences for native species resulting from introduction of minnow are not well understood in the Scottish context, but where studied in Scandinavia (Borgstrom *et. al.,* 2010), reduced recruitment and annual growth rate of brown trout as well as changes in diet were most likely related to the introduction of European minnow.

4.2 Factors affecting freshwater habitat

The assessment of habitat condition on the Isle of Mull provided as part of the Argyll and Lochaber River Basin Plan suggest that most catchments are of good ecological status, but are moderate in Loch Ba and its tributaries and heavily modified and of bad ecological potential in the Bunessan catchment. There may be potential for improvement in the upper Ba catchment, if diffuse source pollution and improved land use practices are achieved. Improvement of ecological status will be more complex to achieve on the Bunessan due to the use of Loch Assapol as a resource for supplying drinking water to nearby communities.

4.2.1 River morphology and channel characteristics

The morphology of river channels surveyed was thought to be natural in most survey sections, but it is possible that historical channel re-alignment (straightening) has been undertaken in some catchments, which can both reduce stream length, sinuosity and habitat diversity. The lower reaches of a number of catchments; Mingary, Bellart, Ba, Bunessan, Forsa all appeared to have been modified to varying degrees. Some morphological alterations on the Forsa and the Ba have been undertaken relatively recently in the form of addition of in-stream structures; weirs and boulder placement. These alterations are likely to be primarily aimed at enhancement of the fishery. Older and more extensive alterations to river channels were found on the lower gradient reaches of the Bellart, Mingary and Bunessan, possibly as a means to aid land drainage for farming and forestry.

The gradient of fall of the river habitat has an influence on stream morphology (and bed substrate composition). The alterations to habitat were all found in relatively low gradient habitats, which are also potentially the most sinuous with meanders and pool/riffle/glide flow sequences. The relative effect on fish populations resulting from the loss of lower gradient habitat cannot be quantified here, but typically a lower diversity of habitat and fewer locations suitable for recruitment were present in modified reaches when compared to natural reaches.

Obstacles to fish migration were more frequent in higher gradient habitat in the upper reaches of most catchments. Typically these were bedrock outcrops or boulder-pool steps, most of which are passable to salmonid fish in favourable flow conditions. Such obstacles may be more limiting of other fish less well adapted to longer migrations such as lamprey and stickleback. Eels may be less affected if there is sufficient moist substrate at the edges of obstacles over which they may pass. The most significant man-made obstacle found was the dam at Loch an Torr on the Mingary catchment, but this is partly a natural feature. Salmonid fish may pass the dam over the spillway, but it is not clear from the survey data if this is the case.

4.2.2 In-river substrates

Habitat survey data indicated that all catchments have substrates that are favourable for recruitment and nursery habitat for salmonid fish, although there appears to be significant areas of some catchments that are unlikely to be suitable for spawning. Notably the lower reach of the Bellart had no coarse substrates and was mainly peat, silt or vegetation for the lower 5 km of the main river. This is potentially a consequence of substrate removal, which is likely to have been undertaken to lower the water table and improve land drainage (as is the channel re-alignment as discussed above).

Where coarse substrates were present, some compaction of the bed with fine sediments was noted in the Aros and Mingary catchments. This may be a natural feature of these river channels, but may also be exacerbated by land disturbance from forestry operations and or poaching of river banks of livestock. Small substrate size and bed compaction is likely to reduce in-stream cover for juvenile salmonids and may subsequently reduce survival as shelter from high flows and predators is less abundant.

Conversely, relatively unstable bed materials were found in the Ba and Forsa catchments and to a lesser degree in the Lussa and Coladoir. The upper Ba tributaries appeared to be the most significantly affected, possibly due to the loss of bank consolidation and high rates of bank erosion and substrate supply. The lower Ba appeared to be more recently effected by some erosion around the weir structures.

The availability of frequent spawning habitat may be limited in both low gradient habitats that have been affected by habitat modification or bed compaction and high gradient habitats where there may be insufficient accumulations of smaller spawning grade material. The most frequent optimal spawning habitat locations were found in low gradient areas of the upper Bellart and the upper Lussa which were highly sinuous with deep pools and stable substrates.

4.2.3 Riparian habitats

The existing and historical land-use on Mull strongly influences the condition of riparian habitats found in the survey. Most catchments were found to have a high abundance of improved and rough grazing or forestry land adjacent to river banks. Typically this was reflected in the survey as a lack of shading of the river channel in reaches with agriculture and a similar lack of broadleaf native trees in forestry affected reaches. The consequence of both land use types are likely to reduce productivity for fish in a number of ways such as the reduction of leaf litter entering the aquatic ecosystem, large woody debris that increase habitat complexity and tree roots that stabilise banks and provide cover for fish. Forestry activity is limited to few of the catchments surveyed (Aros, Forsa, Mingary, Bunessan and

Lussa) but where present did not appear to conform to Forest and Water Guidelines in some sections, probably because much of the planting appeared to have been undertaken prior to the guidelines being implemented. Where present, broadleaf woodland habitats were found to be fragmented by other land uses and increasing the quality and distribution of this habitat type is likely to have long-term benefit for fish populations, particularly as a role in management of water temperature which may increase with other affects of climate change over time.

Invasive non-native plants were found in a relatively small number of sections in relatively few catchments. Of particular note is Japanese knotweed which was found in the upper reach of the Ledmore Burn in the Aros catchment. Control and preferably eradication will be required at an early stage to ensure further habitat is not affected downstream. More widespread is *Rhododendron ponticum* in the Ba mainstem which also has potential to reduce productivity of freshwater habitats and fish populations.

4.3 Factors affecting productivity in marine habitats

The productivity of marine habitats may be considered in two ways; the wider Atlantic ocean that are utilised by Atlantic salmon and the coastal inshore waters which sea trout utilise throughout the marine life-phase, while salmon move through relatively quickly as smolts on their way to the open ocean and on return as adults.

4.3.1 Wider ocean habitats

The wider marine survival of post-smolt salmon is possibly associated with the affects of climate change on the marine environment, but are less well understood compared to that of local marine factors known to affect migratory salmonids. A growing number of studies have indicated that the productivity of ocean habitats may have declined over time with a recorded reduction in sea age of multi sea-winter salmon and reductions in growth of one-sea winter grilse (Todd et. al, 2008). Recent sea survival of post-smolt salmon has also been highly variable with relatively good counts of adult sea returns in the Awe catchment (recorded by the Awe Barrage counter) as recently as 2007 and near record low numbers in 2009. It is not currently known if the most significant factors affecting survival of post-smolt salmon are related to the open-ocean or inshore waters.

4.3.2 Inshore marine habitats

Although not studied as part of this survey, the ecological status of coastal waters suggest west coast lochs of Scridain and na Keal are of good status while the Sound of Mull is of moderate ecological status. The stratification and low oxygen levels found in the Sound of Mull may be a natural and on-going factor, which may be unlikely to affect migratory

salmon to a significant degree. There is potential that aquaculture related factors such as sea lice (*Lepeophtheirus salmonis*) burdens affecting survival and growth of post-smolts and interaction with farmed escapee salmon (McGinnity et. al, 2004) may have an influence on the current status of migratory salmonid fish. Existing data has been collected on sea lice burdens of sea trout as part of the Area Management Agreement process (Tripartite Working Group, 2011, in preparation) in the nearby Loch Linnhe and Firth of Lorne, but there is little or no data from the Sound of Mull itself.

Other studies have found a relationship between lice burdens on sea trout and the distance of the nearest fish farm and also on increased lice burdens when farms are in the second year of production (Butler & Watt, 2002), probably due to the higher biomass of fish in the second year pre-harvest and higher lice levels found on most farms in most production cycles (Penston & Davies, 2009).

The relative contribution of the wider and inshore marine factors effecting adult sea returns has not been established, but the relatively low juvenile abundance found in east coast streams of Mull and other salmon and trout populations in the region indicate that there may be significant factors in the local marine habitats of the Sound of Mull and Firth of Lorn affecting wild salmonids compared to the north and west of the island.

New information on the influence of salmon farm location, wind and tidal movements on sea lice larvae distribution is currently being collected in Loch Linnhe which may further establish this methodology, previously used in Loch Torridon (Penston & Davies, 2009). The data collected as part of this survey indicate that similar information for the Firth of Lorn, Sound of Mull and possibly Loch Spelve would better inform management of aquaculture and wild fish interaction.

4.4 Factors affecting survey results and interpretation of data

There are a number of factors that may influence the results of the survey related to environmental conditions at the time of survey, survey technique and design, the use of habitats by fish and management intervention by fishery operators.

4.4.1 Survey design, technique and environmental conditions

The design of the survey was mainly aimed at establishing an understanding of the broader distribution and abundance of salmonid fish, but due to the limited resources available the number of sites surveyed in each catchment was limited to main river habitats. Single-run surveys do not usually catch all the fish present in the survey site so it is likely that the actual abundance of fish found in the survey are likely to be somewhat lower than recorded. However, the classification scheme used to assess juvenile salmonid fish abundance is established for one-run fishing and estimates of minimum abundance are therefore comparable.

The environmental conditions at the time of survey were relatively favourable for efficient sampling, although the relatively low conductivity of the water in some catchments; the Ba, Coladoir, Lussa and Forsa, may reduce efficiency and fish capture. The relatively low number of smaller tributary streams sampled is likely to provide less detailed information on the status of juvenile trout, compared to salmon that usually dominant main river habitats.

The survey technique used is designed to sample relatively shallow water in streams and hence less is known of the relatively deeper areas of habitat including lochs, which are likely to be favoured habitats of trout parr and other non-salmonid fish. Subsequently, the actual abundance of some species maybe higher in deep pool and stillwater habitats.

4.4.2 Fishery intervention

The stocking of juvenile salmon and trout into freshwater habitats has been undertaken by fishery managers on the Ba and the Forsa catchments. The exact location of stocking is not known, but it is possible that the distribution or abundance of fish found may have been slightly different to the natural state. The numbers of juvenile salmon stocked is not likely to skew the results given here to a high degree as these are thought to be relatively low.

5 IMPLICATIONS FOR MANAGEMENT

The data on fish and their habitats collected in the survey provide an indication of the implications for the management of fish populations on the Island of Mull and how land owners and managers can improve habitats for benefit of fisheries and wider biodiversity.

5.1 Fishery management

The fish species sampled in the survey; Atlantic salmon, brown trout, European eel and flounder have value as part of local biodiversity, however migratory salmonids also have potential to support fisheries that are important to local recreation and economy. The data on juvenile salmon and trout indicate that there is significant potential for sustainable fisheries for these species in the catchments surveyed at this time. However, it is important to maximise spawning escapement of adult fish by employing effective catch and release measures on recreational fisheries to ensure that sufficient spawning escapement and recruitment of smolts is improved over time. Conversely, the current status of salmon populations in the Bunessan catchments indicate that they are not able to support exploitative fisheries at this time and exploitation is likely to decrease potential for future restoration and increase potential for local extinctions.

5.1.1 Maximise spawning escapement

The apparent relatively low numbers of sea returns of salmon and consequent less than optimal status of juvenile populations indicate that it is essential to maximise the spawning escapement from the fishery. Operating fisheries on conservation-minded principles through effective catch and release angling techniques and protecting adult fish from poaching or excessive predation will be essential to maximise recruitment.

5.1.2 Stocking

Current efforts to restore or enhance fishery performance through stocking activities may have potential to stimulate recovery, but they are unlikely to overcome the causes of the decline of catches. While short-term benefit from a stocking strategy may be realised in the fishery, longer-term management of habitat issues and improved management of land and water resources are more likely to derive a sustained improvement in fish health and abundance (Webb et. al, 2009).

Short-term hatchery intervention, where appropriate will need to be focused on the specific requirements of each individual population if they are to be effective. Supporting information on wild spawning activity, genetic structuring of populations and survival of stocked fish will be required to inform biological and ecological aspects of stocking programmes. The genetic

samples collected as part of this study may be used to better inform management of populations, particularly with populations in larger catchments where stock structuring may be more complex.

Avoiding in-breeding depression in small populations and out-breeding depression by crossing different genetic groups is a management consideration for restoration intervention and possibly the longer-term health of populations. Undertaking stocking, even with natal fish, without up-to-date robust information on use of habitats by wild spawned juveniles is likely to result in the over-stocking of sites and increased competition between juveniles.

Given the range of issues raised by the use of hatchery intervention techniques for fish health, biology and ecology, it is likely to be beneficial to review stocking programmes on a case-by-case basis to avoid inappropriate practices and maximise benefit from existing operations.

5.1.3 Biosecurity of fish and fisheries

It will be important for fishery managers to raise local awareness of biosecurity issues and engage a wide range of stakeholders active in the catchment. Guidance for the management of biosecurity issues are identified in the Argyll & The Islands Fisheries Biosecurity Plan (AFT, 2009). The establishment of surveillance, control and eradication programmes are required to manage existing and future threats including health checks of fish from Marine Scotland Fish Health Inspectorate.

It is unlikely that minnow, found in three of the eight catchments surveyed can be eradicated, but their distribution may be controlled to reduce risk of further competition with native species such as trout for limited resources. Ensuring that minnow are not translocated into other catchments will ensure that the productivity of these species is not affected on a wider scale on the island. There is now legislation in place that prohibit the use of live vertebrates as bait and therefore raising local awareness of the issues related to competition and introduction of parasites and other pathogens may prevent further spread of the species.

Although not yet present in the UK, the introduction of the *Gyrodactylus salaris* parasite is a significant threat to the future of fisheries in Scotland. If and when it is introduced to the British Isles it may be spread through the movement of fish (prior to being diagnosed) and therefore the risks associated with movement and stocking of fish reared in commercial facilities for aquaculture and fisheries need to be assessed. American mink were found to be present in the Mingary catchment during the survey and are likely to be present elsewhere on the island. A co-ordinated approach by land managers to control and eventual eradication is likely to bring benefit to fish populations and biodiversity more widely.

The survey found Japanese knotweed, a priority non-native species, at one location in the upper Aros catchment, which if tackled in the short-term may be eradicated from the island and avoid the spread and significant associated management costs in the future.

5.1.4 Administration of fisheries

Currently each fishery on the Isle of Mull is managed independently from one another and while this may be appropriate for the day-to-day management of a fishery, the formation of an over-arching management body for fisheries on the island is likely to benefit fishery managers by providing links with the regional and national management structure. Such links will benefit the knowledge of local managers and provide a centre for providing local fisheries policy, engagement with other land and water resource users on and co-ordinating wider-scale management, conservation and improvement initiatives. Furthermore, a cohesive approach may benefit grant-aid applications for assistance with habitat improvement projects.

5.2 Habitat management

Land owners and managers are the primary drivers for managing habitats and have a very important role to play in securing improvement in management of habitats that influence the productivity of fish populations and fisheries. Longer term aspects of promoting recovery and maintenance of fish populations will be to deliver improvement in the ecological status and productivity of freshwater habitats. Despite the River Basin Plan (RBP) assessment of good ecological status of most of the rivers on Mull, this survey found a number of aspects of land management that may be changed for the benefit of freshwater resources.

The long-term historical grazing of habitats by livestock and deer has left few broadleaf woodland riparian habitats on the island. Regulation of water temperature and delivery of leaf litter, large woody debris, and terrestrial food sources are likely to be important aspects of the management of salmonid fish, biodiversity and fisheries in the future. This may be particularly important to low productivity rivers such as the Ba (where acidification may be a factor), Forsa, Lussa and Coladoir where in-stream food production will be naturally limited compared to rivers with more influence from relatively base-rich geology.

Future phases of the RBP are likely to develop the catchment planning process which will seek to retain and improve the status of freshwater habitats by improving the use of land and water resources. The general binding rules of the Controlled Activities Regulation (CAR) administered by the Scottish Environment Protection Agency are also likely to reduce potential for inappropriate development that will be detrimental to the status of fish habitats. It will be important to engage local land and water resource users into the management of

freshwater habitats to maximise the potential benefits to the productivity of fish populations and the performance of fisheries.

Land owners may action some or all of the habitat management and improvement initiatives with financial assistance from the Scottish Rural Development Programme (http://www.scotland.gov.uk/Topics/farmingrural/SRDP). This programme of economic, environmental and social measures can help individuals or groups deliver the Government's strategic objectives in rural Scotland. The rural priorities for Argyll can be found here (http://www.scotland.gov.uk/Topics/farmingrural/SRDP/RuralPriorities/Argyll), and include areas such as biodiversity, landscape, water and soils and adaptations to mitigate climate change.

Attached to these priorities are packages that can help deliver the desired improvements. For example, forest management or habitat improvements to address morphological pressures are accessed through the Waters and Soils priorities, regional code ARG18 directs you to packages 27-30 to address the issues. Control and eradication of invasive non-native species and improving freshwater habitats supporting salmonids or freshwater pearl mussels, the Biodiversity priority within SRDP provide relevant packages to support this work. Further guidance in relation to SRDP may be undertaken via a land agent or directly in Argyll with:

SGRPID
Cameron House
Albany Street
Oban
PA34 4AE
Tel: 0300 244 9340
Fax: 0300 244 9331
Email: SGRPID.Oban@scotland.gsi.gov.uk

Further guidance for habitat management initiatives are provided in catchment specific reports in support of the summary findings given here.

5.3 Aquaculture management

Changes to the management of marine salmon fish farm production on the east side of Mull since 1999 as part of the Loch Linnhe, Firth of Lorn and Sound of Mull Area Management Agreement (AMA) and the Aquaculture code of good practice are likely to have improved containment and sea lice management on local salmon farms. These changes to

management are likely to have improved the health of both farmed and wild fish. However, since the changes in management associated with the AMA, new challenges have arisen in regard to efficacy of sea lice treatments and increases in biomass of farm fish in the area, where approximately 25% of the Scottish production of farm salmon is grown.

Fish farming on the West side of Mull in Loch na Keal (and previously in Loch Scridain) has been of smaller biomass than on the east and has also undergone changes as part of the AMA process, which is to end in 2011. It is possible that area-based management agreements between wild and farm fish interests will be maintained, but on-going expansion of the aquaculture sector is likely to maintain pressures on wild fish resources in the future.

Avoiding infestation of post-smolt salmonids by higher than natural burdens of sea lice is an important aspect of local management that is an on-going issue for both the aquaculture and wild fishery sectors. The data collected on trout populations indicate that control of sea lice on local farms has been sufficient in recent times to maintain juvenile populations, but further information on older adolescent and mature age classes are required to fully evaluate the current status of sea-run trout. Maintaining high efficiency in lice control will also be required in combination with on-going development of effective sea lice treatments and implementation of production strategies to minimise potential impact of sea lice on wild fish recruitment.

Containment of farm stock is also a priority for both the aquaculture and fisheries sectors. The vulnerable status of local wild salmon populations recorded in the survey indicates that they are susceptible to biological (genetic) and ecological (competition) elements that have potential to further erode wild populations. Any significant loss and subsequent interaction of farm stock with wild fish has potential to undermine the fitness of wild salmon populations and therefore it is important to have effective containment and in the event of an escape of farm fish an adequate recapture plan.

6 CONCLUSIONS

Interpretation of the data collected by fish and habitat surveys in 2010 provides a number of conclusions, some of which are compared to a similar survey undertaken in 2003.

6.1 Fish distribution

Fish surveys undertaken sampled five native fish species; Atlantic salmon, brown trout, European eel, stickleback and flounder. Non-native minnow were found in three of the eight catchments surveyed. Juvenile salmon and trout were found in all catchments, but distribution within some catchments was patchy. The distribution of salmon found in 2010 was similar to that found in 2003, but salmon fry were less well represented in some tributary stream sites in 2010.

6.2 Juvenile salmonid fish abundance

Where present the abundance of juvenile salmon was relatively low-to-moderate, but high in a relatively small number of sites when compared to data from other rivers in the west coast region. When compared to 2003 data, juvenile salmon abundance was lower in 2010 on the Aros, Forsa and Lussa catchments on the east of the Island compared to north and west catchments which were generally of higher abundance in 2010 compared to 2003. Similarly to salmon, trout abundance varied between sites, but unlike salmon, trout abundance was generally higher in smaller streams compared to larger main river habitats. When compared to 2003, trout abundance in 2010 was lower in some catchments and higher in others.

6.3 Factors affecting productivity

The principle factors affecting productivity of migratory salmonid fish are likely to occur in the marine phase of their life-cycle at this time. However, the habitat survey identified a number of factors affecting the productivity of freshwater habitats that are likely to be a consequence of modification of channel features and land use. The naturally low productivity of some catchments is likely to limit the performance of fisheries.

6.4 Fishery management

Operating fisheries on conservation-minded principles through catch and release angling techniques and protecting adult fish from exploitation will be essential to maximise spawning escapement and stimulate recruitment. Where stocking is carried out, site specific information needs to be collected to better inform the use of hatcheries, but this type of intervention is unlikely to overcome the causes of decline in salmonid fish populations.

7 APPRAISAL OF METHODOLOGY AND FUTURE PROGRAMME OF WORK

The two methodologies utilised in the survey; electrofishing and walkover spawning habitat surveys are appraised and their suitability discussed.

7.1. Electrofishing surveys

The results of the electrofishing survey provided basic information to identify the general distribution of fish species and relative abundance of juvenile salmonid fish. However, the survey data collected for non-salmonid fish to SFCC protocols was of a lower resolution, which will require development to improve the standard of data available for other species. Time constraints and weather conditions meant that lamprey specific surveys were not carried out, although habitat survey found few suitable locations.

7.2. Habitat surveys

The data collected in the habitat survey successfully identified the distribution of habitats that are essential to the recruitment of salmonid fish. This information also provided supporting information for the interpretation of electrofishing data and may have further use in establishing an improved network of fish sampling sites and further develop an understanding of factors limiting potential productivity. This information may also be used to develop the catchment management phase of the River Basin Planning process on the Isle of Mull and fishery management plans for individual fisheries. The habitat survey also indicate a relatively limited potential for juvenile lamprey habitat in many catchments, but lamprey specific protocol may be required to improve survey effectiveness.

7.3. Future work

Establishing baseline information and subsequent repeat sampling of fish populations is an important element upon which to understand the current status of the fish and fishery resource. Repeat sampling over a number of generations (3-5 years per generation) will provide a better understanding of changes in populations over time, and inform response of fish populations to management initiatives.

The results of this survey indicate that more regular monitoring of fish populations and further investigation into the factors affecting in the Bunessan catchment may be required to better inform management of land and water resources if the fragile salmon population is to be conserved in the longer term.

Future consultation and joint working with centres of expertise will provide useful information to further assess the habitat data and implications for restoration of morphology, river

processes and habitat functionality that are likely to benefit fish populations and wider biodiversity. This may be more of an immediate priority on the Ba catchment if good ecological status is to be attained in future RBP cycles.

Additional information on wild spawning (redd counts) and stocking activity will be important to establish better understanding of the use of habitat by salmonids and inform policy on the stocking of hatchery reared fish. Analysis of the genetic samples collected in 2010 will also be required to inform the conservation of diversity within the salmon population.

There are also opportunity to better inform the management of aquaculture and interaction between wild and farm fish through the work on sea lice dispersal modelling undertaken previously in Loch Torridon and currently being undertaken in Loch Linnhe. Depending on the results of the Linnhe work it may be appropriate to develop a model to cover the rest of the management area in the near future.

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