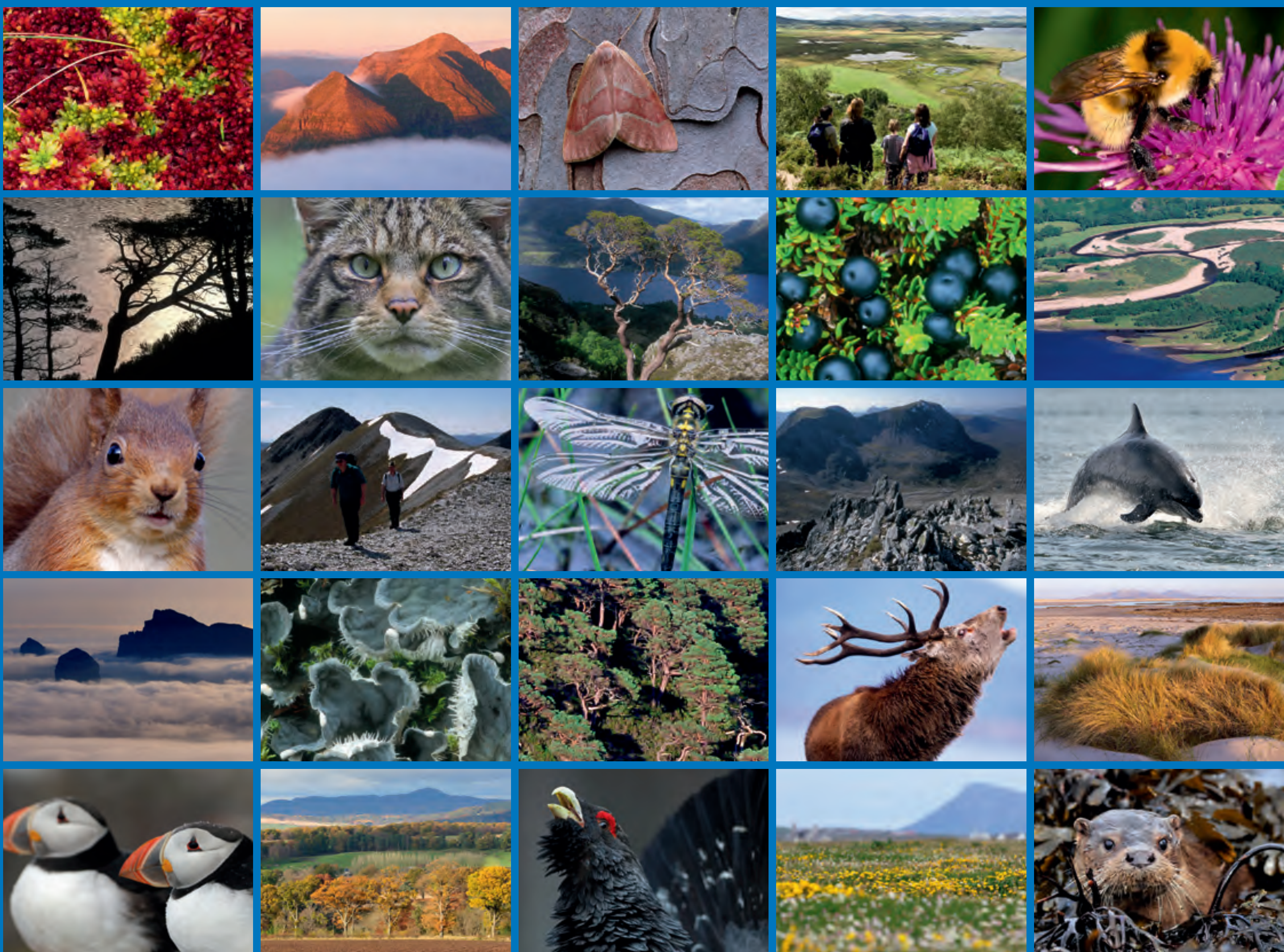
Scottish Natural Heritage
Commissioned Report No. 816

The Scottish Beaver Trial: Fish monitoring 2008-2013, final report



COMMISSIONED REPORT

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For further information on this report please contact:

Professor Colin Bean
Scottish Natural Heritage
Caspian House
Mariner Court
CLYDEBANK
G81 2NR
Telephone: 0141 9514488
E-mail: colin.bean@snh.gov.uk

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COMMISSIONED REPORT

Summary

The Scottish Beaver Trial: Fish monitoring 2008-2013, final report

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Keywords

Beaver; Knapdale; fish populations; electrofishing; redd.

Background

Argyll Fisheries Trust undertook surveys of fish populations and salmonid fish spawning sites as one of a number of monitoring projects investigating the effects of beaver activities on the natural environment during the Scottish Beaver Trial. Following the collection of baseline information in 2008 and 2009 and monitoring in 2010 and 2011, more intensive surveys were undertaken at six locations during 2012 and 2013. These surveys have increased data resolution at sites where beaver activity may interact with fish populations in the future. This report marks the end of a five-year trial period.

Main findings

- In 2012 and 2013, surveys of fish populations and spawning activity were undertaken at two locations where recent beaver activity (tree felling and dam construction) may have affected the passage of fish between habitats. At these locations, the study primarily focused on the migration of adult trout from freshwater lochs into streams used for spawning and the recruitment of juveniles in the nursery habitat. Despite some temporal variation, the surveys in streams in 2012 and 2013 (after dams were constructed) found no significant change to the composition of fish species or their number compared with that found in previous surveys (2008 to 2011).
- Over a similar time period, surveys of fish populations and spawning activity were also undertaken at four locations where no recent beaver activity was known to potentially affect fish habitat. These surveys also found no significant change to the fish species composition or the number of individuals at these sites during the study period.
- The following conclusions were reached: The surveys undertaken during the trial period found no significant change to the species or number of fish found at sites where beaver have recently become active in tree felling and dam building and also at sites where no beaver activity had been recorded. If beaver are retained after the trial period at Knapdale, future monitoring of sites where beaver are active may be necessary to assess potential beaver and fish interaction and inform management.

For further information on this project contact:
Professor Colin Bean, Scottish Natural Heritage, Caspian House, Mariner Court, Clydebank, G81 2NR.
Tel: 0141 9514488 or colin.bean@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. INTRODUCTION

In 2008 the Scottish Government issued a licence to the Scottish Wildlife Trust and the Royal Zoological Society of Scotland to undertake a trial reintroduction of European beaver (*Castor fiber* L.) at Knapdale in Argyll. The five-year trial (2008 to 2013) has been monitored with a series of studies, including fish populations and fisheries which aims to evaluate the response of fish populations at Knapdale within the trial area to the reintroduction of beaver and compare them to with similar habitats where beaver are not present. This report documents the findings of the 2013 survey and compares them with the findings of previous surveys and the activity of beaver at the site.

1.1 European beaver and fish

The European beaver has been reintroduced to a number of countries that were part of its natural range prior to extinction. As a consequence, aspects of their natural behaviour, such as dam building, have raised issues in relation to management of fisheries and water resources (Collen, 1997; Collen & Gibson, 2001, Kemp *et al*., 2010 and Kemp *et al*., 2012). Current published research indicates the potential for European beaver to have impacts on migratory salmonid fish (Atlantic salmon (*Salmo salar* L.) and sea trout (*Salmo trutta* L.) and other native fish varies depending on geographical location, relief and habitat type (Rosell *et al*., 2005, Kemp *et al*., 2010 and Bylak *et al.,* 2014). Loss of habitat penetration by migratory salmonids is described as being insignificant (Parker & Ronning, 2007) or unclear (Halley & Lamberg, 2001) in two Norwegian studies, and as 'serious' by another in Estonia during drought conditions (Tambets *et al*., 2005). Other published studies also recognised potential for changes in fish habitats (Hartman & Tornlov, 2006; Kesminas *et al*., 2013) and fish assemblages due to changes in habitat type related to dam construction (Hagglund & Sjoberg, 1999; Kesminas *et al*., 2013). A review of scientific literature and expert opinion (Kemp *et al*., 2010) found that the impact of beaver on fish populations is spatially and temporally variable, and differs inter- and intraspecifically and that positive impacts were cited more frequently than negative impacts. In regard to the relationship of beaver to migratory salmonid fish, this review determined that the impact on abundance and productivity was considered to be positive, but that the upstream and downstream movement of salmonids was considered to be negative.

1.2 Fish studies at Knapdale

Native fish are a significant ecological and economic resource in Scotland. Therefore, it is important to identify the potential for beaver to affect fish populations at Knapdale during the trial period and provide data to help inform decision makers in regard to the potential for wider reintroduction across Scotland. Following the release of three families of European beavers into three freshwater lochs; Coille-Bharr, Linne and Creagmhor at Knapdale Forest in May 2009, other introductions and movements of individual beavers have also led to Loch Buic being inhabited. Baseline surveys of fish in streams were undertaken by electrofishing in Knapdale streams in 2002, (Kettle-White, 2002). In addition to fish surveys, counts of redds were also undertaken in 2008 (AFT, 2010) and 2009 (Kettle-White *et al*., 2011). A network of stream survey sites were consequently monitored in 2010 (AFT, 2011) and 2011 (AFT, 2012). Higher resolution work at fewer sites in locations where beaver activity may interact with fish populations was undertaken in 2012 (AFT, 2013) and repeated in 2013. Fish population studies were also carried out in standing waters (lochs) within the trial site in 2011 by gill-netting and hydroacoustic survey techniques. These surveys were limited to three lochs where no beaver were present to avoid any potential harm to the beaver population. This report describes the results of the 2013 surveys alongside the summary results of previous surveys in streams and lochs to assess any changes as a result of beaver activity.

2. METHODS

Different survey methods were utilised to assess the fish populations in both lotic (flowing streams) and lentic (standing water) habitats. Given that it was not possible to predetermine where the activities of beaver would become relevant to fish populations at the site, baseline study sites were selected on the basis that they were representative of the favourable habitat available to fish within and outside of the trial area. The methods used for this study were limited to those that would not adversely affect fish populations or the newly introduced beavers and were mainly focused on salmonid fish due to their cultural and economic importance in Scottish fisheries.

2.1 Surveys in stream habitats

Two survey methods were employed to assess the fish populations and their habitat use in the freshwater streams in the Knapdale trial area in 2013; sampling of fish by electrofishing (October) and assessment of spawning activity of salmonid fish (redd counts) by a walk-over survey (December). The electrofishing survey re-sampled four baseline sites previously surveyed (2008-2011) within the trial area and an additional two new sites in close proximity to each of these four sites in 2012 and 2013.

2.1.1 Electrofishing surveys

A standard electrofishing technique was used to temporarily stun fish in the close vicinity of the operator, allowing fish to be retained and processed prior to release. The surveys were designed to investigate the relatively shallow areas of flowing water (< 1m depth) present in the study area at Knapdale which juvenile salmonid and other fish species 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 each survey site in recent years. The technique is also effective for non-salmonid species, although the shallow water habitats sampled may not reflect their preferences which may change on a seasonal basis. Data may therefore be less representative for such species.

Fish surveys were conducted during low-to-medium flow conditions with backpack electric fishing equipment, using smooth direct current between 200 and 350 volts to ensure sampling was effective. The voltage was varied depending on the conductivity, depth and flow of the water at each site; higher voltage was used in larger watercourses and lower voltage used in smaller watercourses to avoid damage to fish while maintaining effective sampling. All electrofishing surveys (see below) were undertaken in accordance with the Scottish Fisheries Co-ordination Centre (SFCC) protocols. An assessment of the in-stream and riparian habitat characteristics was undertaken at each site (SFCC, 2007) to provide information for interpretation of the fish data collected relative to the suitability of the habitat for fish. Measurements of water temperature and conductivity were taken at survey sites using a Hanna Instruments 98129 hand-held tester to identify water chemistry factors potentially affecting the effectiveness of the electrofishing survey method. This is in addition to information which has been recorded through the river habitat surveys undertaken in 2008 (Perfect & Gilvear, 2011) Digital photographs were taken of each site to aid identification during future surveys (Appendix I, AFT 2013).

Fully-quantitative sampling (i.e. each site fished three times over a known area) were utilised to estimate the density of fish present within the site at the time of the survey (Zippen, 1956). Where no fish were sampled during the first or second run, no further sampling was conducted. When data were collected by single-run (semi-quantitative) sampling or where the number of fish sampled was too few, estimates of minimum density of salmonid and other fish species were generated. To enable comparison between sites, minimum estimates of fish density are used throughout the text.

Captured fish were anaesthetised prior to being identified to species level and measured for length. Scale samples were removed from a small 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. Other non-salmonid species were recorded for length only.

Density estimates of fish were calculated separately for fry (young of the year; 0+ years) and parr (juveniles that have spent at least one winter in fresh water; 1+ years, or more; 2+ years, but have not yet been to sea) for trout. Estimates of minimum density for non-salmonids were also 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 categorised according to the SNH classification scheme (Godfrey, 2005) for West of Scotland Region (Table 2.1.1).

Table 2.1.1 Percentile ranges for juvenile trout (minimum no. Fish per 100 m²) for West of Scotland region (Godfrey, 2005)

Min. Percentile	**River Width Class**				
Trout fry (0+)	**<4m**	**4-6m**	**6-9m**	**>9m**	**Class**
No fish					**F**
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**
No fish					**F**
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	

This classification system compares minimum fish abundance sampled at 185 sites in the West of Scotland and places abundance into six percentile ranges according to stream width at the survey site. Minimum estimates of fish density were derived from fully quantitative electrofishing surveys from sites where there were sufficient numbers of fish present to establish three-run catch depletion estimates with 95 % confidence limits, allowing comparison with fish caught at site where fewer fish are present or only a single run was undertaken. Percentile classes A through to E are given for the density of trout found within each percentile range and class F represents an absence of fish as described for the national classification scheme developed for England and Wales (National Rivers Authority, 1994). The 100th percentile represents the highest density found at any one of the 185 sites compared.

A total of 16 survey sites were sampled representing stream habitat utilised by fish for spawning and nursery habitat in three catchments between the 14th and 16th of October 2013 (summarised in Table 2.1.2 and Figures 2.2.2 to 2.2.5). Where beaver dams were present in the Linne catchment, three sites (4, 4a, 4b) were surveyed upstream of two beaver dams (Figures 2.1.1 and 2.2.2) first recorded in November 2009 close to Loch Fidhle. Three other sites (9, 9a, 9b) were also surveyed downstream of Loch Linne where tree felling and construction of two dams by beaver (Figure 2.1.2 and 2.2.2), recorded in August 2010 and May 2012, have subsequently been removed to manage the water level in the loch. Another eleven sites were surveyed at four locations where beaver were present, but no beaver activity (e.g. dam building) had been recorded in stream habitats. In the Coille-Bharr catchment, one site (site 16a, Figure 2.2.3) was surveyed in an afferent stream, flowing into Loch Coille-Bharr, three sites (14, 14a and 14b, Figure 2.2.3) in an efferent stream flowing from Loch Barnluasgan into Loch Coille-Bharr and three sites (sites, 17, 17a, 17b, Figure 2.2.4) in the efferent stream flowing out of Loch Coille-Bharr into the sea (but is not accessible to anadromous fish due to a waterfall obstacle further downstream). Three sites (24, 24a and 25, Figure 2.2.5) were surveyed in the efferent stream flowing out of Loch Buic in the Creagmhor catchment.

Table 2.1.2 Electrofishing survey sites summary (2013)

Site Code	Sub-catchment	Location relative to beaver dam	Easting	Northing	Average width (m)	Water conductivity (μS cm^{-1})
4	L. Fidhle inflow	Upstream	179526	690498	0.9	102
4a		Upstream	179721	690685	0.7	102
4b		Upstream	179760	690741	1.4	102
9	L. Linne outflow	Downstream	179306	690461	2.6	93
9a		Downstream	179213	690371	2.0	93
9b		Downstream	179209	690354	2.4	93
14	L. Coille-Bharr inflow	None	178896	690940	1.4	152
14a		None	178859	690868	1.3	152
14b		None	178925	690951	1.4	152
16a	Un-named inflow	None	178531	690631	2.5	164
17	Un-named outflow	None	177900	689865	2.9	138
17a		None	177343	689810	3.6	138
17b		None	177823	689785	2.5	138
24	L. Creagmhor outflow	None	179702	689146	1.1	116
24a		None	179061	689113	1.4	116
25		None	179062	689241	2.3	143

Figure 2.1.1 Beaver dam on Loch Fidhle inflow stream (downstream of sites 4, 4a and 4b)

Tree felling by beaver adjacent to the Loch Fidhle inflow stream, close to the loch, was first recorded in the 2010 redd count survey and subsequently two dams were found in the 2011 Survey. The dams consisted of sticks and branches harvested from felled trees which were arranged both horizontally and vertically across the stream and packed with mud. The distance between the water surface above and below the larger of the two dams (Figure 2.1.1) was 0.7 m high. The stream had begun to divert a flow of water around the left side of the dam (looking downstream) where the difference in height between the bank top and the water surface was 0.5 m.

At the outflow of Loch Linne, mature trees had been felled along approximately 30 m of the stream (Figure 2.1.2), mainly from the right bank (looking downstream). The 2009 redd count survey found that the trees had not been used to make a dam complete dam structure but adjacent riparian land was flooded indicating a slight rise in loch level. However, the building of a dam structure by beaver has been discouraged by the trial managers (by removing woody debris) with the aim of maintaining the loch level at the existing height to protect the Special Area of Conservation (SAC) status of the site.

Figure 2.1.2 Beaver-felled trees on Loch Linne outflow (upstream of sites 9, 9a and 9b)

2.1.2 Redd count surveys

In December 2013 a walkover redd count survey was undertaken for stream habitats in three catchments (Loch Linne, Loch Coille-Bharr and Lochan Buic) where electrofishing surveys had been undertaken in October. The aim of the survey was to monitor the use of habitat utilised for recruitment by brown trout and provide background information for interpretation of electrofishing survey data. The survey technique was founded on the basic elements of the SFCC habitat survey protocols and undertaken by walking upstream during low and clear flow conditions. Redds were identified as a depression (pit) in the stream bed lying at the head of a slightly raised area of excavated material (tail) on the downstream side of the pit (Figure 2.2.1).

The location of active spawning sites (six figure grid references identified by hand-held GPS) and the number and relative size of redds observed were recorded. Information on site characteristics at each site was also recorded; stream width, in-stream situation of redds and other features. The size of the female fish making the redd is a major factor influencing the size of the redd, therefore the length of the depression (pit) of the redd was estimated and categorised; small (less than 0.5 m), large or a composite of a number of redds (more than 0.5 m). The location and area of habitat surveyed are given in Table 2.2.1 and the location survey areas within the Loch Linne, Loch Coille-Bharr and Lochan Buic catchments is provided in Figures 2.2.2-5.

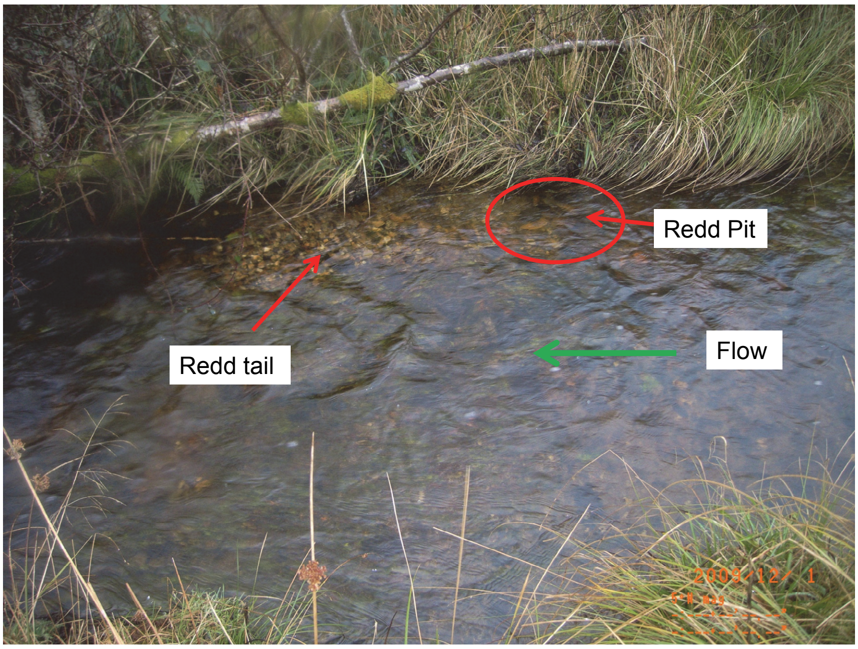


Figure 2.2.1 Typical redd feature at a spawning site

Table 2.2.1 Redd count survey site description in relation to the location of beaver dams

Sub catchment	Location in relation to beaver dams	E-fish survey sites	Survey Length (m)	Avg. Width (m)	Survey area (m²)
L. Fidhle inflow	Upstream	4, 4a, 4b	473	1.0	473
L. Linne outflow	Downstream	9, 9a, 9b	374	2.3	860
L. Barnluasgan outflow	None	14, 14a, 14b	349	1.4	489
L. Coille-Bharr inflow	None	16a	22	2.5	55
L. Coille-Bharr outflow	None	17, 17a, 17b	270	3.0	810
L. Creagmhor / Buic outflow	None	24, 24a, 25	280	1.6	448
	Total		**1,768**		**3,135**

The redd count undertaken on the Loch Fidhle inflow stream was conducted between Loch Fidhle and the track culvert over a length of 473 m which included a 20 m length of habitat downstream of the beaver dams (which was not suitable as spawning habitat) and the remaining habitat upstream of the dams where patches of spawning habitat were present. This habitat is available to spawning fish from Loch Fidhle but is separated from Loch Losgunn by a series of waterfalls. The 374 m length of habitat surveyed at the outflow of Loch Linne included habitat that was not suitable for spawning (where trees had been felled by beaver) and habitat further downstream where spawning habitat was present. There are significant obstacles to fish passage (sea trout) upstream from the sea, but there are no such obstacles to spawning fish migrating downstream from Loch Linne.

There are no beaver dams on the other survey reaches; a 349 m length of the stream habitat surveyed for redds between Loch Barnluasgan and Loch Coille-Bharr. This reach of stream is accessible to fish from both loch habitats and patches of spawning habitat are present throughout. The spawning habitat in the inflow to Loch Coille-Bharr is limited to a 22 m length of stream by an impassable waterfall and the suitability of the site for spawning may be impaired when the level of the loch is high. The 270 m length of habitat at the outflow of Loch Coille-Bharr is accessible to spawning fish migrating downstream from the loch, but is not accessible to sea-run trout due to an impassable waterfall at the downstream end of the survey site. Unlike the patches of spawning habitat available to fish in the outflow of Loch Coille-Bharr, there is limited availability of suitable spawning sites for fish migrating downstream in the 280 m length of stream surveyed at the outflow of Loch Buic.

2.2 Surveys in loch habitats

Monitoring of lacustrine freshwater fish in Scotland is based on two techniques: gill netting and quantitative hydroacoustics which are combined, where appropriate, to reduce the netting effort required to assess the status of fish populations. This study followed the survey protocol developed for Arctic charr (*Salvelinus alpinus* L.) and coregonid fish species (Bean 2003 a,b).

2.2.1 Gill net surveys

Gill netting is the most commonly employed technique for sampling freshwater fish in standing waters. This study utilised 'NORDIC' multi-mesh gill nets in accordance with the current CEN standard (CEN 2013a) where each net consists of 12 different mesh sizes ranging between 5 to 55 mm (bar mesh size) measured from knot to knot. The mesh sizes are arranged in a geometric series (Table 2.2.2).

Table 2.2.2 Mesh-size distribution (knot to knot) in the Nordic multi-mesh gill nets (after Appelberg 2000)

Mesh number	Mesh size (mm)
1	43
2	19.5
3	6.25
4	10
5	55
6	8
7	12.5
8	24
9	15.5
10	5
11	35
12	29

Two types of net were utilised to sample benthic and pelagic habitat (where there was sufficient depth). Each benthic gill net is constructed from homogeneous, uncoloured nylon and measured 30 m in length and 1.5 m in height. Each mesh panel is 2.5 m long and the hanging ratio is 0.5 for all mesh sizes. Pelagic gill nets are deeper than their benthic counterparts and extend to a depth of 6 m. Each net was fished for two periods; once in daylight and once in the subsequent night.

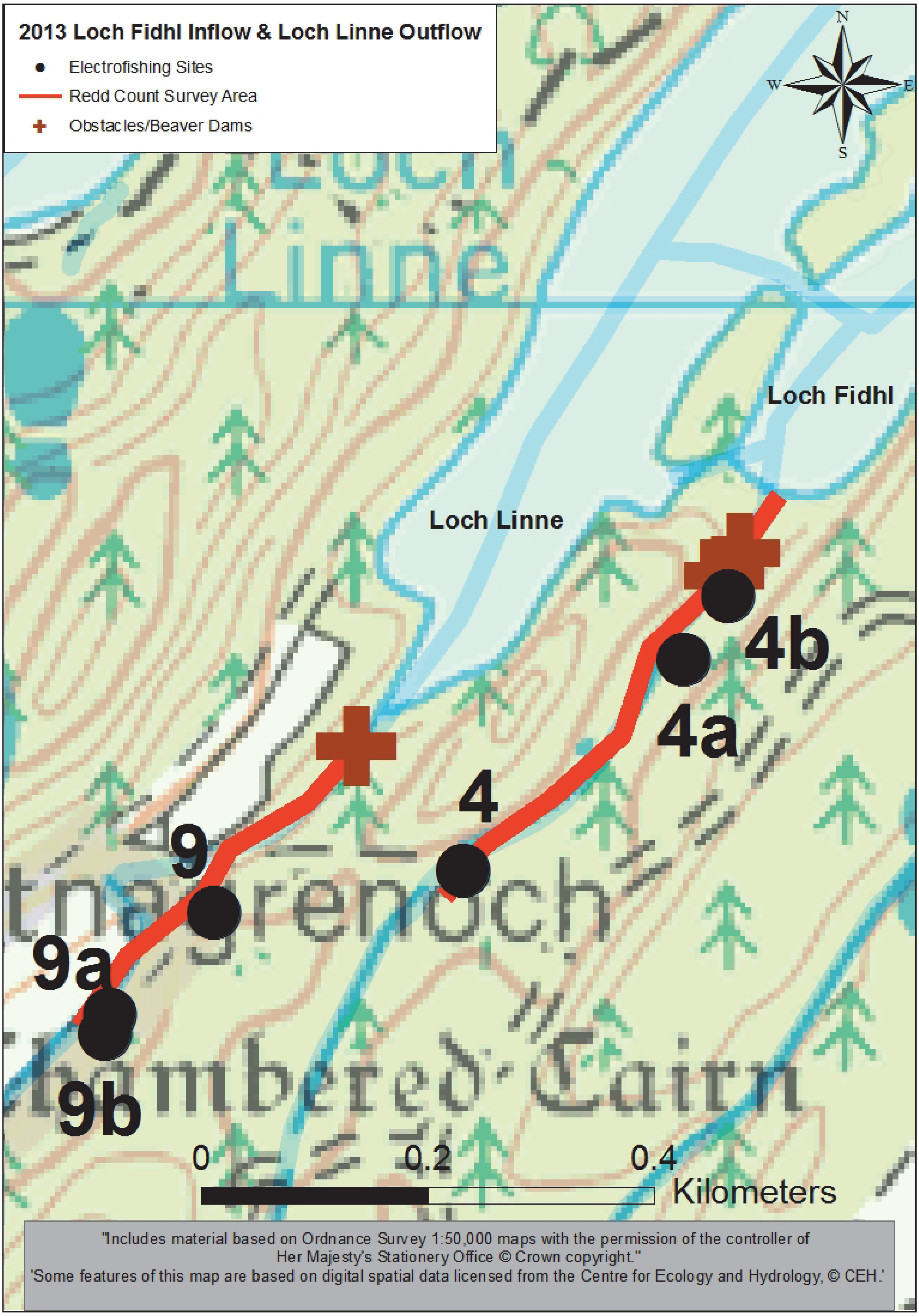


Figure 2.2.2 Location of electrofishing and redd count surveys where beaver dams are present

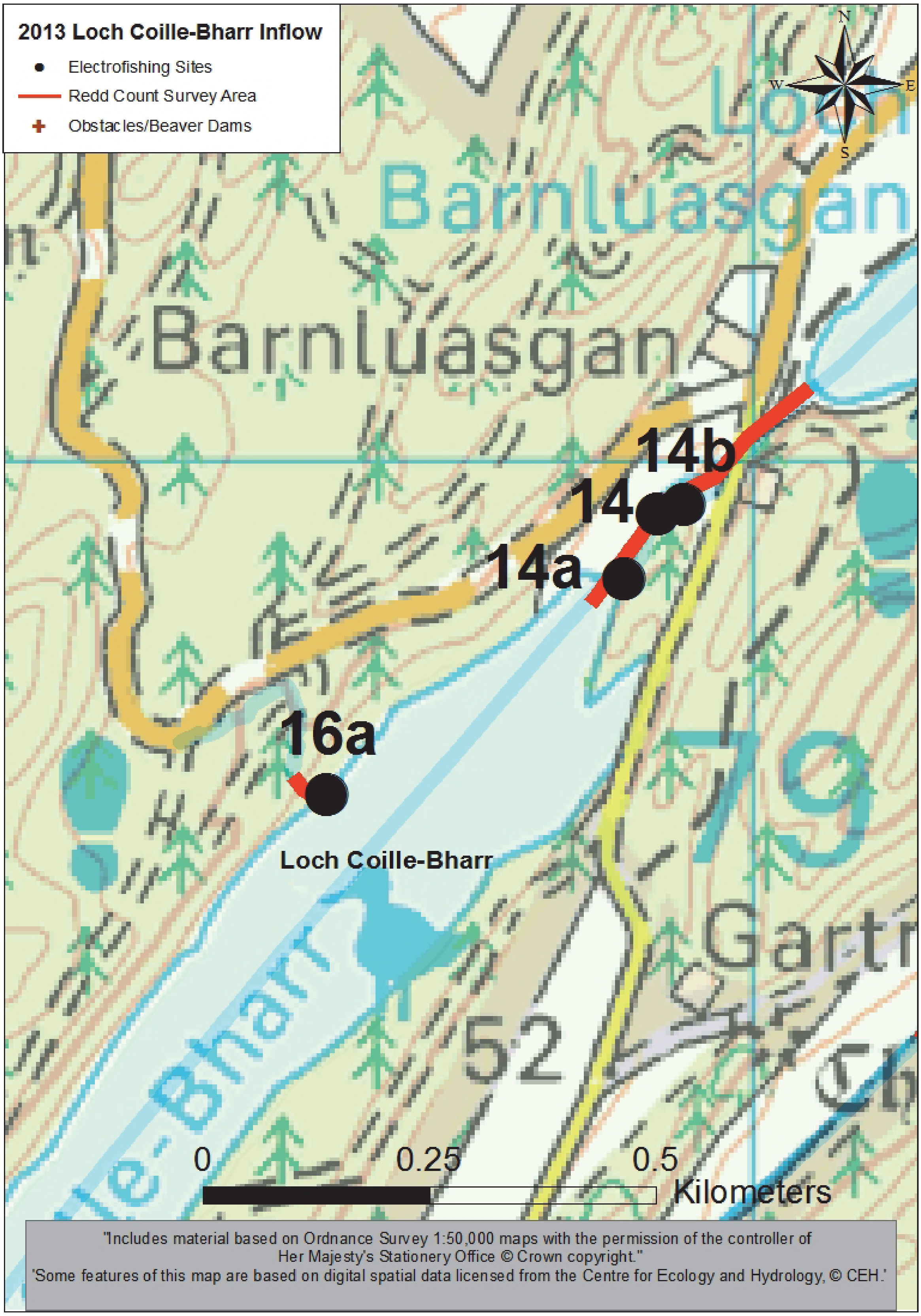


Figure 2.2.3 Location of electrofishing and redd count surveys at inflow streams to Loch Coille-Bharr

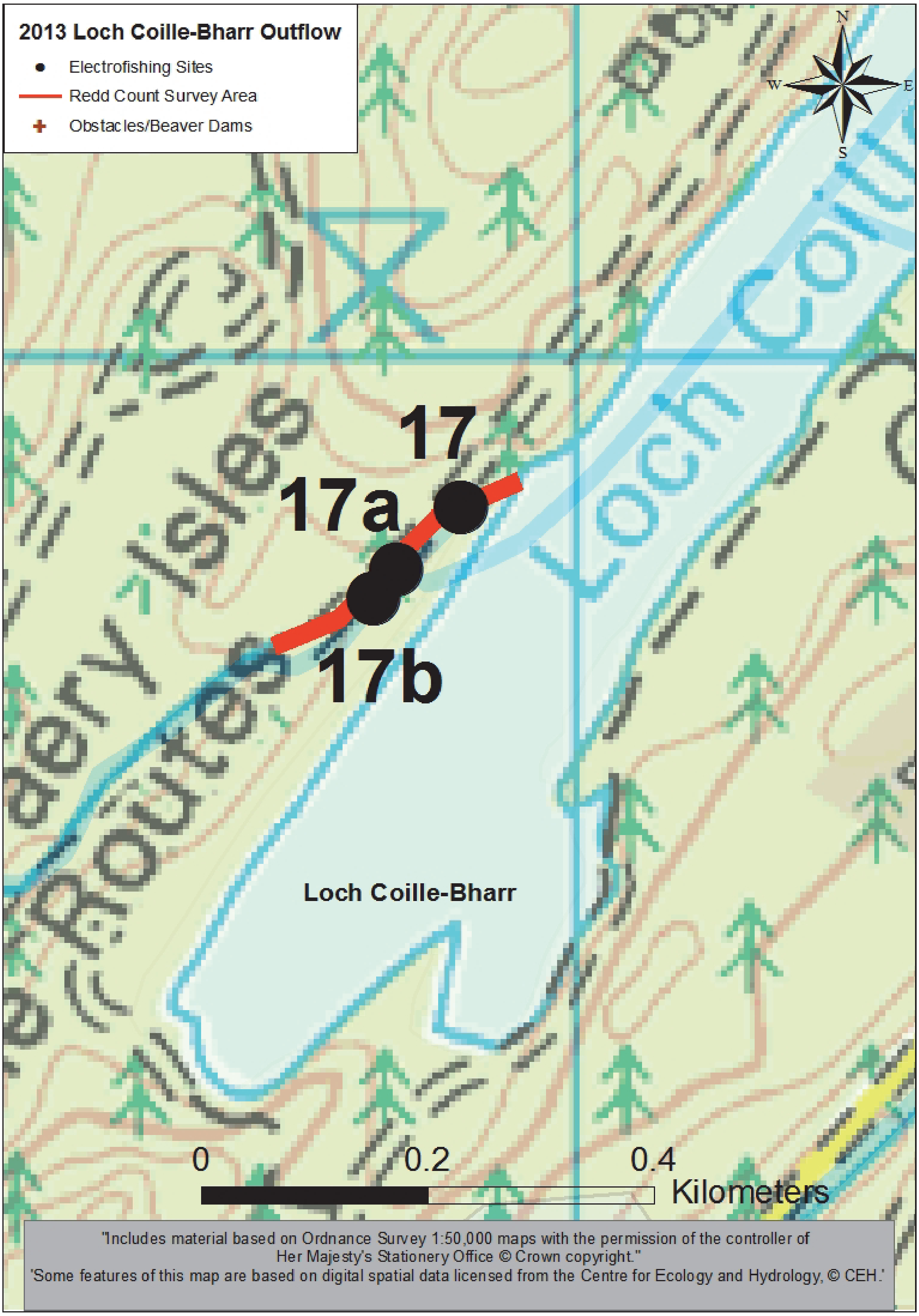


Figure 2.2.4 Location of electrofishing and redd count surveys at the outflow of Loch Coille-Bharr

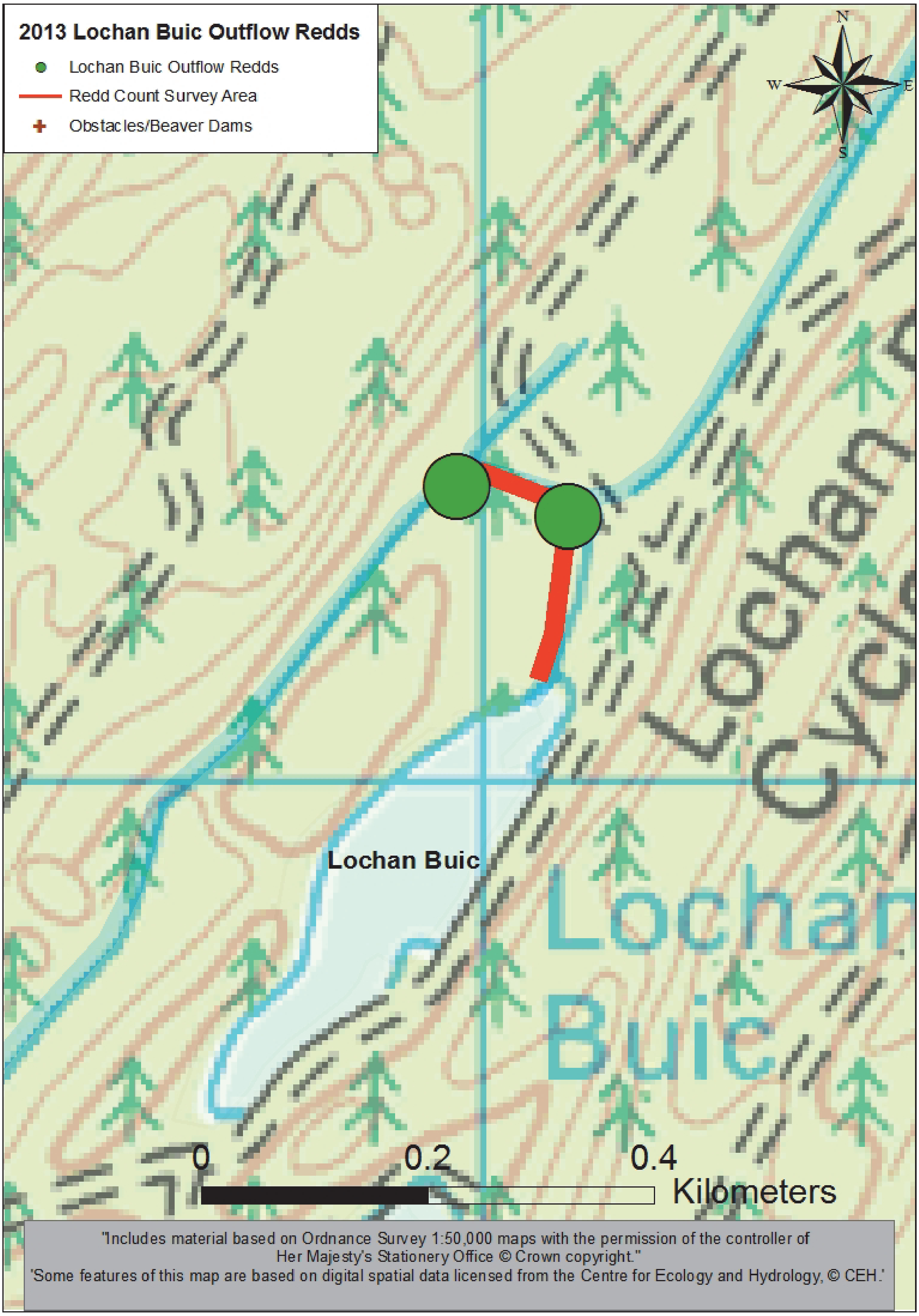


Figure 2.2.5 Location of electrofishing and redd count surveys at the outflow of Lochan Buic

Three lochs were surveyed between the 14th and 16th of September 2011 with two benthic gill nets in Loch Losgunn and Loch McKay and an additional pelagic net in Loch Barnluasgan where there was sufficient depth of water (over 6 m) (Table 2.2.3).

Table 2.2.3 Gill net survey locations

Loch	Net	Easting	Northing	Orientation	Standard net type
Barnluasgan	A	179083	691098	West to east	1.5 m Benthic
	B	179380	691422	West to east	1.5 m Benthic
	C	179296	691286	North to south	6 m Pelagic
Losgunn	A	179150	689844	North to south	1.5 m Benthic
	B	179094	686796	North to south	1.5 m Benthic
McKay	A	179799	688577	West to east	1.5 m Benthic
	B	179868	688657	North to south	1.5 m Benthic

Fish captured by gill nets were identified to species level, the fork length (mm) and weight (g) measured. Where possible, the sex of fish was recorded and a number of scales were taken for ageing.

2.2.2 Hydroacoustic surveys

The use of hydroacoustic methods for the assessment and monitoring of lake fish populations has increased markedly throughout Europe and North America over the last two decades. When used in conjunction with Global Positioning Systems and analysis software, hydroacoustics offer a rapid and cost-effective means of obtaining information of lake fish abundance, demographics and geographical distribution (Winfield *et al.*, 2009).

Hydroacoustic surveys were carried out on the three lochs (Barnluasgan, Losgunn and McKay) during September when fish are likely to actively forage in pelagic areas and under-yearling fish have had the opportunity to attain a full summer growth. This increases the likelihood of being able to discriminate between smaller fish and other components of the pelagic zone are substantially increased. Each loch was surveyed twice, firstly in daylight hours and again during the hours of darkness.

The hydroacoustic survey used during the survey was a split beam system which has been calibrated for use in fresh water, and is compliant with CEN standards (CEN 2013b). The transceiver used was a SIMRAD EK6 which was multiplexed to run both vertical and horizontal split beam transducers (ES120-7C) simultaneously at a frequency of 120 kHz. Target strength and echo density data produced by the hydroacoustic system was analysed using Sonar5-Pro (version 5.9.8 Lindem Data Aquisition, post-processing software package).

Hydroacoustic data were converted to fish lengths using the target-strength (TS) –fish length (F) relationship described by Love (1971), where TS = (19.1 log L) – (0.9 log F) – 62.0 (TS is the recorded target strength (-dB); and L is total fish length (mm)). The aim of the survey was to estimate the total number of fish in each loch by summing the data obtained for each fish size category (classifying fish targets into either small, medium or large length categories) within each transect and calculating an overall geometric mean for each size class. Fish densities were then reported as the number of individuals (of each size class) per hectare in the form of geometric means with 95% confidence limits.

3. RESULTS

3.1 Surveys of stream habitats

The results of stream-based surveys in each catchment are presented below separately for salmonid and non-salmonid fish species.

3.1.1 Electrofishing survey results for salmonid fish in 2013

Brown trout were found in all of the 16 electrofishing surveys conducted in October 2013 and similarly to previous surveys, no salmon were caught. Trout fry (young of the year) were found at all sites with the exception of site 24a. Trout parr (fish older than one year) were found at 10 sites. Estimates of the density of trout found are given as the number of fish per 100 m² of wetted stream bed (Table 3.1.1). The classification of fry density (Figure 3.1.1) and parr density (Figure 3.1.2) and length frequency (Table 3.1.2) are also given below.

Table 3.1.1 Electrofishing survey results for brown trout (no. of fish per 100 m²) 2013

Site No.	Location of site in relation to beaver dams	Trout fry				Trout parr			
		Min. Est.	Zippen Est.	95 % C.L (+/-)	Class	Min. Est.	Zippen Est.	95 % C.L (+/-)	Class
4	Upstream	15.3			**D**	0			**F**
4a	Upstream	21.0			**D**	0			**F**
4b	Upstream	12.2			**D**	6.1			**C**
9	Downstream	22.7	25.1	1.21	**C**	0			**F**
9a	Downstream	51.6	59.3	3.97	**B**	6.7			**C**
9b	Downstream	21.4			**D**	10.7			**B**
14	None	9.5			**E**	0			**F**
14a	None	11.9			**D**	0			**F**
14b	None	17.7	21.6	3.1	**D**	0			**F**
16a	None	27.4			**D**	0			**F**
17	None	17.4	29.0	14.5	**D**	3.4			**E**
17a	None	24.5	30.1	3.8	**C**	7.6	9.5	2.3	**B**
17b	None	38.4	51.9	2.7	**B**	4.8			**D**
24	None	3.3			**E**	0			**F**
24a	None	0			**F**	0			**F**
25	None	15.8			**D**	19.7			**A**

Where found, minimum estimates of trout fry density ranged from 3.3 (site 24) to 51.6 (site 9a) fry per 100 m² of stream sampled. The densities of trout fry were classified as being relatively low (classes D and E) at most sites; all three sites in the Loch Fidhle inflow (sites 4, 4a and 4b), Loch Linne outflow (site 9b), Coille-Bharr inflow (sites 14, 14a and 14b), Loch Coille-Bharr inflow (site 16a), Loch Coille-Bharr outflow (site 9) and Lochan Buic outflow (sites 24 and 25). More moderate densities (class C) of fry were found at the Loch Linne outflow (site 9) and Loch Coille-Bharr outflow (site 17a). Higher densities (class B) were found at the Loch Linne outflow (site 9a) and Loch Coille-Bharr outflow (site 17b).

No trout parr (class F) were found at sites 4, 4a, 9, 14, 14a, 14b, 16a, 24 and 24a at the time of survey. Where found, minimum estimates of parr density ranged from 3.4 to 19.7 parr per 100 m² of stream sampled. Relatively low classification of density (classes D and E) were found at two sites (17 & 17b). More moderate densities (Class C) were also found at two sites (4b and 9a) in the Linne catchment. A higher classification of parr density (class B) was found at two other sites (9b and 17a) and the highest classification (class A) was found at one site in the Creagmhor catchment (site 25).

The mean length of the 155 trout fry sampled ranged from 56 mm (site 4) to 78 mm (site 4b upstream of the beaver dam). A total of 27 one-year-old trout parr were sampled at seven sites with the mean length ranging from 98 mm (site 17) to 122 mm (sites 4b and 9a). Four older parr were found at two sites on the outflow of Loch Linne (sites 9a and 9b) and two sites on the outflow of Loch Coille-Bharr (sites 17a and 17b) with mean lengths ranging from 134 to 162 mm.

Table 3.1.2 Frequency and length (mm) of brown trout at different ages (yrs) 2013

Site No.	**Location of site in relation to beaver dams**	**Trout fry**			**Trout parr (1+ years)**			**Trout parr (2++ years)**	
		No.	Mean	Range	No.	Mean	Range	No.	Mean
4	Upstream	4	56	51-66	0			0	
4a	Upstream	6	71	63-80	0			0	
4b	Upstream	4	78	70-85	2	122	118-126	0	
9	Downstream	21	65	52-83	0			0	
9a	Downstream	23	64	51-77	2	122	108-123	1	136
9b	Downstream	10	65	58-77	4	109	104-120	1	162
14	None	6	68	61-83	0			0	
14a	None	6	71	62-78	0			0	
14b	None	11	64	51-83	0			0	
16a	None	5	63	55-78	0			0	
17	None	10	69	63-75	2	98	87-110	0	
17a	None	16	66	43-77	5	103	93-122	1	137
17b	None	24	62	44-87	2	109	100-118	1	134
24	None	1	75		0			0	
24a	None	0			0			0	
25	None	8	67	58-77	10	109	90-127	0	
Total. / Avg.		**155**	**67**		**27**	**110**		**4**	**142**

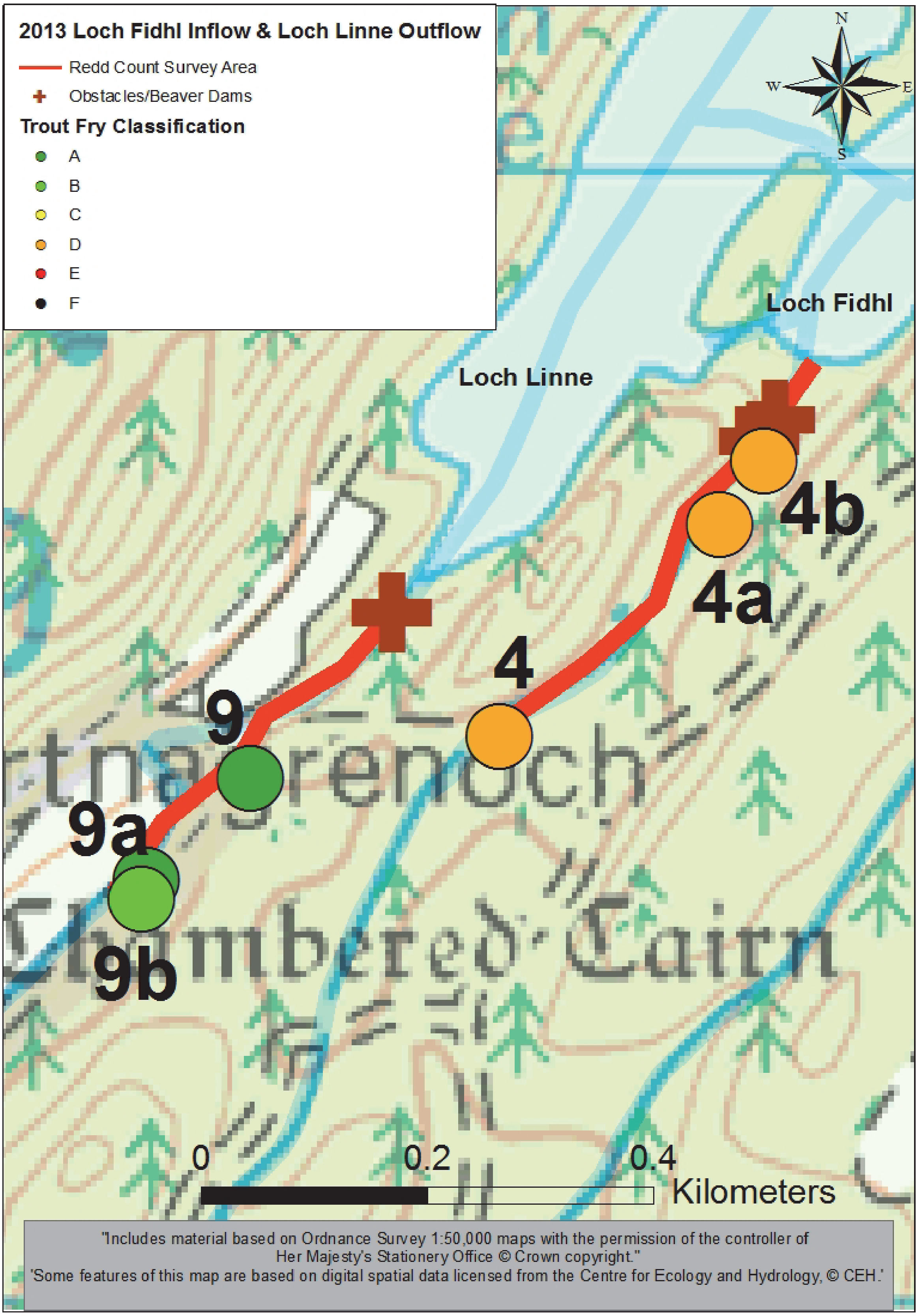


Figure 3.1.1 Classification of trout fry density where beaver dams were found (2013)

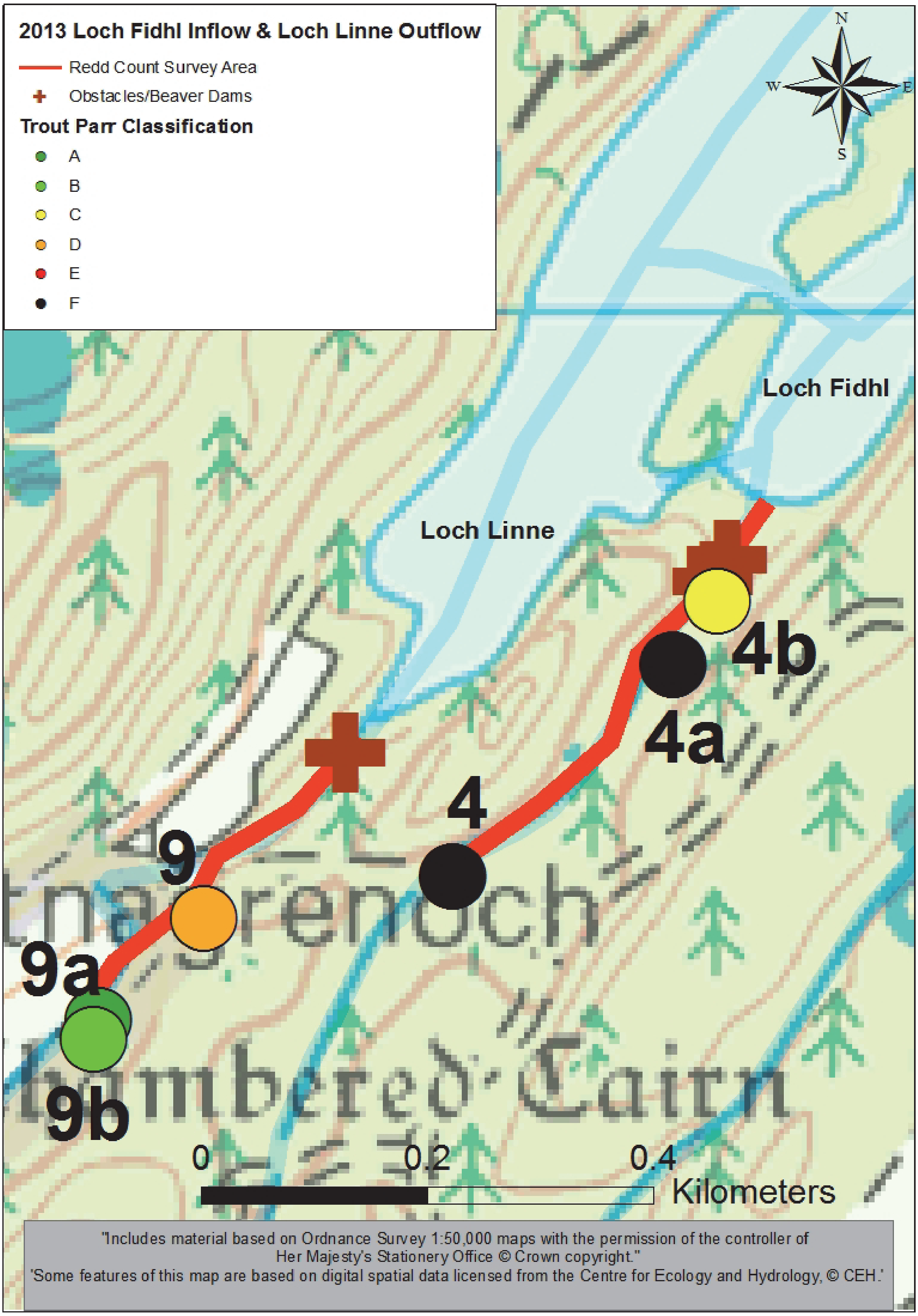


Figure 3.1.2 Classification of trout parr density where beaver dams were found (2013)

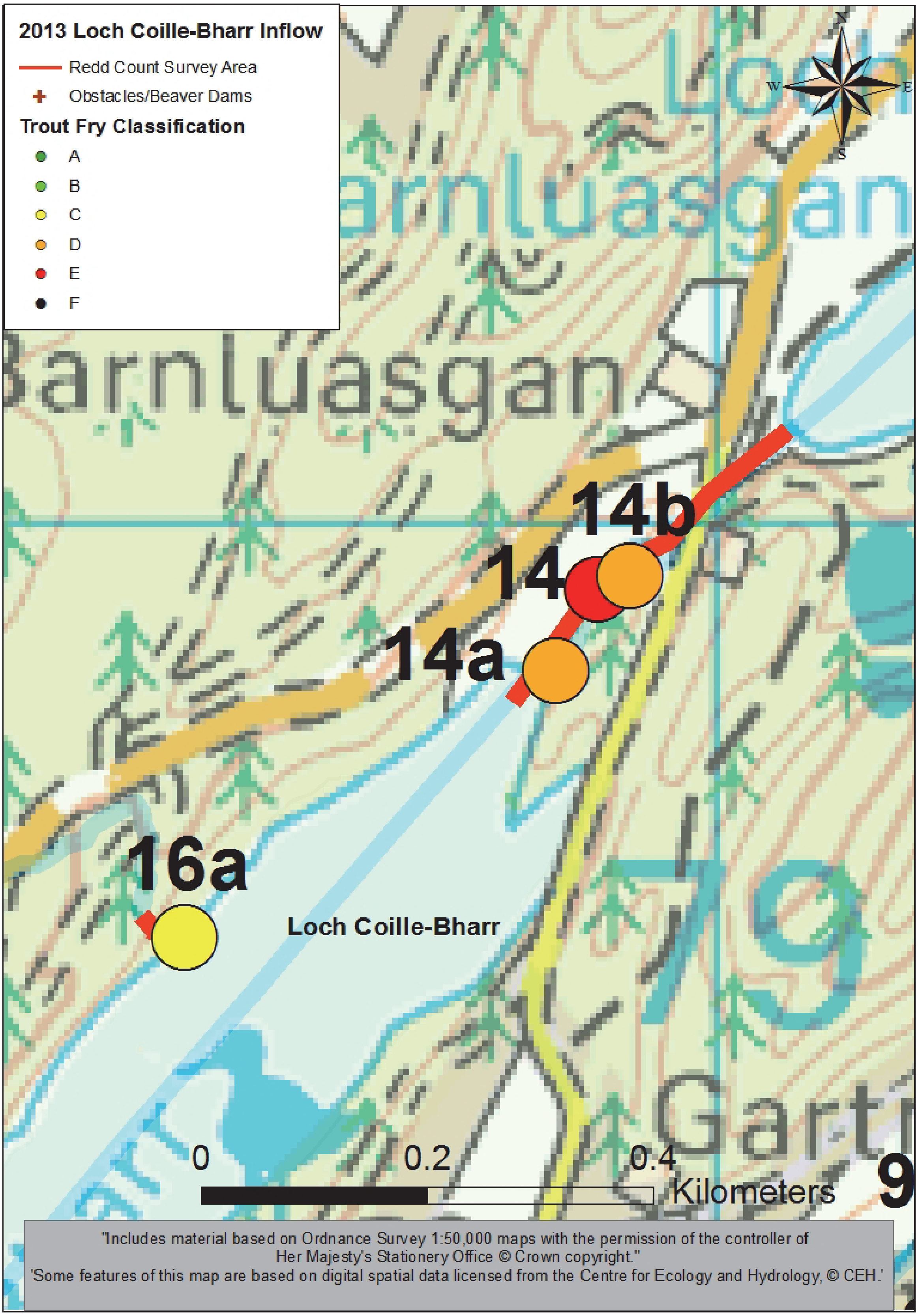


Figure 3.1.3 Classification of trout fry density where no beaver dams were found in the streams flowing into Loch Coille-Bharr (2013)

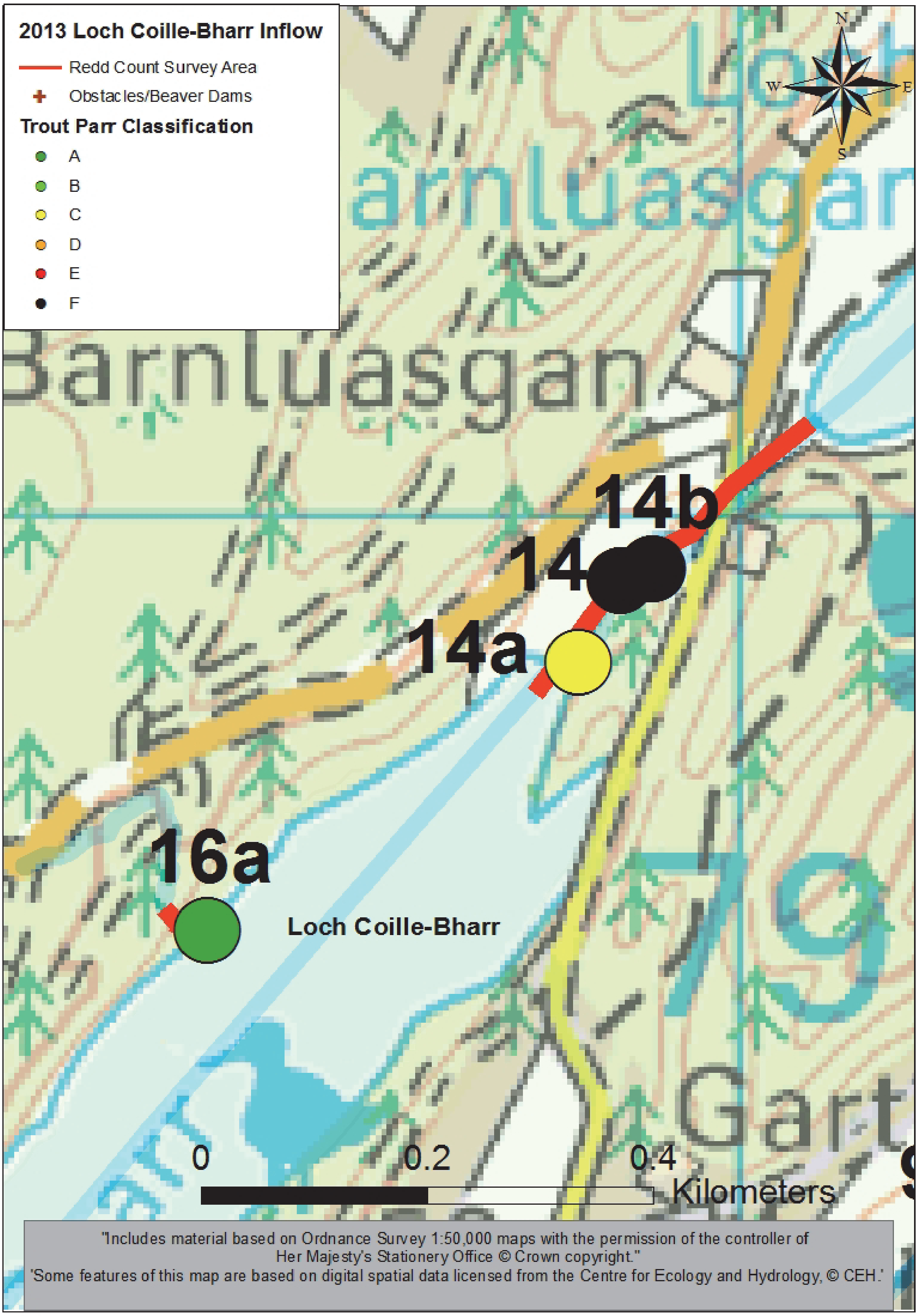


Figure 3.1.4 Classification of trout parr density where no beaver dams were found in the streams flowing into Loch Coille-Bharr (2013)

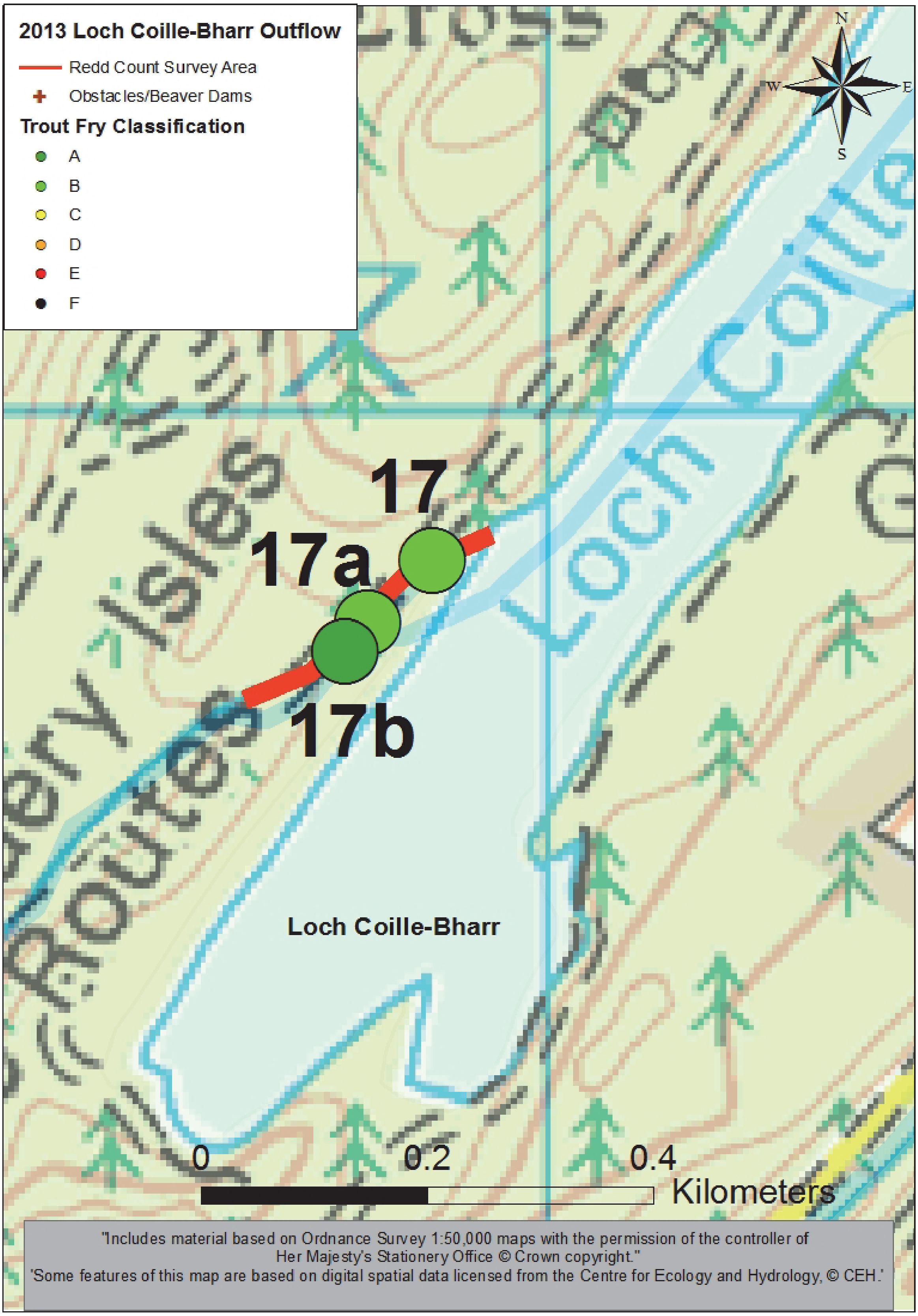


Figure 3.1.5 Classification of trout fry density where no beaver dams were found in the outflow stream of Loch Coille-Bharr (2013)

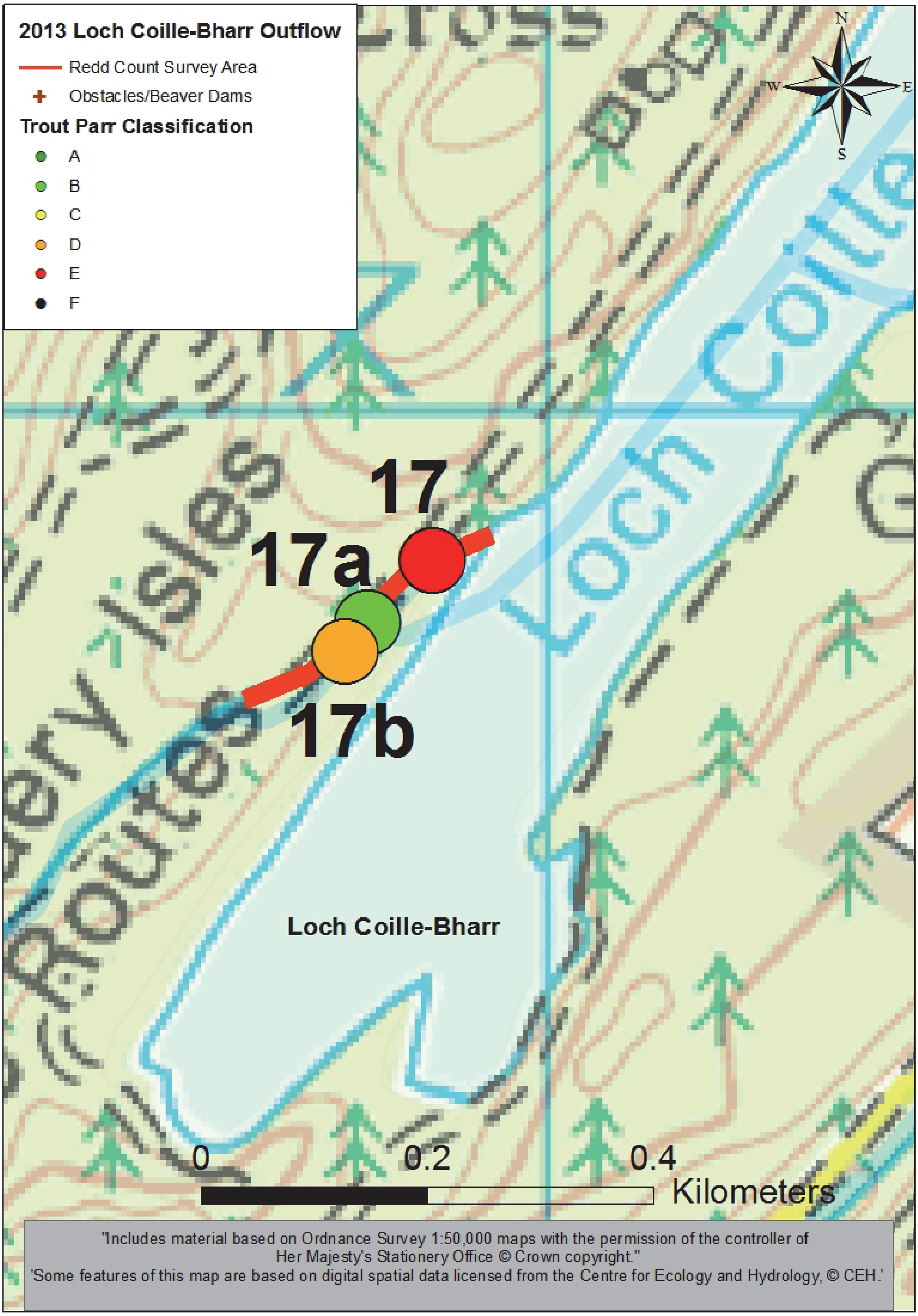


Figure 3.1.6 Classification of trout parr density where no beaver dams were found in the outflow stream of Loch Coille-Bharr (2013)

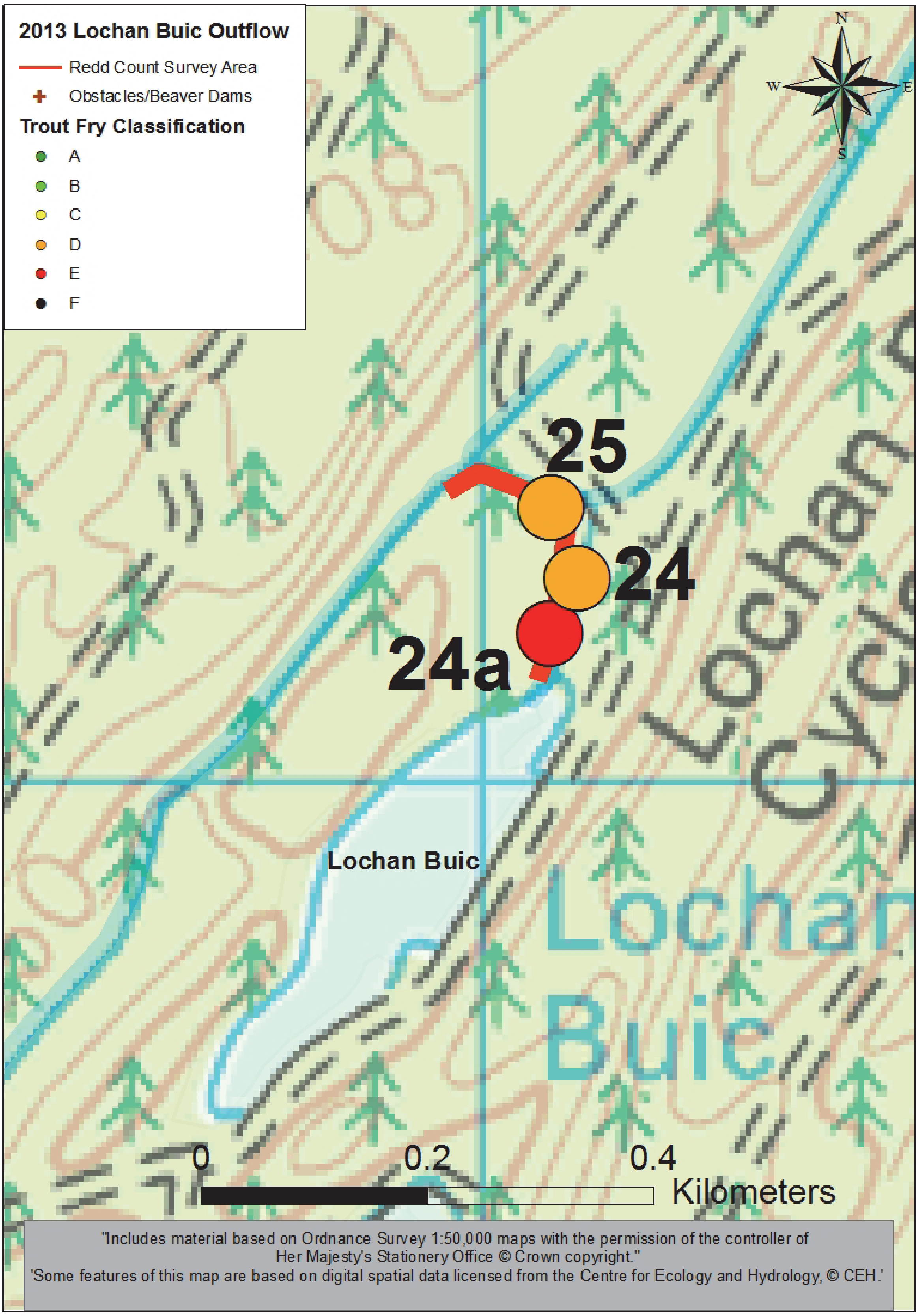


Figure 3.1.7 Classification of trout fry density where no beaver dams were found in the outflow stream of Lochan Buic (2013)

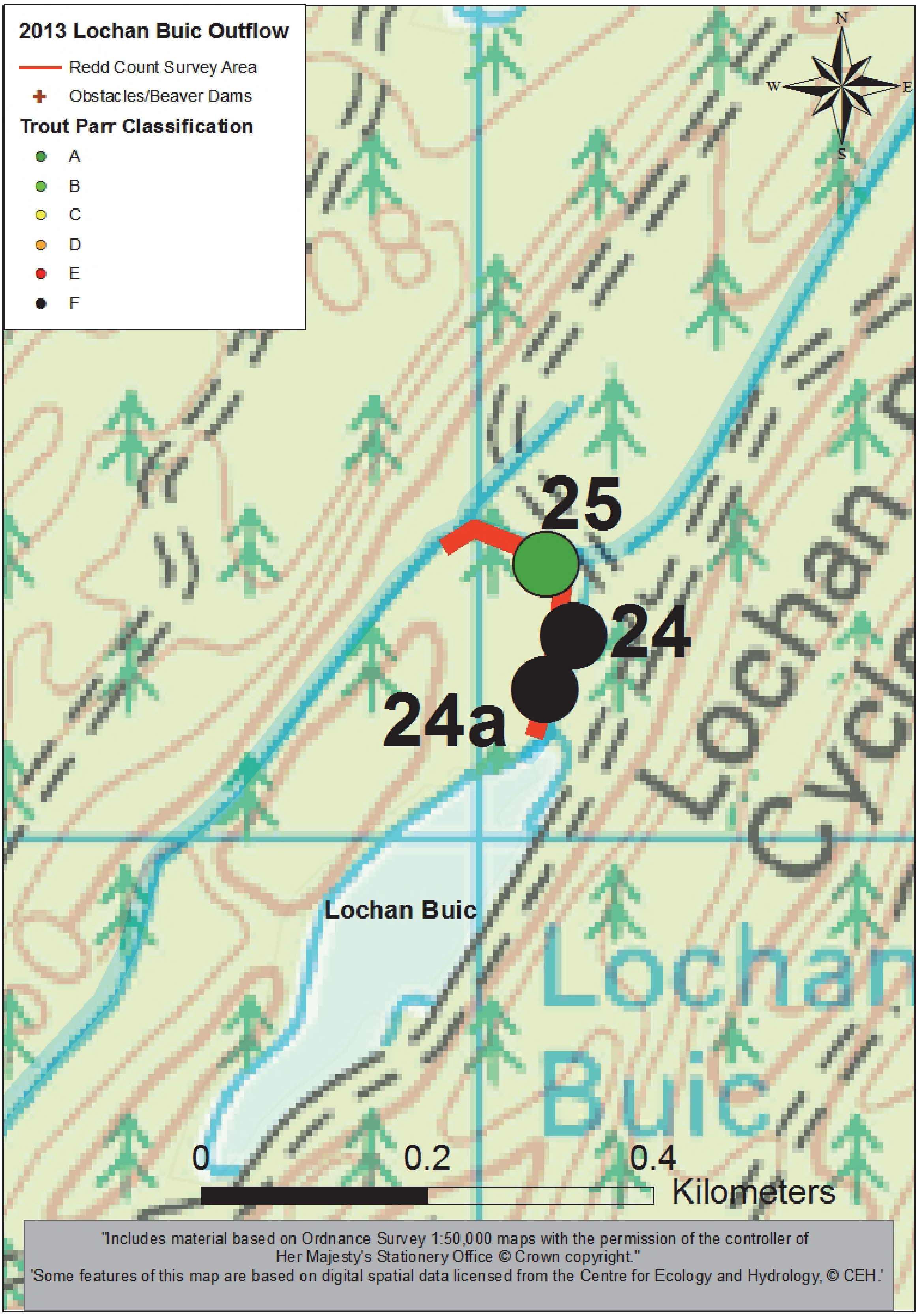


Figure 3.1.8 Classification of trout parr density where no beaver dams were found in the outflow stream of Lochan Buic (2013)

3.1.1.1 Comparison of trout densities (2008-13)

The minimum densities and classification of trout fry and parr found in 2013 are compared with those found in five previous surveys at three sites (4, 9 and 14b), four previous surveys at four sites (14, 17, 24 and 25), two previous surveys at another (16a) and one previous survey (2012) at eight sites (4a, 4b, 9a, 9b, 14a, 17a, 17b and 24a) in each catchment below.

3.1.1.1.1 Comparison of trout densities (2008-13) where beaver dams are present

The fish surveys undertaken at the six sites surveyed in the Linne catchment, where beaver are active, generally found higher densities (Table 3.1.3) and classification (Table 3.1.4) of trout fry (Figure 3.1.3) and parr, (Figure 3.1.4) where present, in the stream flowing out of Loch Linne (sites 9, 9a and 9b) compared with those found in the stream flowing into Loch Fidhle (sites 4, 4a and 4b).

Table 3.1.3 Minimum densities of trout (2008-2013) where beaver dams are present

Site no.	Trout fry						Trout Parr					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
4*	17.9	23.8	0.0	3.8	24.2	19.4	0.0	0.0	0.0	0.0	0.0	0.0
4a*					10.5	21.1					0.0	0.0
4b*					9.2	12.3					0.0	6.1
9**	54.8	52.6	72.5	47.0	118.1	32.7	2.7	1.4	0.0	2.1	4.3	0.0
9a**					85.4	58.4					18.0	6.7
9b**					47.2	20.5					10.3	10.3

**Sites upstream of beaver dams, **Sites downstream of beaver dams*

Table 3.1.4 Classification of trout density (2008 to 2013) where beaver dams are present

Site No.	FRY						PARR					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
4*	D	D	F	E	D	D	F	F	F	F	F	F
4a*					D	D					F	F
4b*					E	D					F	C
9**	B	B	B	B	A	C	E	E	F	E	D	F
9a**					A	B					A	C
9b**					B	D					B	B

**Sites upstream of beaver dams, **Sites downstream of beaver dams*

Six surveys undertaken upstream of the two beaver dams built on the inflow to Loch Fidhle (at site 4) found that fry density was lower in 2010 (when no fry were found) and 2011 (3.8 per 100 m²), shortly after the dam had been built by beavers, compared with densities of fry found before the construction of the dams in 2008 (17.9) and 2009 (23.8). Higher densities were found in 2012 (24.2) and 2013 (19.4) which suggests a recovery in spawning effort after the dams were built. However, a higher density (62.1) was found at site 4 in June 2011 suggesting fry may have emigrated from the site prior to the autumn survey. Fry densities found at the two adjacent sites further upstream of the beaver dams were similar at site 4b in 2012 (9.2) and 2013 (12.3) but more variable at site 4a when a lower density was found in

2012 (10.5) compared with 2013 (21.1). Trout parr were found only in one survey (6.1 parr per 100 m²) in 2013 at the site closest to the beaver dam (site 4b).

Six surveys undertaken downstream of the cleared beaver dams built on the outflow to Loch Linne (at site 9) found that trout fry density varied most between 2012 (118.1 fry per 100 m²) and 2013 (32.7) but remained relatively abundant between 2008 and 2011 (range 47.0 to 72.5 fry per 100 m²). Trout parr were found in four of the six surveys at this site when densities were relatively low (range 1.4 to 4.3). Fry densities found at the two adjacent sites were higher at both sites (9a and 9b) in 2012 (85.4 and 47.2 respectively) compared with 2013 (58.4 and 20.5 respectively). Trout parr were also found to be higher in 2012 (18.0) compared with 2013 (6.7) at site 9a and the same (10.3) in both 2012 and 2013 at site 9b.

3.1.1.1.2 Comparison of trout densities (2008-13) where no beaver dams are present

The fish surveys at the seven sites surveyed in the Coille-Bharr catchment generally found higher densities (Table 3.1.5) and classification (Table 3.1.6) of trout in the stream flowing out of Loch Coille-Bharr (sites 17, 17a and 17b) compared to those found in the stream flowing into Loch Coille-Bharr from Loch Barnluasgan (sites 14, 14a and 14b) and similar to that found in another inflowing stream close to Loch Coille-Bharr (site 16a).

Table 3.1.5 Minimum densities of trout (2008-2013) where no beaver dams are present

Site no.	Fry						Parr					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
14		21.7	14.0	0.0	7.8	9.3	0.0	0.0	0.0	0.0	0.0	0.0
14a					10.7	12.8					6.4	0.0
14b	4.5	22.6	6.9	3.1	12.4	20.2	0.9	1.1	1.7	6.2	0.0	0.0
16a				15.0	38.5	27.5				0.0	16.5	0.0
17		10.1	25.3	12.2	65.6	16.7		4.0	2.8	10.0	3.3	1.1
17a					61.3	29.1					7.7	9.2
17b					92.8	51.2					4.8	4.8
24		0.0	12.5	6.2	5.4	3.4		8.9	16.1	0.0	0.0	0.0
24a					2.2	0.0					0.0	0.0
25		0.0	13.0	5.0	13.8	15.8		0.0	8.7	2.5	21.7	19.8

Table 3.1.6 Classification of trout density (2008 to 2013) where no beaver dams are present

Site No.	Fry						Parr					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
14		D	D	F	E	E		F	F	F	F	F
14a					D	D					C	F
14b	E	D	E	E	D	D	E	E	E	C	F	F
16a				D	C	D				F	A	F
17		D	D	D	B	D		D	E	D	E	E
17a					B	C					B	B
17b					A	B					D	D
24		F	D	E	D	E		B	A	F	F	F
24a					E	F					F	F
25		F	D	E	D	D		F	B	E	A	A

Six surveys undertaken at site 14b and the five surveys at site 14 on the inflow to Coille-Bharr found that fry density remained generally low over the study period (range 3.1 to 22.6 and 0 to 21.7 respectively). The two surveys conducted at site 14a found similar densities of fry in 2012 (10.7) and 2013 (12.8). Trout parr were found at low density at site 14b in three surveys between 2008 and 2010 (range 0.9 to 1.7), a more moderate density in 2011 (6.2 parr per 100 m²) but none were found in 2012 or 2013. Parr were only found on one other occasion at site 14a in 2012 also at moderate density (6.4).

Three surveys undertaken in the other inflow stream (site 16a) found more variable densities of fry, where they were relatively low in 2011 (15.0 fry per 100 m²) and 2013 (27.5) and more moderate in 2012 (38.5). Trout parr were found only in 2012 at high density (16.5 parr per 100 m²).

The studies undertaken at site 17 in the outflow stream of Loch Coille-Bharr found relatively low densities of fry in four of the five surveys (range 10.1 to 25.3 fry per 100 m²) and a higher density in 2012 (65.6). Moderate to high densities of fry were found at the two other sites (17a and 17b) where fry densities were higher in 2012 (61.3 and 92.8 fry per 100 m² respectively) compared with those found in 2013 (29.1 and 51.2 respectively). Trout parr were recorded at relatively low densities in five surveys (2009 to 2013) at site 17 (range 1.1 to 10.0), and at site 17b in 2012 and 2013 (4.8 parr per 100 m²). Higher densities of parr were found at site 17a in both 2012 (7.7) and 2013 (9.2).

The fish surveys at the three sites surveyed in the Creagmhor catchment (sites 24, 24a and 25) between 2009 and 2013 found relatively low densities (Table 3.1.5) and classification (Table 3.1.6) of trout fry but parr densities were relatively high compared with other catchments.

Of the five surveys undertaken at site 24, no trout fry were found in 2009 but low densities of fry were found between 2010 and 2013 (range 3.4 to 12.5) and similarly low densities were also found at site 25 over the same period (range 5.0 to 15.8). Fry were also found at low density, only in 2012 at site 24a (2.2 fry per 100 m²). Trout parr were found at relatively high density at site 24 in 2009 (8.9) and 2010 (16.1) but were more varied at site 25 where parr were found at high density in 2010 (8.7), 2012 (21.7) and 2013 (19.8) and low density in 2011 (2.5). No trout parr were found at site 24a in either survey undertaken in 2012 or 2013.

3.1.1.2 Electrofishing survey results for non-salmonid fish

Other than trout, two other native species of fish were sampled at nine sites in 2013 (Table 3.1.7). European eel (*Anguilla anguilla* L.) were found at eight sites (Figure 3.1.9) with minimum densities ranging from 1.6 to 9.0 per 100 m² and three-spine stickleback (*Gasterosteus aculeatus* L.) at six sites (Table 3.1.9), ranging from 1.1 to 2.2 per 100 m². One translocated species (non-native); the European minnow (*Phoxinus phoxinus* (L.)), was also recorded at four locations (Figure 3.1.11) in the Linne and Coille-Bharr catchments, and densities ranged from 1.8 to 8.5 fish per 100 m².

Table 3.1.7 Electrofishing survey results for other species (min. no. of fish per 100 m²) (2008-2013) where beaver dams are present

Site no.	**Eel**						**Three-spine stickleback**						**Minnow**					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
4*	0	0	0	4.8	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0
4a*					0	0					0	0					0	0
4b*					0	0					0	0					0	0
9**	4.0	0	2.8	8.5	11.4	4.3	0	0	0	0	0	0	1.3	0	11.4	47.0	1.4	0
9a**					2.2	9.0					0	0					0	0
9b**					0	0					0	0					10.3	0

**Sites upstream of beaver dams, **Sites downstream of beaver dams*

Table 3.1.8 Electrofishing survey results for other species (min. no. of fish per 100 m²) (2008-2013) where no beaver dams are present

Site no.	**Eel**						**Three-spine stickleback**						**Minnow**					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
14			1.6	0	1.6	0		0	1.6		0	1.6		0	1.6	0	0	0
14a					0	0					2.1	2.1					0	8.5
14b	0	0	3.5	3.1	0	1.6	0	0	1.7	1.6	0	1.6	0	0	0	10.9	0	0
16a					0	5.5					5.5	0					0	0
17		0	0	2.2	2.2	2.2		0	4.2	10.0	0	1.1			7.0	33.4	25.6	3.3
17a					7.7	7.7					1.5	0					0	0
17b					9.6	3.2					1.6	1.6					4.8	0
24		0	0	3.1	0	0		0	0	0	8.9	0		0	0	0	0	1.8
24a					2.2	0					4.5	2.2					0	0
25					2.0	0					0	0					0	0

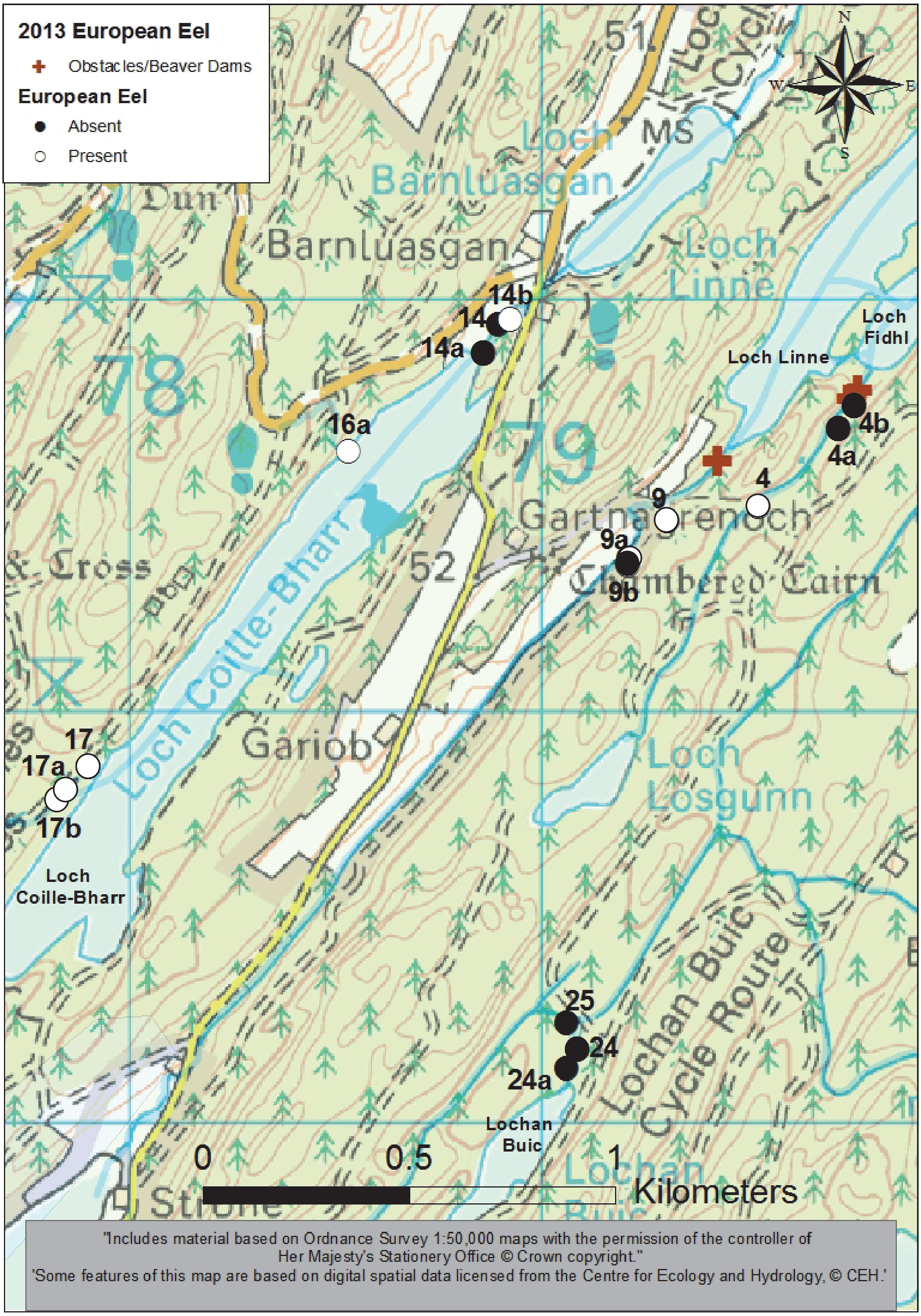


Figure 3.1.9 Distribution of European eel 2013

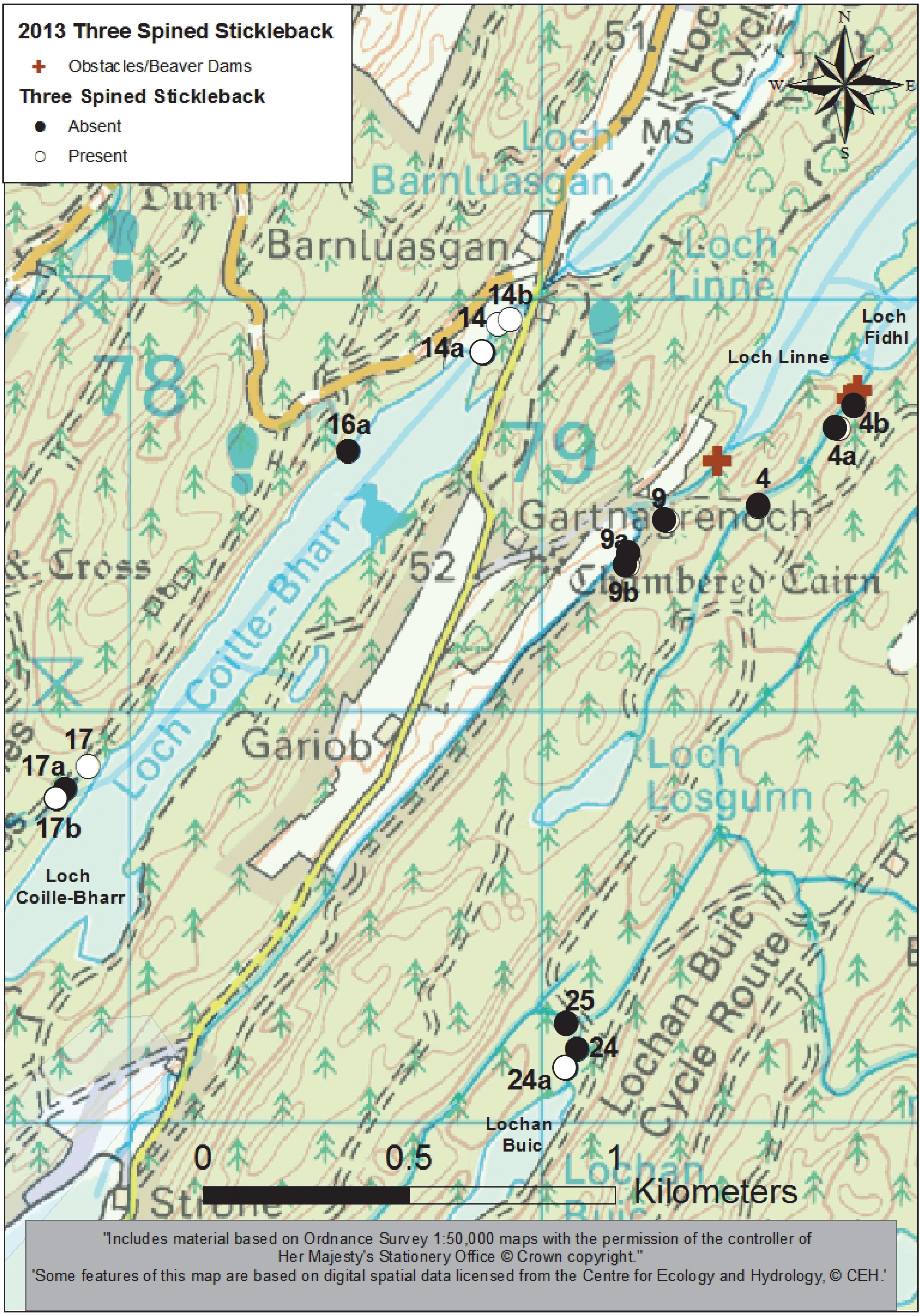


Figure 3.1.10 Distribution of Three-spine stickleback 2013

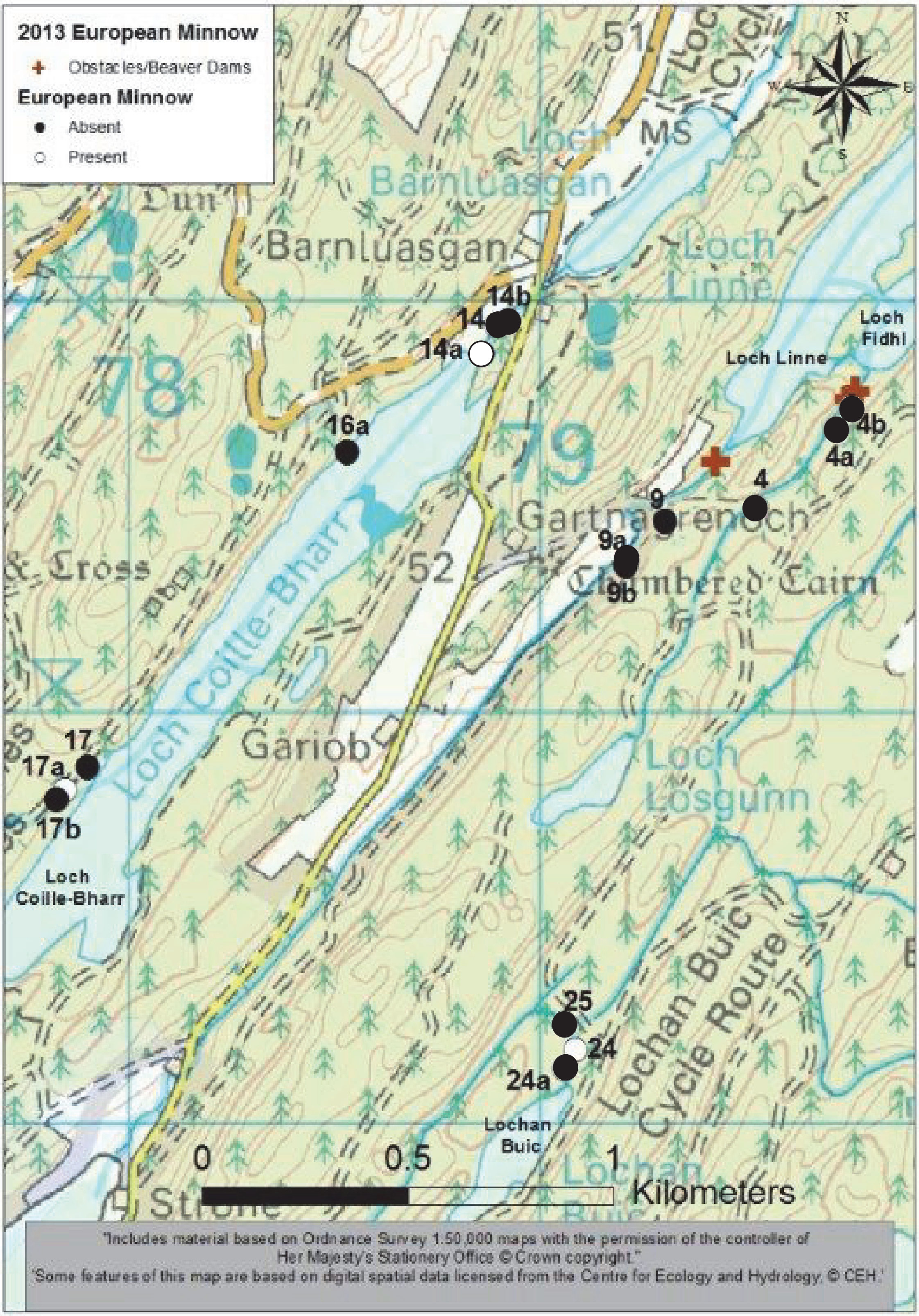


Figure 3.1.11 Distribution of European minnow 2013

3.1.1.3 Habitat at electrofishing survey sites

Relatively detailed information on the habitat found at electrofishing survey sites (as a percentage of the habitat available in the survey site) provide some information which may be used to aid the interpretation of the density of fish found at each sampling location.

3.1.1.3.1 Habitat at electrofishing survey sites where beaver dams are present

On the stream flowing into Loch Fidhle (Table 3.1.9), comparisons of habitat characteristics found at survey sites indicate that fine sediment and glide and pool flow characteristics were a feature common at all three sites. However, compared with other sites, the water was generally deeper, fine sediment and glide and pool flows were more common, while bank cover for fish was less so at site 4b which is situated on the upstream side of the beaver dams.

Table 3.1.9 Summary of habitat variables at survey sites on the Loch Fidhle inflow stream

Site No. (2013)	Depth (% area)			Substrate (% area)			Flow (% area)			Bank cover (% length)	
	< 11 cm	11-30 cm	>30 cm	Fines	Gravel & Pebble	Cobble & Boulder	Run / Riffle	Glide / pool	Torrent	Left	Right
4	20	60	20	45	40	15	40	60	0	90	90
4a	70	30	0	60	40	0	15	85	0	90	90
4b	0	20	80	90	10	0	0	100	0	40	40

On the stream flowing out of Loch Linne (Table 3.1.10), comparisons of habitat characteristics at site 9b with the other sites further downstream, indicate that this site was generally deeper, had a higher proportion of fine sediment and glide and pool flow, but had a higher availability of bank cover for fish than the other two sites surveyed.

Table 3.1.10 Summary of habitat variables at survey sites on the Loch Linne outflow stream

Site No. (2013)	Depth (% area)			Substrate (% area)			Flow (% area)			Bank cover (% length)	
	< 11 cm	11-30 cm	>30 cm	Fines	Gravel & Pebble	Cobble & Boulder	Run / Riffle	Glide / pool	Torrent	Left	Right
9	40	60	0	30	45	25	60	20	20	90	80
9a	20	80	0	30	20	50	60	40	0	70	60
9b	0	0	100	100	0	0	0	100	0	100	100

Site 9a had a higher percentage of deeper water and larger substrate and a lower percentage of glide or pool flow and bank cover for fish when compared with site 9.

3.1.1.3.2 Habitat at electrofishing survey sites where no beaver dams are present

Habitat characteristics at fish survey sites where no beaver dams were found (Table 3.1.11) in 2013 did not differ significantly from those found in previous surveys with the exception of site 16a where the water depth was influenced by the level of water in Loch Coille-Bharr.

Table 3.1.11 Summary of habitat variables at survey sites (percentage of habitat area) where no beaver dams were found (2013)

Site No. (2013)	Depth (% area)			Substrate (% area)			Flow (% area)			Bank cover (% length)	
	< 11 cm	11-30 cm	>30 cm	Fines	Gravel & Pebble	Cobble & Boulder	Run / Riffle	Glide / pool	Torrent	Left	Right
14	40	50	10	45	40	15	30	70	0	80	80
14a	40	60	0	30	70	0	25	75	0	90	90
14b	40	60	0	40	40	20	35	65	0	40	30
16a	0	100	0	0	80	20	20	80	0	90	90
17	30	30	40	50	30	20	40	60	0	80	80
17a	30	40	30	20	40	40	60	40	0	20	20
17b	0	60	40	30	50	20	15	85	0	20	20
24	10	70	20	100	0	0	0	100	0	20	20
24a	30	60	10	100	0	0	0	100	0	5	5
25	100	0	0	100	0	0	0	100	0	5	5
Avg.				**54.4**	**31.3**	**14.4**	**25.0**	**73.8**	**1.3**	**58.1**	**56.3**

At the three sites surveyed in the stream flowing from Loch Barnluasgan into Loch Coille-Bharr (14, 14a and 14b) habitat characteristics were relatively similar with moderate percentage of shallow water, fine substrate and run and riffle flows, but bank cover for fish was lower at site 14b compared with site 14 and 14a. Habitat in the other stream flowing into Loch Coille-Bharr (site 16) was of moderate even depth, had a high percentage of small coarse substrates in pool or glide flow and a relatively high level of bank cover for fish. The habitat found at sites surveyed in the stream flowing out of Loch Coille-Bharr (17, 17a and 17b) all had moderate percentage of deeper water and larger coarse substrates (cobble and boulder) compared with other sites studied. Glide and pool water flow was more common at site 17b and bank cover for fish was more common at site 17 compared with the other two sites. At the three sites surveyed on the Lochan Buic outflow stream (24, 25 and 24b), fine substrates (silt, sand and fine gravel) were found at all sites with glide and pool flow types, but deeper water was more common at site 25 compared with the other two sites. Bank cover for fish was more common at site 24, but was generally lower than that found at most other study sites.

3.1.2 Redd count survey

The results of the redd counts undertaken at the six study sites (2008-2013).are given below in relation to beaver activity and the subsequent numbers of trout fry found in the fish surveys in the following year.

3.1.2.1 Redd counts at sites where beaver dams are present

Redd counts were undertaken at two sites where beaver have built dams. At the Loch Fidhle inflow stream, redd counts were undertaken between 2009 and 2013 and subsequent trout fry densities were available for comparison for three of those years (2010-2012). At the outflow of Loch Linne, redd counts were undertaken between 2008 and 2013 and subsequent trout fry densities were available for comparison for four of those years (2009-2012).

Upstream of where the beaver dams began to be first constructed in 2010 to 2011, the number of large or composite redds found by surveys in the 473 m² of habitat surveyed ranged from none in 2012 to seven in 2009 (Table 3.1.12), while the number of small redds ranged between 11 in 2011 and 25 in 2010. Redd density ranged from 2.5 per 100 m² of habitat in 2011 to 5.5 in 2010 and 2013. The subsequent density of trout fry found in the following year at site 4 ranged from no fry (resulting from the 2009 spawning effort) to 24.2 per 100 m² (resulting from the 2011 spawning effort).

Table 3.1.12 Redd count survey results and subsequent redd and trout fry density (min. no. per 100 m²) 2009-2013 at the Loch Fidhle inflow stream

Redd Count Results					**E-Fish Survey Results (+ 1 year)**	
Year	No. Large	No. Small	Total No.	Redd Density	E-fish site No.	Trout fry density
2009	7	7	14	3.0	4	0.0
2010	1	25	26	5.5	4	3.8
2011	1	11	12	2.5	4	24.2
2012	0	17	17	3.6	4, 4a, 4b	19.4
2013	3	23	26	5.5	4, 4a, 4b	
Mean	2.4	16.6	19.0	4.02		11.85

The number of large or composite redds found by surveys in 860 m² of habitat in the stream flowing out of Loch Linne, ranged from none in 2008, 2011and 2013 to two in 2009 and 2010 (Table 3.1.13). The number of small redds ranged between one in 2012 and 10 in 2010. Redd density ranged from 0.2 per 100 m² of habitat in 2012 to 1.4 in 2010. The subsequent density of trout fry found in the following year at site 9 ranged from 32.7 fry (resulting from the 2012 spawning effort) to 118.1 per 100 m² (resulting from the 2011 spawning effort). The location of spawning sites where beaver dams were found in the Linne catchment is shown in Figure 3.1.12.

Table 3.1.13 Redd count survey results and subsequent trout fry density (min. no. per 100 m²) 2008-2013 at the Loch Linne outflow stream

Redd count survey results					**E-fish survey results (+1 year)**	
Year	No. Large	No. Small	Total No.	Redd Density	E-fish sites	Trout fry density
2008	0	9	9	1.0	9	52.6
2009	2	3	5	0.6	9	72.5
2010	2	10	12	1.4	9	47.0
2011	0	5	5	0.6	9	118.1
2012	1	1	2	0.2	9, 9a, 9b	32.7
2013	0	7	7	0.8	9, 9a, 9b	
Mean	0.8	5.8	6.7	0.78		64.59

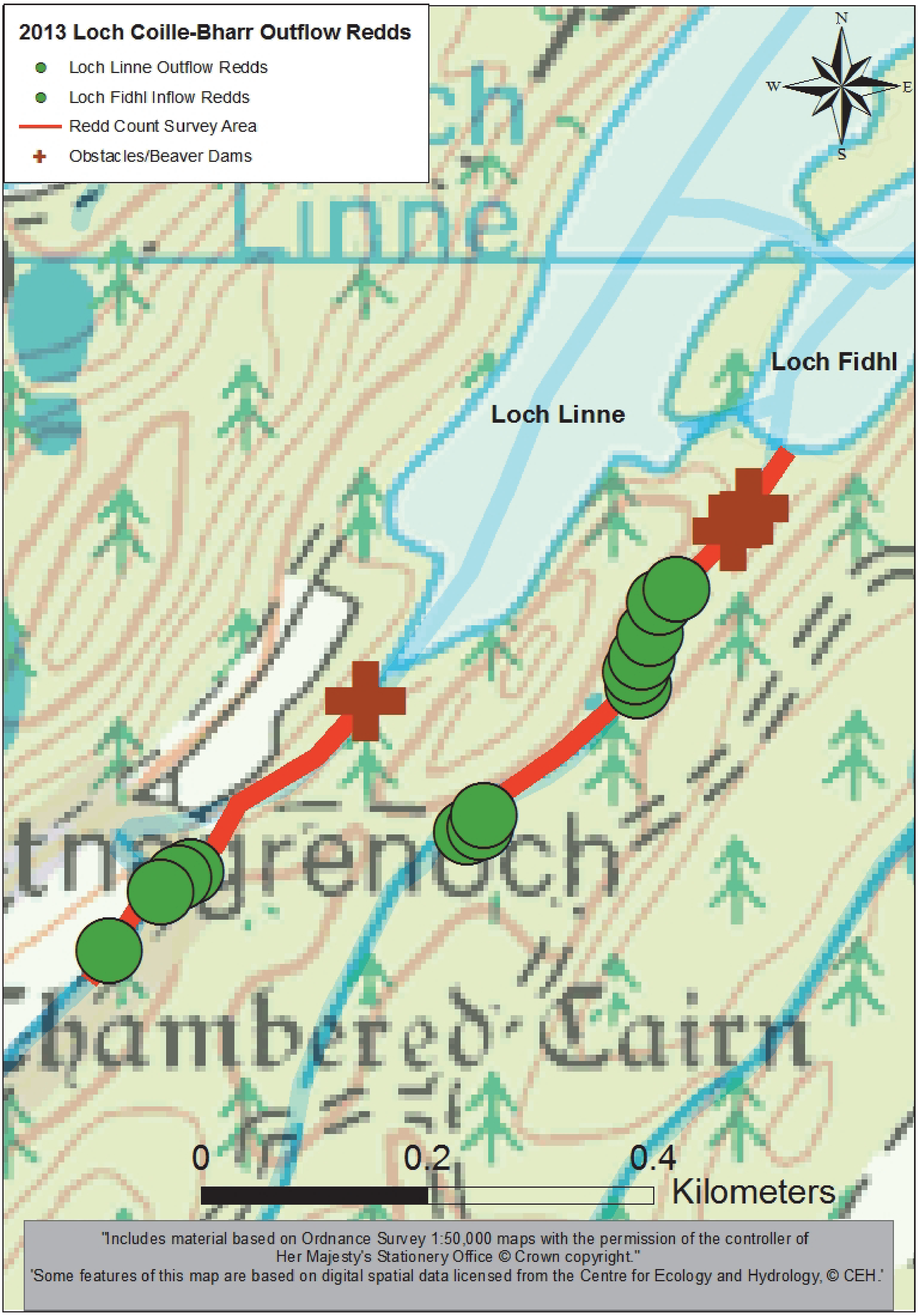


Fig. 3.1.12 Location of spawning sites where beaver dams were found in the Linne catchment (2013)

3.1.2.2 Redd counts at sites where no beaver dams are present

Redd counts were undertaken at four sites where beaver have not built dams. At the Loch Coille-Bharr inflow/Loch Barnluasgan outflow stream, counts were undertaken between 2008 and 2013 and subsequent trout fry densities were available for comparison for five of those years (2008-2012). In the other stream flowing into Loch Coille-Bharr, redd counts were undertaken between 2009 and 2013 and subsequent trout fry densities were available for comparison for three of those years (2010-2012). At the study site on the outflow stream of Loch Coille-Bharr, redd counts were undertaken between 2009 and 2012 and subsequent trout fry densities were available for comparison for four of those years (2009-2012). In the outflow stream of Lochan Buic, redd counts were undertaken between 2012 and 2013 and trout fry density was available only for the cohort spawned in 2012.

3.1.2.2.1 Redd count surveys at the Loch Coille-Bharr inflow stream from Loch Barnluasgan

Where beaver had not built dams in the Loch Coille-Bharr inflow/Loch Barnluasgan outflow stream, the number of large or composite redds found by surveys in the 489 m² of habitat surveyed ranged from none in 2008, 2010, 2012 and 2013 to eight in 2011 (Table 3.1.14), while the number of small redds ranged between 10 redds in 2010 and 66 redds in 2008. Redd density ranged from two redds per 100 m² of habitat in 2010 to 13.5 2008. The subsequent density of trout fry found at site 14 in the following year ranged from 3.1 fry (resulting from the 2011 spawning effort) to 21.7 per 100 m² (resulting from the 2008 spawning effort).

Table 3.1.14 Redd count survey results and subsequent trout fry density (min. no. per 100 m²) 2008-2013 at the Loch Coille-Bharr/Loch Barnluasgan outflow stream

Redd count survey results					**E-fish survey results (+1 year)**	
Year	No. Large	No. Small	Total No.	Redd Density	E-fish sites	Trout fry density
2008	0	66	66	13.5	14, 15	21.7
2009	6	39	45	9.2	14, 16	14.0
2010	0	10	10	2.0	14, 17	7.8
2011	8	22	30	6.1	14, 18	3.1
2012	0	44	44	9.0	14, 14a, 14b	9.3
2013	0	49	49	10.0	14, 14a, 14b	
Mean	2.3	38.3	40.7	8.3		11.2

3.1.2.2.2 Redd count surveys at the Loch Coille-Bharr inflow stream

Where beaver had not built dams in the Loch Coille-Bharr inflow stream, the number of large or composite redds found by surveys in the 52 m² of habitat ranged between none in 2012 and seven in 2009 (Table 3.1.15), while the number of small redds ranged between none in 2009 and eight in 2013. Redd density ranged from 1.9 per 100 m² of habitat in 2012 to 17.4 in 2013. The subsequent density of trout fry found at site 16a in the following year ranged from 15.0 fry (resulting from the 2010 spawning effort) to 38.75 per 100 m² (resulting from the 2011 spawning effort).

Table 3.1.15 Redd count survey results and subsequent trout fry density (min. no. per 100 m²) 2009-2013 at the Loch Coille-Bharr inflow stream

Redd count survey results					**E-fish survey results (+1 year)**	
Year	No. Large	No. Small	Total No. Redds	Redd Density	E-fish sites	Trout fry density
2009	7	0	7	13.5		
2010	3	4	7	13.5	16a	15.0
2011	2	2	4	7.7	16a	38.5
2012	0	1	1	1.9	16a	27.5
2013	1	8	9	17.4		
Mean	6.79	13.00	17.40	34.81		27.00

3.1.2.2.3 Redd count surveys at the Loch Coille-Bharr outflow stream

Where beaver had not built dams in the Loch Coille-Bharr outflow stream, the number of large or composite redds found by surveys of the 810 m² of habitat ranged from none in 2012 to six in 2010 and 2013 (Table 3.1.16), while the number of small redds ranged between five in 2009 and 2011 and 23 redds in 2011. Redd density ranged from one per 100 m² of habitat in 2009 to 3.6 in 2010. The subsequent density of trout fry found at site 17 in the following year ranged from 12.2 fry (resulting from the 2010 spawning effort) to 65.6 per 100 m² (resulting from the 2011 spawning effort). The location of spawning sites where no beaver dams were found in the streams flowing into, or out of, Loch Coille-Bharr in 2013 are shown in Figures 3.1.13 and 3.1.14.

Table 3.1.16 Redd count survey results and subsequent trout fry density (min. no. per 100 m²) 2009-2013 at the Loch Coille-Bharr outflow stream

Redd count survey results					**E-fish survey results (+1 year)**	
Year	No. Large	No. Small	Total No.	Redd Density	E-fish sites	Resulting fry density
2009	3	5	8	1.0	17	25.3
2010	6	23	29	3.6	17	12.2
2011	5	5	10	1.2	17	65.6
2012	0	19	19	2.3	17, 17a, 17b	16.7
2013	6	21	27	3.3	17, 17a, 17b	
Mean	4.0	14.6	18.6	2.30		29.97

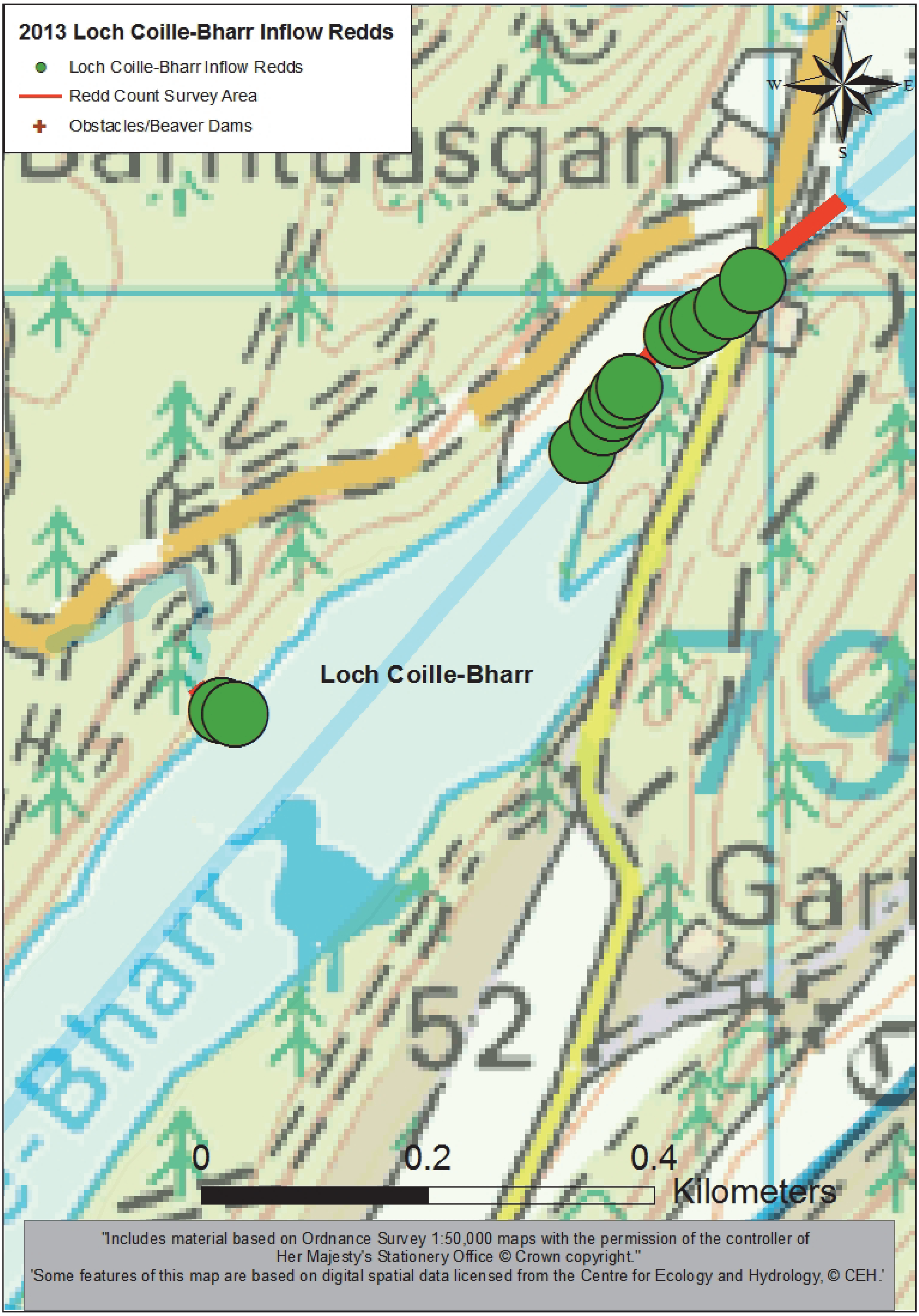


Fig. 3.1.13 Location of spawning sites where no beaver dams were found in the streams flowing into Loch Coille-Bharr (2013)

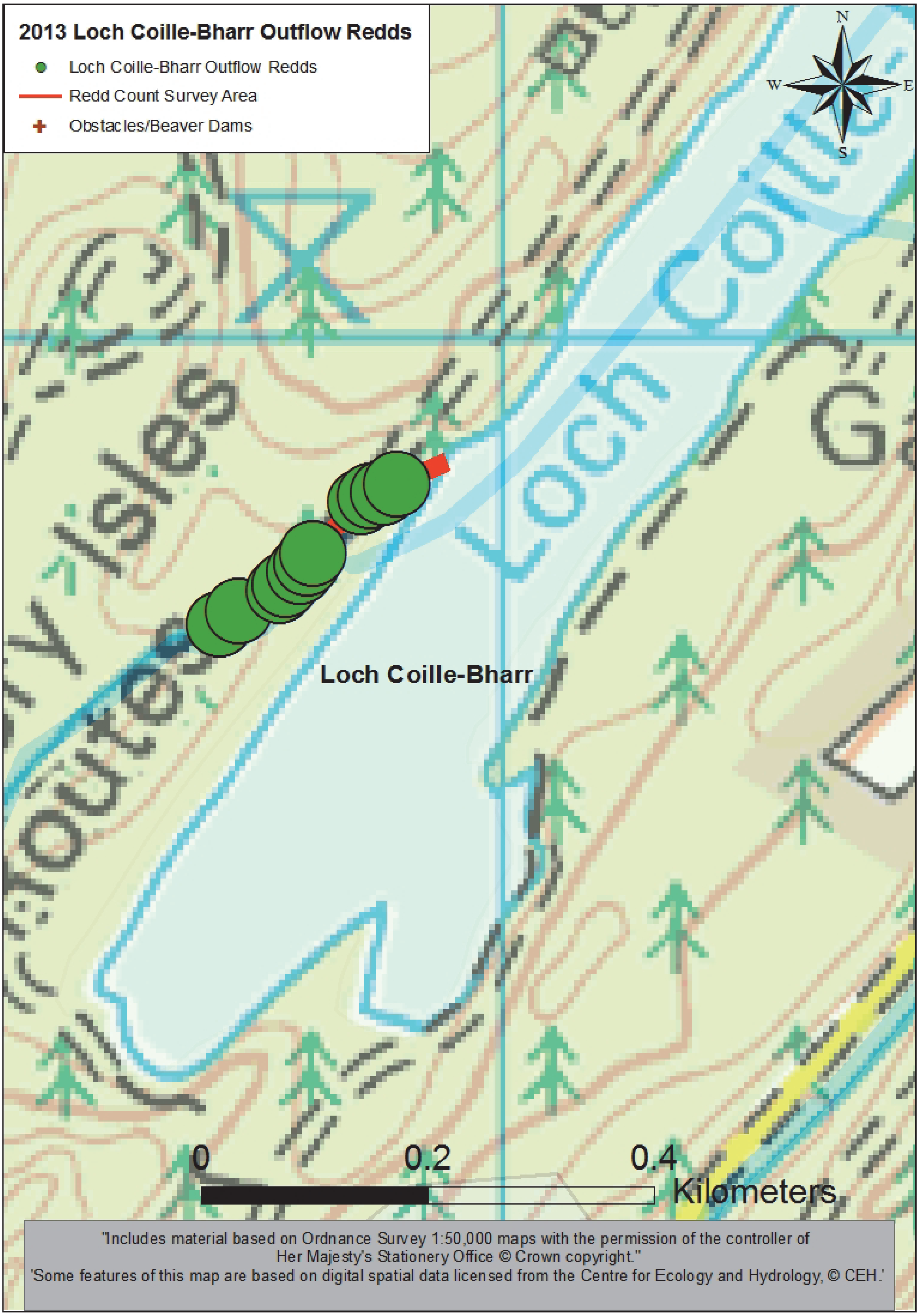


Fig. 3.1.14 Location of spawning sites where no beaver dams were found in the stream flowing out of Loch Coille-Bharr (2013)

3.1.2.2.4 Redd count surveys at the Loch Buic outflow stream

Where beaver had not built dams in the Loch Buic outflow stream, the number of large or composite redds found by surveys in the 448 m^2 of habitat ranged from one in 2012 to two in 2013 (Table 3.1.17), while the number of small redds ranged between two in 2012 and five in 2013. Redd density ranged from 0.7 per 100 m^2 of habitat in 2012 to 1.6 in 2013. The subsequent density of trout fry found at site 24 in the following year was 3.4 fry resulting from the 2012 spawning effort. The location of spawning sites where no beaver dams were found in the streams flowing out of Lochan Buic in 2013 are shown in Figure 3.1.15.

Table 3.1.17 Redd count survey results and subsequent trout fry density (min. no. per 100 m^2) 2009-2013 at the Lochan Buic outflow stream

Redd count survey results					**E-fish survey results (+1 year)**	
Year	No. Large	No. Small	Total No.	Redd Density	E-fish sites	Resulting fry density
2012	1	2	3	0.7	24, 24a, 24	3.4
2013	2	5	7	1.6	24, 24a, 25	

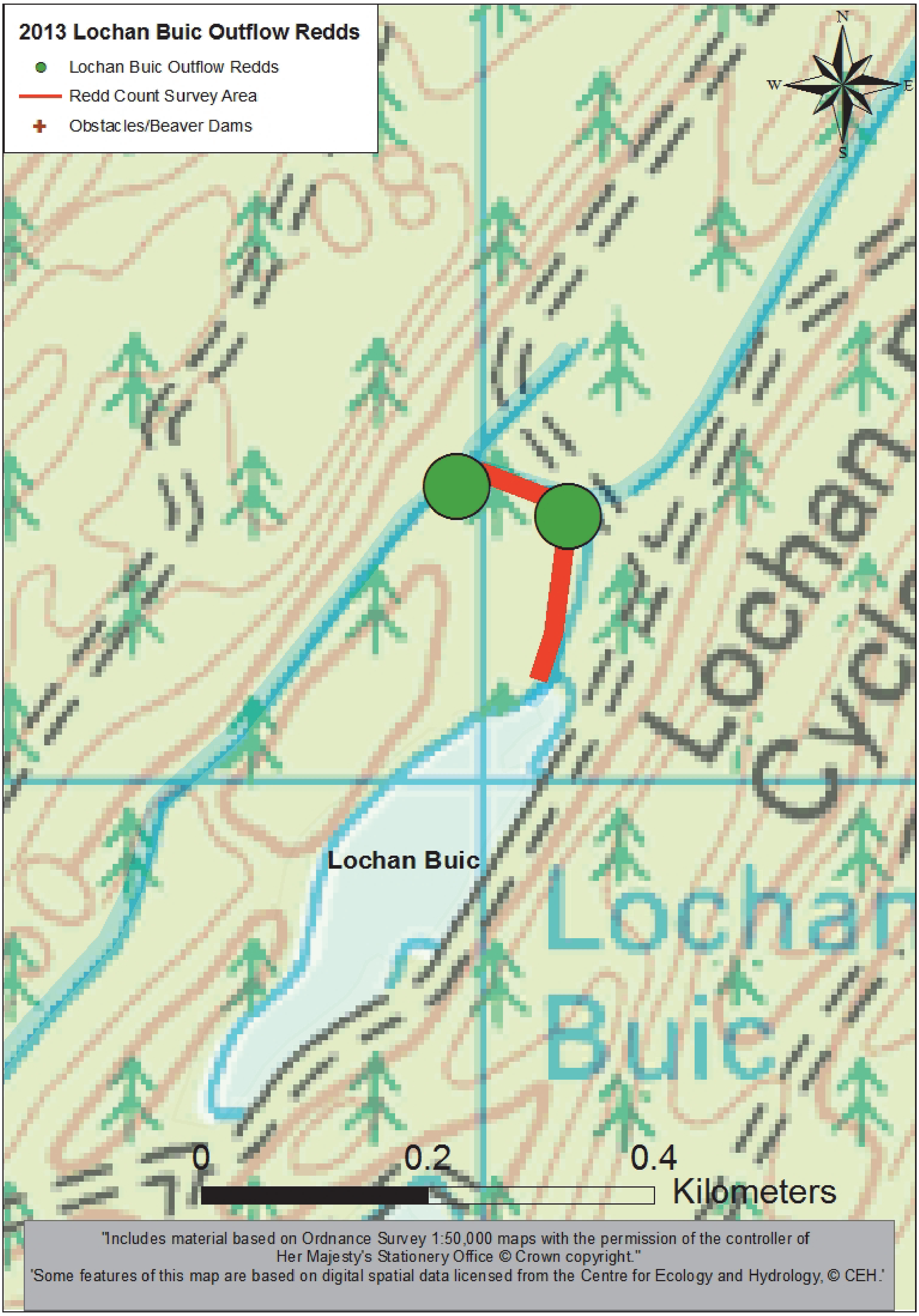


Fig. 3.1.15 Location of spawning sites where no beaver dams were found in the stream flowing out of Lochan Buic (2013)

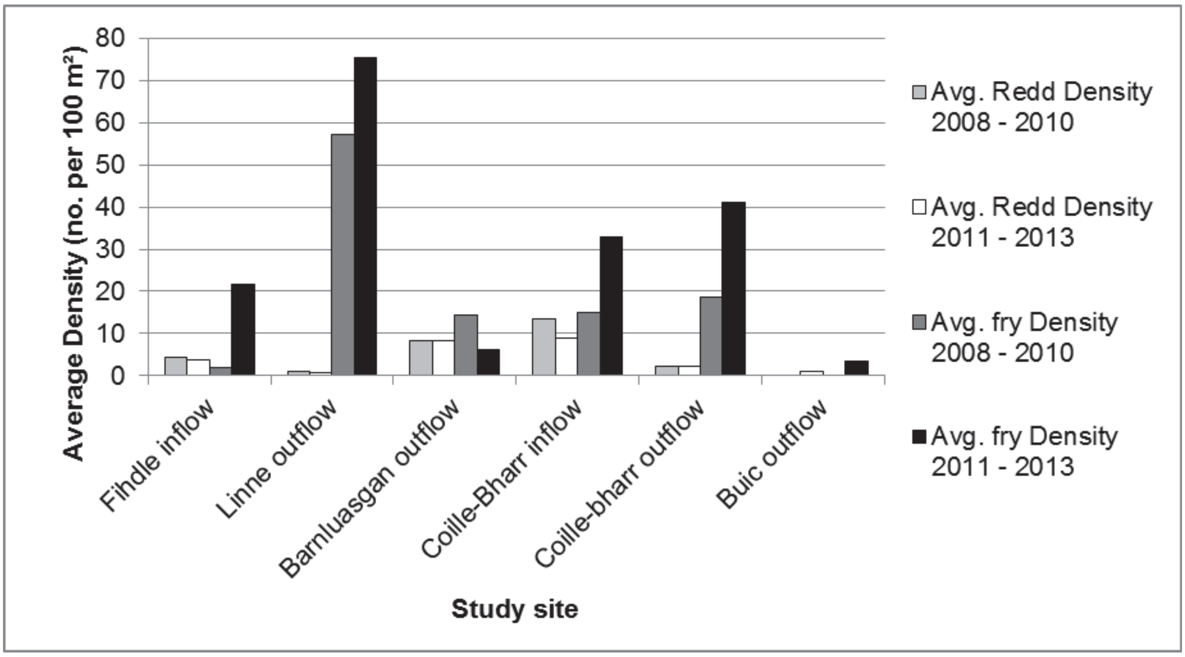
3.1.3 Comparison of redd and trout fry density in relation to beaver dams

The average density of redds and the subsequent density of trout fry before any dams were constructed by beavers (2008 to 2010) and those found after construction (2011 to 2013) are compared below (Table 3.1.18).

Table 3.1.18 Average density of redds and subsequent trout fry (no. per 100 m²) at study sites (2008-2013) pre and post beaver dam construction

Study site	Average redd density (no. per 100 m²)			Average trout fry density (no. per 100 m²)		
	2008 - 2010	2011 - 2013	Average (2008-2013)	2008 - 2010	2011 - 2013	Average (2008-2013)
L. Fidhle inflow	4.2	3.9	4.0	1.9	21.8	11.9
L. Linne outflow	1.0	0.5	0.8	57.4	75.4	64.6
L. Barnluasgan outflow	8.3	8.4	8.3	14.5	6.2	11.2
L. Coille-Bharr inflow	13.5	9.0	10.8	15.0	33.0	27.0
L. Coille-bharr outflow	2.3	2.3	2.3	18.8	41.2	30.0
L. Buic outflow		1.1			3.4	
Average	**5.85**	**4.20**	**5.24**	**21.51**	**30.16**	**28.92**

Figure 3.1.16 Density of redds (no. per 100 m²) found at survey sites (2008-2013)



At the Loch Fidhle inflow stream, where beaver dams were built in 2010/11, the average density of redds before dam construction was 4.2, but after the dams were built redd density fell slightly to 3.9 per 100 m². The subsequent average density of trout fry found upstream of the dams was 1.9 per 100 m² before the dams were built compared to 21.8 after dams were built. At the other site where dams were built, but subsequently managed over the same time scale, average redd density fell from one per 100 m² before construction to 0.5 after construction. The subsequent average density of trout fry found upstream of the dams was

57.4 fry per 100 m² before the dam was built compared with 75.4 fry after dams were constructed.

At the Loch Coille-Bharr inflow (Barnluasgan outflow stream), where no beaver dams were built, the average density of redds found between 2008 and 2010 was 8.3 per 100 m² compared with a similar average density of 8.4 found between 2011 and 2013. The subsequent density of trout fry found between 2008 and 2010 averaged 14.5 fry per 100 m² compared with 6.2 fry between 2011 and 2013. At the other inflow stream to Loch Coille-Bharr, average redd density was 13.5 per 100 m² between 2009 and 2010 compared with 9.0 between 2011 and 2013. The subsequent density of trout fry found at this site between 2009 and 2010 was 15.0 per 100 m² compared with 33.0 between 2011 and 2013. At the study site on the outflow of Loch Coille-Bharr, average redd density was 2.3 per 100 m² during both the 2009 to 2010 and the 2011 to 2013 study periods. The subsequent density of trout fry found at this site between 2009 and 2010 was 18.8 fry per 100 m² compared with 41.2 between 2011 and 2013. The same comparison could not be made at the study site at the outflow of Loch Buic where surveys began in 2012.

3.2 Results for surveys in loch habitats

3.2.1 Gill net survey results

Three brown trout were sampled from Loch Losgunn in the Linne catchment by the gill net survey. A larger catch of 24 brown trout was sampled from Loch Barnluasgan in the Coille-Bharr catchment but only one fish, a stocked rainbow trout (*Oncorhynchus mykiss* (Walbaum)), was sampled from Loch McKay in the Creagmhor catchment (Table 3.2.1).

Table 3.2.1 Gill net survey results

Loch	Trout species	Age (yrs +)	No.	Length (mm)	Wet Weight (g)	No. Male	No. Female
Losgunn	Brown	2	3	220-256	134-225	2	1
Barnluasgan	Brown	1	8	163-209	55-111	2	6
	Brown	2	11	223-308	138-318	6	5
	Brown	3	5	195-286	195-272	3	2
McKay	Rainbow	2	1	498	1699	0	1

From scale readings, all three brown trout sampled from Loch Losgunn were found to be two years of age, while three different age classes were found in Loch Barnluasgan (one to three years of age). Comparisons of two year-old brown trout from Lochs Losgunn and Barnluasgan indicate a similar length at age (220 and 223 mm respectively) at the lower end of the range, but larger trout were sampled in Loch Barnluasgan (256 and 308 mm respectively). Some of the two year-old fish were larger than a number of the three year-old fish in Loch Barnluasgan. It was not possible, however, to determine if brown trout sampled from Lochs Losgunn and Barnluasgan were stocked or wild. Reading of the scales taken from the large rainbow trout sampled in Loch Mckay suggests it was two years of age and had been stocked by the local angling club.

3.2.2 Hydroacoustic survey results

Prior to the hydroacoustic survey being carried out there was no knowledge of the bathymetry of the lochs within the trial area. Once this had been ascertained it was concluded that, because the lochs (with the exception of very restricted areas of Barnluasgan) were less than 5m in depth and heavily structured (i.e. large quantities of macrophytes present), the use of a hydroacoustic population assessment methodology would be inappropriate. Other, non-lethal methods of fish capture, such as the use of seine nets, were similarly discounted based on the availability of suitable sampling sites and the abundance of macrophyte growth within these lochs. It was decided, therefore, to restrict the fish survey in these lochs to a simple description of the fish community.

4. DISCUSSION

The fish species sampled in the sites surveyed during the 2008 to 2013 study of fish at Knapdale included brown trout, European eel, three-spine stickleback and European minnow. These are commonly found in other similar waters in the Argyll region. Another species, rainbow trout, was also captured in one loch which had been stocked for fishery purposes. The general distribution of wild-spawned species found in the stream survey sites was likely to be influenced by a number of potential factors including: the suitability of the habitat, seasonal migrations between loch and stream habitats, competition for resources between and within species. The differences in catch composition and fish densities observed during the surveys may also be due to variation in environmental conditions, such as precipitation and subsequent stream flow discharge that may influence fish migration into or emigration from sites before surveys were undertaken. The findings of the surveys undertaken on streams and lochs over the study period are discussed below in relation to the trial reintroduction of European beaver.

4.1 Fish populations at sites where dams were built by beavers

Activity of beavers likely to affect fish habitat and fish distribution was recorded at two of the six study sites monitored between 2011 and 2013; the stream flowing from Loch Losgunn into Loch Fidhle and the out-flowing stream from Loch Linne.

4.1.1 Loch Fidhle inflow stream (Linne catchment)

Beaver activity on the stream flowing from Loch Losgunn to Loch Fidhle was limited to a relatively short stretch of stream close to its confluence with Loch Fidhle. The location of this obstacle to fish passage meant that both redd counts and electrofishing surveys undertaken upstream of the dams could not be compared with any data from similar habitat downstream of the dams. However, data collected upstream of the dams before and after dam construction do allow some assessment of any effect on the recruitment of juvenile brown trout that has been caused by the dams.

When compared with the 2008 and 2009 survey results, the density of trout fry found at site 4 in 2010 and 2011 suggested that there had been a reduction in the recruitment of trout upstream of the dam. However, this appears to have been a temporary decline as later surveys (2011-2013) suggests that mature trout migrating upstream from Loch Fidhle were once again able to ascend past the dam structures as redd and trout fry densities were similar to those found prior to the dams being built. The redd count results, however, did not support this assessment as redds were present in similar densities in 2010 and 2011 when fry density declined. This may be partly explained by a fish survey undertaken earlier in the summer at site 4 (in June 2011) which found a relatively high density of fry compared with lower densities found later in the autumn survey, which suggest that the majority of fish fry may emigrate downstream into the loch after emerging from the redds in late spring, prior to the autumn surveys being undertaken.

The relatively low density of trout fry found in surveys indicate that while the habitat in this stream is suitable for spawning it has limited in-stream habitat to support high numbers of growing fry. The ability of the habitat in this reach of stream to sustain young trout (and other fish) is likely to be influenced by habitat condition which has been influenced by channel re-alignment and simplification as part of a forest drainage scheme. It is also heavily shaded from conifer plantation trees, both of these factors are likely to have some influence on the ability of the site to support fish. Therefore, the lack of fry found in 2010, and the lower than average density found in 2011, may have occurred as a result of the fish’s reaction to environmental conditions rather than beaver dams affecting the access of spawning adults into the study site.

The ponding upstream of the dam was limited to an approximately 20 m reach of stream which increased water depth. The two surveys conducted in 2012 and 2013 within the newly ponded reach (site 4b) captured trout parr that were not found in shallower water habitat further upstream. It is possible that the dam has provided habitat preferred by larger trout, but lack of fish data at this site prior to the construction of the dam means that it was not possible to establish if this was the case in this study.

4.1.2 Loch Linne outflow

The results of fish and redd count surveys suggest that mature adult fish move between Loch Linne and stream habitats to access spawning habitat. It is not known if the study sites are accessible to migratory (sea) trout from Loch Sween (located approximately 2 km further downstream) due to the presence of potential obstacles to fish movement.

Beaver activity in Loch Linne has included felling of trees across the outflow stream and dam construction, which has subsequently been managed (removed or reduced) during the trial period to maintain favourable conditions for macrophytes. While it is not known if beaver may eventually have influenced the movement of fish between these habitats, the results of surveys undertaken in the stream out-flowing from Loch Linne (sites 9, 9a and 9b) may therefore, inadvertently, represent a potential scenario where the result of beaver activity may be managed to minimise any effect on the movement of fish between habitats.

The density of trout redds found was relatively stable over the study period (2008-13) and trout fry densities remained relatively high with the exception of the 2013 survey which found only moderate densities of fish. With no apparent change in the condition of the habitat or accessibility of the spawning sites to trout in autumn of 2012, the lower density of fry found in 2013 suggests survival of eggs and fry through to the autumn may have been independent of spawning effort.

The study found some variation in fish species distribution during the study period. While trout fry have been found in all six surveys at site 9 (2008-13), parr were not found in 2010 or 2013. However, both fry and parr were found in two sites (9a and 9b) further downstream where the habitat included deeper water. Therefore, the absence of parr at site 9 may be a result of downstream movement to utilise the deeper water habitat found there. European eel were also found in five of the six surveys undertaken at site 9, while minnow were found in four of the surveys, suggesting the habitat was suitable for a range of species, but there are influences on movement of these species not observed by this study.

The habitat data collected at the fish survey sites suggest that water depth, flow type and substrates are relatively diverse compared with most other sites which, in combination with the proximity of the sites to loch habitat, may explain the greater number of species found. The higher densities of trout fry found in this reach of stream (compared with others sampled in the catchment) also suggest that the outflow stream is important to the recruitment of trout in Loch Linne. Given the range of species and the movement of fish between habitats, this reach of stream offers some potential for future investigations into beaver activity, management of beaver dams and subsequent impacts on fish populations.

4.2 Fish populations at sites where no beaver dams were built

4.2.1 Loch Barnluasgan outflow / Loch Coille-Bharr inflow

No beaver activity that affected the area of stream habitat between Lochs Barnluasgan and Loch Coille-Bharr (0.049 Ha) was recorded during the study period. The redd count surveys suggest that the stream is utilised for recruitment by adult trout migrating upstream from Loch Coille-Bharr, and possibly by trout migrating downstream from Loch Barnluasgan.

The densities of redds found in surveys varied between years, but fewer were found in 2010 (two per 100 m²) compared with other years (range 6.1 to 13.5). The fish surveys undertaken in the Loch Barnluasgan outflow stream (sites 14, 14a and 14b) also found some variation in trout fry densities, where redd density and subsequent fry density follow a similar pattern. These data may therefore suggest that the spawning adult population utilising the stream for recruitment may have varied during the study period. This is not unexpected. The redd densities found in other years were amongst the highest found at any site within the study area, but fry densities in the following autumn, when found, were relatively low in each of the surveys. The ability of the habitat to support juveniles may be inhibited by the relatively high percentage of fine sediment in the stream bed substrates at these sites, which in turn is likely to reduce in-stream cover for young fish compared with larger substrates found at some other sites such as sites 9 and 17. Therefore the apparent abundance of spawning activity and egg deposition in this habitat may not be reflected in fish surveys undertaken in autumn after trout fry may have emigrated from the site prior to the survey taking place. However, the habitat at these survey sites appears to be suitable for eels, stickleback and minnow that were recorded in surveys in most years.

4.2.2 Loch Coille-Bharr west inflow

Water depth, flow velocity and access to bank cover varies considerably in the relatively small area of habitat (~50 m2) downstream of the waterfall at site 16a (that prevents further upstream migration of trout from Loch Coille-Bharr). These attributes are influenced by water levels within the loch. Therefore, potential beaver activity at the outflow of Loch Coille-Bharr could affect loch level and subsequently may have affected both spawning success and the density of fish present in that site at the time of survey.

Redd survey data suggest that this small area of accessible habitat is utilised for recruitment in most years, but the density of trout fry found at this site was classified as low or moderate. Given the limited size of the habitat and ease of access from Loch Coille-Bharr, it is likely that the results of the autumn fish surveys may not accurately reflect spawning activity in the previous winter and may also sample fish that have utilised the site as refuge or feeding habitat.

4.2.3 Loch Coille-Bharr outflow

Unlike the outflow of Loch Linne, beaver did not attempt to construct any type of dam at the outflow of Loch Coille-Bharr during the trial period. Similar to the stream that flows out from Loch Linne, the outward flowing stream sampling site at Loch Coille-Bharr (extending to 810 m^2) is characterised by fish habitat that has a wider diversity of flow depths, types and substrates. Unlike the Linne outflow, however, a waterfall some 270 m downstream of the loch restricts access to sea-run trout and therefore is only utilised by loch trout already resident in Loch Coille-Bharr. In comparison with the Linne outflow, the density of redds found at the site was relatively high, as were the densities of trout fry found in fish surveys.

The comparatively wide variation in trout parr abundance found in most survey sites indicates that older trout may emigrate back upstream into Loch Coille-Bharr where habitat is more suitable for larger, older fish. It may also be possible for juveniles to migrate downstream over the waterfall, but that was not investigated during this study. The physical and flow characteristics of the stream, and the proximity of the sampling site to lacustrine habitat, possibly explains why a range of non-salmonid fish (European eel, stickleback and minnow) were also found at higher density here than in in-flowing stream habitats.

4.2.4 Lochan Buic outflow

Although beaver have felled trees near the outflow of Loch Buic, no trees have entered the stream nor have any dams been constructed. Unlike the streams flowing out of Lochs Linne and Coille-Bharr, the water flowing from Loch Buic is of much lower volume. The habitat between the loch and the confluence with the Loch Creagmhor outflow stream consists of a small realigned drainage channel with fine sediment substrate, little bank cover and over-shading by conifer plantation trees. No redds and few fish (site 24a) were found by this study suggesting that there are insufficient resources for spawning or nursery habitat for trout, and there is little cover for any other fish.

There is a larger area of habitat downstream of the confluence with the Loch Creagmhor outflow stream, but the habitat is similarly affected by land use. Redd count surveys suggest that spawning habitat is limited to a few small patches, which is likely to limit recruitment of trout. Both redd counts and fish surveys indicate that recruitment is variable with few fry and higher numbers of parr when sufficient habitat is available. This was the case in 2012 and 2013 when fallen branches provided in-stream cover in the form of large woody debris. Wider surveys suggest that this site is potentially accessible from the sea by sea-run trout, but access into Loch Creagmhor further upstream is less likely to be due to the presence of a sluice structure. The fish data do not provide a clear insight into the movement of fish from Loch Buic into the survey areas, but there appears to be no alternative spawning habitat for loch-based trout.

4.3 Loch Surveys

The gill net surveys undertaken in Lochs Barnluasgan and Losgunn indicate that the larger lochs within the trial area support populations of brown trout, while smaller standing waters such as Loch McKay may not naturally support trout populations and have subsequently been utilised as stocked rainbow trout fisheries. The brown trout found in these lochs were generally older and larger than those sampled from stream habitats reflecting the habitat preference for different age classes of trout. The hydroacoustic survey, however, was not able to quantify the abundance of fish present in these lochs because of their relatively small size, presence of aquatic vegetation and shallow depth. The surveys of other lochs where beaver are present could not be undertaken due to risks of beaver becoming entrapped in gill nets and therefore other non-invasive methods will need to be used to ascertain the species present in these lochs. In contrast to the lochs surveyed by this study, hydroacoustic surveys are likely to be more effective in the larger, deeper lochs such as Loch Linne and Loch Coille-Bharr.

5. IMPLICATIONS FOR MANAGEMENT

While the information on fish distribution, abundance and spawning sites collected in 2012 and 2013 was confined to fewer locations compared with the wider baseline monitoring in previous years (2008 to 2011) it has investigated potential implications for the management of fish populations in relation to the trial reintroduction of beaver to the Knapdale area.

With the exception of Atlantic salmon and lampreys, the fish species found in this study (brown trout, European eel and three-spine stickleback) represent fish communities found throughout Scotland which have intrinsic biodiversity, and in the case of trout, sporting value. However, if beaver is to be reintroduced more widely, the emphasis of future management is likely to focus on anadromous salmonids such as Atlantic salmon (*Salmo salar* L.) and sea trout. Both Atlantic salmon and sea trout are currently of conservation concern and both have considerable economic and cultural value. Partly as a result of the lack of opportunity to study Atlantic salmon during the trial reintroduction of beaver at Knapdale, other studies are being undertaken within the Tay catchment to better inform beaver/fish management (Dugan and Armstrong, pers. comm.) and additional research work is under way at the University of Southampton. While sea trout are known to be present within the trial site, beaver activity has not yet occurred within their known range and, as a result, only loch-based brown trout populations have been studied in relation to beaver activity at Knapdale.

Depending on the propensity of beavers to build dams in the Scottish landscape, their presence can be expected to have positive and negative effects on fish fauna (Beaver-Salmonid Working Group, 2015). As an example, European minnow has been introduced to some catchments within the trial area, probably as a result of their use as bait by anglers. A recent study in Lithuania (Kesminas *et al*., 2013) suggests that minnow may benefit from changes in habitat created by Eurasian beaver.

Since their introduction in 2008, the activity of beavers in streams has been limited to two sites where beaver appear to have had no significant influence of fish distribution or density. Consequently there have been few instances where beaver activity in relation to fish populations could be investigated in detail during this study. Studies of fish and beavers undertaken elsewhere in response to the reintroduction of Eurasian beaver may provide some information on the response of fish populations to be expected as a result of a wider introduction of beavers. While limited research has been undertaken in areas where the distribution of Eurasian beaver and migratory salmonids overlap, there is some reference to practical management of beaver in relation fish distribution (Halley & Bevanger, 2005). The management of beaver in relation to fish in a Scottish context has recently been described by the Beaver-Salmonid Working Group in their report to The National Species Reintroduction Forum (Beaver-Salmonid Working Group, 2015).

5.1 Beaver dams and fish migration

Salmonid and other native fish species require access to a range of habitats during the freshwater phases of their life-cycles (Armstrong *et al*., 2003). In-stream barriers can have varied effects dependent on fish species, hydrology, barrier characteristics, temperature, previous experience and life history (see Thorstad *et al*., 2008; Kemp & O'Hanley, 2010), including both the up- and down-stream migration of different life-stages. Access to spawning and rearing habitat in low order streams can be curtailed by beaver dams (Schlosser & Kallemeyn, 2000; Mitchell & Cunjack, 2007; Taylor *et al*., 2010; Elmeros *et al*., 2003). However, the successful movement of mature and juvenile fish past dams has also been documented, typically during high flow conditions (Schlosser, 1995; Loktеff *et al*., 2013; Niles *et al*., 2013; Dugan & Armstrong, pers comm.).

These studies of beaver dams indicate that it may be difficult for managers to assess the specific effects of an individual beaver dam on a fish population. Therefore, where there is sufficient conservation or economic interest in fish populations or fisheries, site specific investigations may be required in some cases to assess whether management intervention may be required. The limited activity of beaver in stream habitats during the trial period has meant that no significant management issue in relation to fish has needed to be addressed. This study found that the two relatively small dams (maximum height of 0.7 m) built on the burn flowing into Loch Fidhle from Loch Losgunn appear to have had no effect on the use of the habitat upstream for recruitment of young trout since it was constructed. Management of the dam building activity of beavers at the outflow of Loch Linne was undertaken for reasons other than fish, but subsequent relaxation of this management may see future activity of beavers affect fish habitat at this site, providing opportunities for further study.

Current legislation (the Salmon and Freshwater Fisheries (Consolidation)(Scotland) Act 2003) requires that fishery management organisations (currently the District Salmon Fishery Boards) maintain the natural range of Atlantic salmon and sea trout as part of their statutory duties and powers. Identifying and managing issues on the basis of fishery performance is unlikely to be possible in all situations and hence issues affecting fisheries arising from the reintroduction of beaver are consequently likely to be identified and quantified from detailed studies of fish populations and their habitats. Therefore, the wider introduction or spread, of beaver, is likely to be followed by an increase in demand for management resources if the conservation and economic value of fish populations are to be maintained.

5.2 Habitat changes at beaver dams

The recruitment of salmonid fish requires a habitat with a range of physical and fluvial characteristics to be present. This is particularly true during spawning, egg incubation and when fish are present as pre-emergent fry. The availability of spawning-grade gravel substrates and the flow of oxygen-bearing water to sustain ova and yolk-sac fry during incubation are essential to maintain viable populations.

The survey data gathered to date at Knapdale indicate that fish utilised a wide range of habitats within the trial area, some of which appear to have been heavily modified by land use. The data suggest that fish populations may benefit from habitat improvement in streams which can influence the recruitment levels of young fish. Restoring stream habitat to a more natural condition is also likely to benefit biodiversity and, in some instances, reduce the reliance on stocking farm-reared trout to support fisheries. Smith *et al.* (2013) reported that North American beaver (*C. canadensis* Kuhl) dams altered habitat within streams in four ways. These were based on upstream versus downstream differences (including stream width), depth, velocity and substratum. In general, habitat heterogeneity, measured using two indices, was greater at beaver dams than control sites.

6. CONCLUSIONS

The data collected by fish and redd surveys from a range of stream sites, both within and outside the trial area (2008-2011), has established a baseline of information that may be used to assess future changes within the beaver trial site. The higher resolution of information collected by this study in 2012 and 2013 at fewer sites where beavers have been active, and at sites where fish habitat may be affected if beaver become active has found no significant effect on fish populations.

6.1 Surveys at sites where beaver are active

Fish population and redd counts were undertaken at six sites at two locations where beaver have become active. Two small beaver dams made on the burn flowing from Loch Losgunn to Loch Fidhle do not appear to have affected fish spawning or juvenile recruitment upstream. Dam building by beaver at the outflow of Loch Linne has been managed to maintain existing water levels. This activity did not appear to affect the movement of brown trout from Loch Linne to their spawning and nursery habitat downstream. European eel, three-spine stickleback and minnow were also at sites where they had been found before the occurrence of beaver activity.

6.2 Surveys at sites where beaver are not active

Fish population and redd counts were undertaken at 10 sites at four locations in streams where no beaver activity was found. Fish distribution and abundance at these sites appear similar in 2012 and 2013 to that found in baseline and follow-up surveys (2008 to 2011). Baseline information has also been collected on fish populations in three lochs in the trial area but further work may be required to assess the status of fish populations in larger lochs where beaver are present.

6.3 Future work at Knapdale

If beaver are to be retained at Knapdale after the trial period, it may be beneficial to monitor beaver activity in watercourses where it has potential to affect fish habitat to further inform management. Given the beavers ability to construct dams that can hinder fish movement, and the potential loss of spawning habitat, it will be advantageous to establish mitigation measures where circumstances dictate. Such measures may be documented and used to inform management of fish and fisheries in respect to any wider reintroduction of Eurasian beaver.

7. APPRAISAL OF METHODS AND FUTURE PROGRAMME OF WORK

The two methods used in the survey – electrofishing and walkover redd surveys and survey site selections – were appraised and their suitability considered in relation to filling knowledge gaps and future work.

7.1 Survey site selection

The location of the fish sampling sites surveyed in streams during this study may have some influence on the findings of the study as they provide data for a relatively small area of habitat at a particular point in time. The selection of a wide survey approach meant that the trial could obtain information on the distribution of fish in a variety of habitats both within and outside of the trial area. This was necessary because it was not possible to predict how the introduced beavers would subsequently colonise and utilise stream and river habitats after their release. Therefore, it was necessary to adopt new sites and increase the number of sites in stream reaches where beaver had begun actively to affect stream habitats, once these became known. The generally consistent results found in both fish and redd count surveys between years at the same location over the study period suggest that the sites surveyed during the trial are representative of the range of habitats available to fish.

The location of the standing water surveys in a small number of lochs provided some information on the brown trout populations in three of the lochs within the trial area. However, the relatively small and shallow lochs surveyed were not suitable for the hydroacoustic surveys to assess fish abundance at these sites. Additionally, the gill net survey method could not be used in lochs where beaver were already present. Ideally, loch surveys should have been carried out before the introduction of beaver to the site, but the timescales of the decision making process and the subsequent physical introduction of beaver meant that this could not be achieved.

7.2 Survey timing

The seasonal timing of electrofishing surveys in streams in the autumn is likely to reflect a lower abundance of juvenile trout than that present in early summer shortly after emergence of fry from spawning sites due to natural mortality, carrying capacity of the habitat and density-dependent dispersal of fish that compete for limited resources. There is also potential for non-density-dependent factors such as droughts and floods to influence fish distribution and abundance (Elliott, 1993) in any one year, which will influence results of fish surveys.

It is also possible for some species to use habitats on a diurnal or seasonal basis. Stickleback and minnow may potentially utilise stream habitats for recruitment in the early summer months or possibly as refuge from larger fish, such as eels. Surveys conducted in the autumn are likely to record higher abundance of sexually mature trout as they migrate from freshwater lochs or marine habitats toward spawning sites. No mature adult trout were found in the 2012 or 2013 surveys, indicating that no spawning activity had yet commenced in early October. The autumn electrofishing surveys were conducted in autumn when water temperature was close to, but not below the recommended minimum 8 ºC (SFCC, 2007). This may potentially reduce the effectiveness of the sampling technique and increase the potential for sampling error compared with surveys undertaken in warmer temperatures.

Ideally, spawning habitat surveys (redd counts) should be undertaken once spawning has been completed as surveys conducted earlier than this may affect results. The timing and duration of spawning activity may vary between different populations of trout but the surveys conducted as part of this study in December each year appear to have yielded relatively consistent results. The environmental conditions, such as water temperature or flow levels, can also influence timing of spawning in any one year. High water flow levels may obscure or reduce the form or visibility of redds to surveyors or low water flow levels may delay or reduce access to spawning habitats. Therefore, it is possible that the results of this study may not fully reflect the distribution and frequency of redds.

The results of electrofishing and redd count surveys suggest that the timing of loch-based gill net surveys (in September 2011) was likely to reflect the fish population at a point where they have achieved their maximum growth within the year and mature trout have not yet begun to migrate into stream habitats in preparation for spawning later in October and November.

7.3 Electrofishing survey method

The electrofishing surveys over the study period were carried out under a nationally agreed protocol by trained operatives. The results of these surveys have provided adequate data to identify the fish species present at sampling sites and an indication of their relative abundance at the time of survey. However, the survey method is primarily aimed at the capture of salmonid fish and may not be as effective for other species (such as European eels) and therefore may not fully reflect the distribution or density of non-salmonid fish species. Where the number of fish caught in the first electrofishing run was sufficient, the reduction in fish numbers caught by repeated electrofishing runs at the same site have provided some verification that the survey method has generally been effective. Therefore, the baseline of information collected by this study may confidently be used to assess any further sampling undertaken at the same sites after the trial period.

7.4 Redd count survey method

The data collected in the spawning habitat survey successfully identified habitats that were being used for the recruitment of salmonid fish at the time of survey and potential obstacles to adult fish access to spawning sites. This information also provided supporting evidence for the interpretation of electrofishing data. Although there is no nationally agreed survey protocol for surveying salmonid spawning habitat, an experienced surveyor may provide very useful information to build a more concise picture of the use of habitats by brown trout in the trial area. Further development of the technique appears to have potential benefits for better understanding the full range of habitats required by salmonid fish to complete their life-cycle. There may be potential to develop a survey protocol through the partners of SFCC in future.

7.5 Gill net and hydroacoustic survey methods

Similar to the electrofishing survey method used in streams, gill net surveys provide data on fish populations present at a particular location at one point in time and therefore may not reflect the full range of species that utilise the loch habitat over time. In addition, some fish species, such as European eel, are less likely to be caught by this method due to their body shape. Unlike electrofishing surveys, it is not usually possible after the survey to return alive the fish caught in gill nets and therefore intensive gill netting is not a method that can be repeated annually without affecting the status of fish populations in relatively small water bodies.

Used in combination with the gill net survey method, hydroacoustics offer a non-destructive method to quantify the fish populations in large water bodies. However, the hydroacoustic surveys undertaken as part of this study could not accurately assess the status of fish populations in the relatively small lochs surveyed. Despite this, in future it may be possible to use this method in larger lochs, such as Linne and Coille-Bharr, if the fish species present can be identified.

7.6 Future work

While the information collected by this study provide a baseline of information against which any future changes may be compared, there are gaps in our understanding of a number of fish species and habitats.

Fish studies at Knapdale have relied on baseline sampling of fish populations in streams within the trial area in 2008 and expanded on these sites in 2009 to include sites outside of the trial area. Repeat monitoring of these survey sites was continued in 2010 and 2011 to reflect possible temporal changes in fish populations. Sampling of fish populations was also undertaken in three loch habitats in 2011. A more intensive sampling of fewer sites in 2012 and 2013 at locations where beaver have become active and similar sites where beaver may become active in the near future has begun to focus on potential interaction between fish and beaver at the trial site.

Any future surveys will need to continue to assess any effect on fish populations at sites where beaver are known to be active as well as maintaining the monitoring of a core of study sites where no beaver activity is known to have occurred so that potential changes may be compared. Additionally, sampling of fish may also have to include new sites where beaver become active. Other studies of beaver and fish in Scotland currently being undertaken in the River Tay catchment and elsewhere may also provide new information or methods that could better inform future studies at Knapdale.

In addition, it will be beneficial to explore any new opportunities that arise to better understand fish populations in standing waters, particularly methods of non-destructive sampling of fish which may be used in combination with hydroacoustic surveys of larger water bodies such as Lochs Coille-Bharr and Linne. If beaver are retained at Knapdale after the end of the trial period it will be desirable to observe beaver behaviour in relation to the construction of dams, investigate fish passage issues (with, for example, active tracking equipment) and measure changes in the distribution and abundance of each component of the fish community. The potential management activities and techniques required to resolve or manage fish passage issues in future are likely to require further investigation.

Information, on fish or fish habitats may be forthcoming from other studies at Knapdale as part of the Scottish Beaver Trial including beaver ecology, river habitat, hydrology, aquatic macrophytes, water chemistry, monitoring for woodland, public health, otter, Odonata and other elements.

In addition to the completion of electrofishing, spawning habitat surveys (redd counts) and gill net surveys for all catchments within the trial and a sub-sample of habitats outside of the trial area as part of this project, the additional monitoring projects listed above have provided a wider understanding of the character of freshwater habitats within the trial area.

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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