Student Project

A study of macro-invertebrates and the feeding behaviour of juvenile salmon in the Little Gruinard River SAC, 2014

External organisation:

Wester Ross Fisheries Trust

Harbour Centre

Gairloch

Wester Ross, SCOTLAND

IV21 2BQ

BILLIER Geoffrey
Engineering Student at Ecole Nationale Supérieure Agronomique de Toulouse 'ENSAT'

May, 2014

Supervisor:
Peter D. Cunningham
Biologist at Wester Ross Fisheries Trust

● *ECOLE NATIONALE SUPERIEURE AGRONOMIQUE DE TOULOUSE* ●

Avenue de l'Agrobiopole - Auzeville-Tolosane - 31326 Castanet-Tolosan

Preface

Geoffrey Billier stayed at Little Gruinard from mid February until the end of May 2014, in accommodation kindly provided by Little Gruinard Estate and prepared by Carol and Brian Fraser and Stuart Allison as an ideal study base.

Wester Ross Fisheries Trust asked Geoffrey to carry out a survey of aquatic macro-invertebrates within the Little Gruinard River to learn more about relationships between food availability and the growth and production of juvenile salmon in the Little Gruinard River SAC. The study was envisaged partly to fulfil an obligation to SNH following receipt of a grant for purchase of new electro-fishing equipment (for juvenile fish sampling) and sweep net (for sampling sea trout).

At the outset Geoffrey set himself ambitious objectives, and developed and completed a work programme which during the first three months of his internship provided little time for anything other than sample collection and study, often working late into and sometimes through the night.

His work included regular sampling of macro-invertebrates at a series of sites within the Little Gruinard River, sorting and identification of macro-invertebrate taxa; studies of drift of macro-invertebrates within the river during 24hr period; a study of the food of juvenile salmon (fry, parr and pre-smolts) during the day and night in April.

Geoffrey prepared this report prior to completing his internship with Wester Ross Fisheries Trust. Within the following pages there is much new information on aquatic invertebrates within the Little Gruinard River. Some of the wording is possibly not what might be expected from a native English speaker; I've edited it with a light touch: this is Geoffrey's report.

This report provides the results of the most detailed study of aquatic macro-invertebrates and how they relate to juvenile salmon that has been carried out by Wester Ross Fisheries Trust to date. It is possibly the most detailed study on this subject that has been carried out in this part of Scotland. There is much scope for future studies.

We are very grateful to Geoffrey for his ambition, initiative, enthusiasm, dedication, energy and for much hard work and look forward to seeing him back in Wester Ross in the future.

Peter Cunningham, WRFT Biologist, August 2014.

info [at] wrft.org.uk

Acknowledgements

I would like to thank Wester Ross Fisheries Trust for giving me the opportunity to do an amazing internship in one of the most beautiful areas in the world. Sincere thanks to Peter Cunningham, who gave me much advice about the project and spent a lot of his time with me, doing field survey. I am also very grateful for his help regarding this report, it could not have been written without his correction of my "French-English".

I would like to express my thanks to the volunteers who helped me for the field surveys and Stuart Allison for all of the lifts to the top of the Little Gruinard River.

Thank you to Peter Jarosz for all of your lifts to the office and your company, I am very glad to have met someone like you.

Thank you to Mr. Gordon, of Little Gruinard Estate, who allowed me to carry out this study and provided me with wonderful accommodation.

Sincere thanks for all of the people that I have met during my internship in Wester Ross and especially, Katherine, Lisa, Ginny, Carol, Dave and Brian.

Lastly, I want to thank my family and Lisa for their assistance and encouragement, without which this project would not have been possible.

Figure 1 Little Gruinard River (top of 'the deer fence pool'). Photo: Geoffrey Billier

Contents

Glossary*

Abundance: The relative amount of a species in a particular ecosystem

Benthos: All the plant and animals living on or closely associated with the bottom of a body of water

Biodiversity: The variability among living organisms from all sources including aquatic ecosystems

Biotic Index (Invertebrates): An average (by numerical abundance) of the tolerance scores of the different macroinvertebrates collected

Clay: Substrate particles that are smaller than silt (diameter < 0.004 mm)

Catchment area: Drainage area of a stream, river or lake

Dammed pool: Pools created by the impoundment of water upstream from a flow obstruction

Diversity: The relative abundance of the species

Evenness: A measure of the relative abundance of the different species making up the richness of an area

Glide: A section of stream that has little or no turbulence

Invertebrate Drift: Downstream transport of invertebrates in the water column. Can be active or passive

Kick net or D-Frame Net Sampler: A net with a pole handle that is used to collect aquatic macroinvertebrates in a stream

Larva (stage): The newly hatched, wingless, often wormlike form of many insects before metamorphosis

Macroinvertebrates: Organisms that are large enough to be seen with the naked eye and lack a backbone

Macrophytes: Aquatic plants that are large enough to be seen with the naked eye

* FAO glossary & Atlantic Salmon Ecology (Aas, et al., 2013) & Methods in Stream Ecology (Richard Hauer, et al., 1996)

Nymph (stage): The larval form of certain insects usually resembling the adult form but smaller and lacking fully developed wings

Oligotrophic: Usually refers to a body of water having a low primary productivity, poor in nutrients and rich in oxygen

Peat: Partially decomposed plants and other organic material that build up in poorly drained wetland habitats

Periphyton: Microflora (e.g. algae) and fauna (e.g. cyanobacteria, heterotrophic microbes) attached to the bottom or other submerged objects

Plunge pool: Pool resulting from the vertical fall of water over an obstruction onto the streambed

Pool: Small depression with standing water or an area of slow water in a stream.

Pupa (stage): The nonfeeding stage between the larva and adult

Rapids: A reach of stream characterized by small falls and turbulent high velocity water

Reach: A section of stream between two defined points

Riffle: A reach of stream characterized by shallow, fast moving water broken by the presence of rocks and boulders

Riparian area: An area of land and vegetation adjacent to a stream that has a direct effect on it. This includes woodlands, vegetation, and floodplains

Run: A reach of stream characterized by fast flowing low turbulence water

Silt: Substrate particles smaller than sand and larger than clay

Species Richness: The number of different species in a system (e.g. sample). The more species present in a system, the richer the system.

Surber Sampler: A standard collecting device used for quantitative analysis of benthic stream organisms

Salmon fry: The first stage of free-living period of a salmon juvenile. Usually used during their first summer

Salmon parr: Juvenile salmon after the fry stage, named for the characteristic black 'parr' marks on the side of their bodies

Salmon smolt: Fully silvered juvenile salmon migrating or about to migrate to sea

Taxonomy: Science of classification of living organisms. Invertebrates are divided into a few large groups called phyla. Each phylum is made up of a number of classes. Classes are divided into orders, orders contain families, families are composed of genus, and genus of species.

Figure title list

1. Introduction

1.1. The Little Gruinard River and Atlantic Salmon

The Little Gruinard River is located in Wester Ross in North West of Scotland, which runs from Fionn Loch into the sea at Gruinard Bay. The distance from Eileach Mhic'ille Riabhaich "Boat Pool" to the sea is approximately 8 km but the catchment area is much more bigger (78-81 km^2) (Walker, et al., 1991). The top of the river is at about 180 m elevation from the sea. The catchment area is an old forested area which is now a semi-natural ecosystem with very poor nutrients (especially Nitrogen and Phosphorus) (Cunningham, 2011). The heather and grasses are the predominant vegetation type in this area. A small wooded area is located at the last kilometre of the river. Moreover, some trees can be found in the gorges and above the boulders, which are inaccessible by the deers. The river system is known to be oligotrophic which means a river with low levels of species diversity and productivity.

Three native species are presents in the river, Atlantic salmon (*Salmo salar*), Brown Trout (*Salmo trutta*) and European Eel (*Anguilla anguilla*). In contrast to many others West river, the catch of salmon in the Little Gruinard has not shown the same level of decline that has been reported in other areas. Since 1990, a "catch and release" policy has been applied and it is likely that the policy has been significant effects about the population of salmon in the river. Moreover, the Little Gruinard River is a Special Area of Conservation (SAC) for Atlantic salmon.

More information about the characteristics of the Little Gruinard River catchment area and the salmon and trout ecology in this river can be found on the report "Little Gruinard River Fisheries Management Plan 2011" by Peter Cunningham.

1.2. The Benthic Macroinvertebrates

By breaking down the term, it is possible to give a good definition of what is a Benthic Macroinvertebrate. By convention, the term "benthic" means the bottom of a loch or a river, "macro" refers to the organisms large enough to be seen without the use of a microscope and "invertebrate" means without a backbone. By consequence, a benthic macroinvertebrate is an invertebrate fauna (i.e. a "water bug") living at the surface of the channel bottom (e.g. sand, gravel, cobble, boulder...) retained by a 500-µm net. This includes arthropods (insects, mites, scuds and crayfish), molluscs (snails, limpets, mussels and clams), annelids (segmented worms), nematodes (roundworms), and platyhelminthes (flatworms). Most of the invertebrates live part or most of their life cycle attached to submerged rocks, logs, and vegetation (Richard Hauer, et al., 1996). At last the abundance and diversity of macroinvertebrates can be used as an indicator of ecosystem health and of local biodiversity.

1.3. About the study and the author

I am a French student in the engineering school, Ecole Nationale Supérieure Agronomique de Toulouse ‘ENSAT’, and I am currently in a gap year. I am studying quality and management environmental and I want to specialize in Fisheries management.

During my gap year, I had the opportunity to do an internship in the Wester Ross Fisheries Trust and to conduct my own project during four months. This project involves studying the benthic macroinvertebrates on the Little Gruinard River. One of the main purposes of this study is to do an inventory of the macroinvertebrates that can be found on the river. In fact, a project consisting of planting trees in all the Little Gruinard River catchment area will be carry out in 2015. The aim of this project is to improve the quantity of nutrients in the system and therefore to increase the biodiversity and the productivity of the river. Such a project will affect the macroinvertebrates (composition, number, biodiversity...). In order, to assess the effects of this project on the macroinvertebrate communities and more generally on the river, analyses have to be carrying out before and after the realisation of the project. This study is therefore the ‘pre-study’ before the achievement of the project.

2. Inventory of aquatic macroinvertebrates in Little Gruinard River

2.1. Introduction

As explained in the previous paragraph, one of the main purposes of this study is to provide baseline information on the aquatic invertebrates in the Little Gruinard River. This inventory will provide information on the current aquatic macroinvertebrates assemblage but also a macroinvertebrates database for further analyses (e.g. assessment of water quality). Furthermore, the study will allow doing replicates with the same protocol in the future in order to make comparisons.

The inventory aims to answer the different following questions:

- Which are the invertebrates present in the Little Gruinard River?
- Which are the five most common species?
- Is there a difference in terms of invertebrate composition and diversity with the elevation?
- What about the biodiversity of the river?
- What kind of habitat is the more favourable to the invertebrates?
- Are there some specific patterns of microhabitat preference?

2.2. Methods and site selection

2.2.1. Stream profile of Little Gruinard River and sampling sites

In order to assess the diversity of macroinvertebrates in the river, it is necessary to choose different habitat types (macro and micro habitats) at different elevation along the river. In fact, physical attributes (i.e., elevation, depth, velocity, substratum...) usually dictate the diversity and abundance of invertebrates (Hynes, 1970). For example, the macroinvertebrate populations which occur in a pool will probably be different from the invertebrates which are present in a riffle. In the same way, the macroinvertebrate assemblage is probably different according to the substratum (silt/clay, gravel, boulder...). In order to help to the determination of the sampling site a Stream profile of the Little Gruinard River was conducted.

We used a GPS Garmin Etrex (precision +/- 5m) and we walked along the river from the river mouth (sea) to the Boat Pool. The elevation was recorded each 50 m and any interesting structures (e.g., forest, stream, pool, cascade…) were marked (Fig. 2).

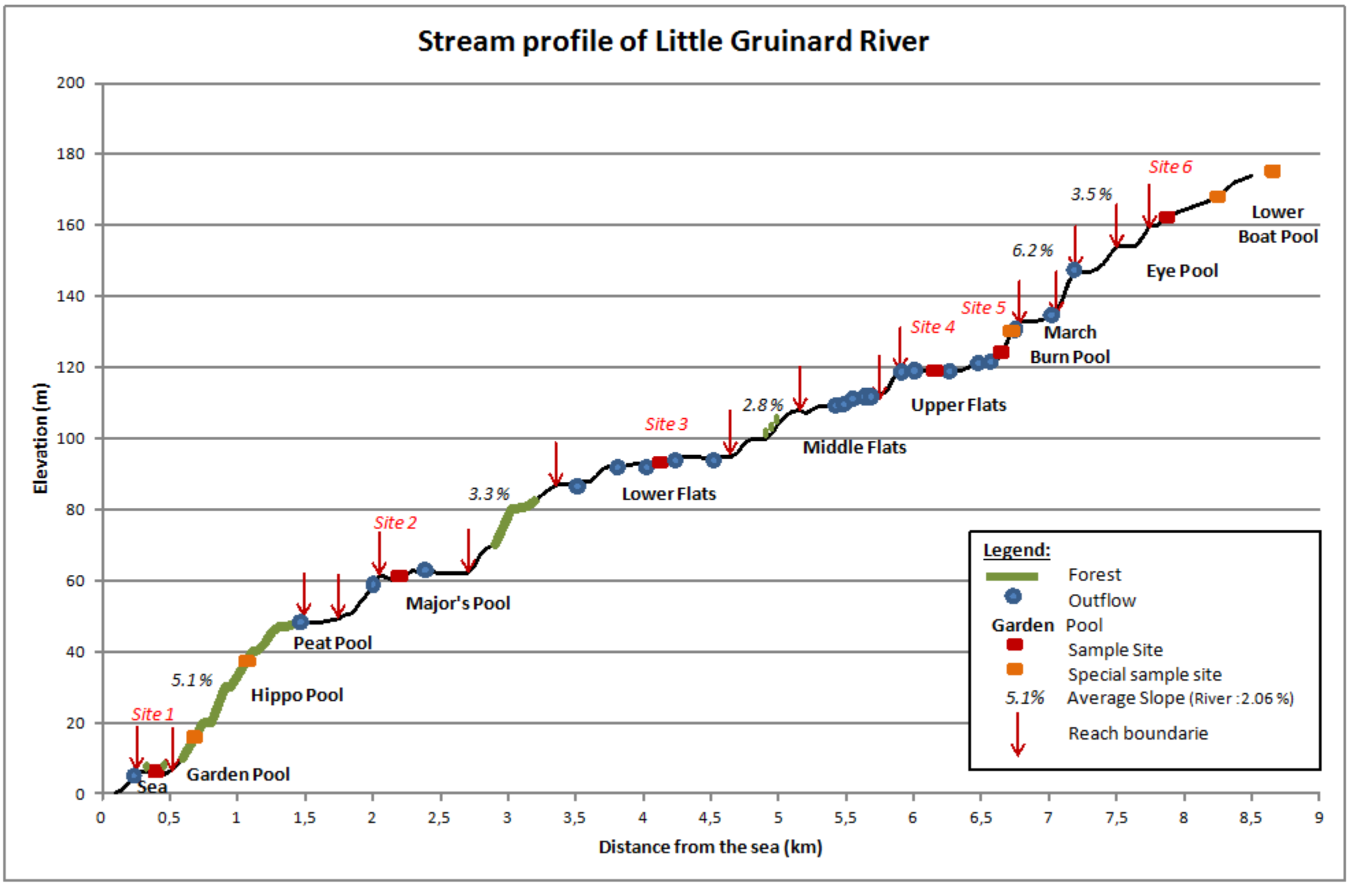

Figure 2 Stream profile of Little Gruinard River constructed from field survey

The channel units (e.g., cascade, riffle, run, glide, pool...) are recognizable and identifiable on the graph. Note that the trees are only located on the gorge where the slope is important. The average slope of the river is 2.06% with some more sloping section at 6.2%.

Using this stream profile and the onsite field observations (e.g. substratum) six sampling sites were selected along the stream. To take account to the influence of the loch and the sea one sampling site at both locations was chosen. Then, the other sampling sites were selected to represent a variety of habitats and physical attributes. The size categories used to describe the diameter of the substratum were: silt/clay (<0.06 mm), sand (0.06-2.0mm), gravel/pebble (2-64mm) and cobble/boulder (>64mm).

For each sampling sites a 'sample sheet' containing all the characteristics of the habitat was filled (Annex 1). All the data in the localization description were recorded by a GPS. The wide and the mean depth of the river were estimated with a tap. The mean velocity was recorded by the Velocity-Area method using a float. Finally, the physical and chemical parameters of water such as conductivity, pH, temperature and the presence of aquatic weeds were noted in each sampling sites.

This is a small description of the sampling sites:

- Site 1: Below Garden Pool

It is a step/pool with some riffle/run located at the mouth of the river. The substratum is mainly boulders and the water velocity is relatively important (16/03/2014: 93.16 cm/s, 14/04/2014: 55.98 cm/s). There are also some particular habitats such as plunge pool, dammed pool...

- Site 2: Above Hamishes Run

It is a riffle/run section very shallow (average depth: 39 cm) located at 2.25 km from the sea. The water velocity is important (16/03/2014: 78.54 cm/s, 14/04/2014: 73.56 cm/s) and the substratum is mainly small cobbles. It is a salmon redds.

- Site 3: Lower Flats

This section is a flat located at 4.15 km from the sea. Silt and sand are the mains substratum. The average depth is quite important (95 cm) and the water velocity is relatively low (16/03/2014: 43.91 cm/s, 14/04/2014: 22.58 cm/s). The aquatic vegetation is very abundant.

- Site 4: Upper Flats

It is a glide situated at 6.1 km from the sea. The substratum is mostly sand and gravel. The water velocity is low (16/03/2014: 47.70 cm/s, 14/04/2014: 30.40 cm/s).

- Site 5: Above the Upper Flats

It is a riffle/run channel situated at 6.84 km from the sea. The water velocity is quite high (16/03/2014: 66.81 cm/s, 14/04/2014: 28.02 cm/s) and the substratum is cobble. It is a salmon redds.

- Site 6: Eye Pool

This pool is located just below the Pait Fhearchair at 7.48 km from the sea. The water velocity is very low (< 10 cm/s) and the substratum is mainly silt and clay with large boulders.

To finish, five special sampling sites were selected. They are some particular micro-habitats. The five special sampling sites are:

- The Garden Pool Forest (forested area, many woody debris, shadow section)
- The Fire Tree Pool (cascade section)
- Allt an Ruidh Mhaoil (a small stream flowing into Little Gruinard River)
- Pait Fhearchair (a big pool)
- Below the boat Pool (a riffle section between the pool and the loch)

2.2.2. Kick Net sampling

Several methods and sampling devices exist to collect the macroinvertebrates (Surber sampler, Kick Net sampler, Hess sampler, Ekman grab...) and all of them have benefits and disadvantages depending on the size of the river, the depth, and the size of substratum. In the river, the macroinvertebrates can be collected by disturbing bottom sediments and catching them in a net held downstream. Kick Net sampler also called D-frame net sampler was selected for this study (Fig. 3). In fact, it is the most efficient sampling device when the depth can be higher than 60 cm (but less than 1 m) and the size of the substratum bigger than 20 cm.

The Kick sampling method requires two people for two reasons: the safety and the difficulty to carry the sample. A kick area (30 cm * 100 cm) was delineated in the bottom of the river. The mesh size of the net was 500-µm which is not enough smaller to collect the early life stages of the invertebrates and the Oligochaeta. The first person held the kick-net and the second one did a combination of hand and foot action in order to disturbed the substratum materials and dislodged the invertebrates. Then by the action of the current they were swept into the net. The biggest cobbles were also carefully brushed in front of the net to collect the invertebrates stuck on the surface. The substratum was kicked during 45 seconds. Replicates were carried out upstream the previous one in order to not disturb the results.

Figure 3 Kick Net sampling at Little Gruinard River. Photo: Peter D. Cunningham

The invertebrates were kept into container (1 L) only filled with river water. The containers were also analyzed within the 72 hours after the sampling to prevent specimens from deteriorating. The macroinvertebrates were identified (until the maximum level of identification) and measured to the nearest mm. Sparkling water was used to anesthetize the macroinvertebrates before their identification and 60 % of them were released alive. Then the data were used to determine the abundance, taxa richness, community composition, and biodiversity/dissimilarity index for each sampling site. The depth, the substratum size, the temperature, the ph, the conductivity, and the velocity were also measured.

The best season to carry out an inventory is the spring because most of the invertebrates have not yet hatched and the larva, pupa and nymph are still on the water. In order to record the variation during the spring and because some Trichoptera and Diptera are too small to being identified at the beginning of March five sampling surveys were conducted. The samples were carried out every two weeks from February, 22th to April, 21th. Also two samples were taken at each sampling site (one on the side and the other one on the middle of the stream) so 12 for the entire river. Graphical and statistical analyses were performed using Excel 2003 and the software R using the Vegan package.

2.3. Results

2.3.1. Inventory of macroinvertebrates

Overall, 6,212 individuals from 93 morphotaxa in 56 families, of 18 orders of aquatic insects were classified mostly to the genus and species level (Fig. 4). A full inventory is presented in appendix (Annex 2). The different orders of the class Insecta found in the Little Gruinard River are:

- Ephemeroptera or ‘Mayflies’ ‘Up-Winged Flies’
- Plecoptera or ‘Stoneflies’
- Trichoptera or ‘Caddis-flies’
- Diptera or ‘True Flies’ including Gnats, Midges, etc.
- Odonata or ‘Dragonflies and Damselflies’
- Lepidoptera or ‘Butterflies and Moths’
- Coleoptera or ‘Beetles’
- Megaloptera or ‘Hellgrammites’
- Hemiptera
- Heteroptera

The class of Hirudinea, Oligochaeta, Arachnida, Bivalvia, Gasteropoda, Gordiacea, Nematoda, and Tubellaria were also recorded in the Little Gruinard River.

Taxonomic Group	Taxa	Sites					
		1	2	3	4	5	6
Arachnida	*Acari*	5	1	1	16	2	0
	Acari	9	5	0	13	9	4
	Acari	2	0	2	0	0	0
Bivalvia	*Pisidium sp.*	49	107	11	2	61	0
Coleoptera	*Carabidae*	0	0	0	0	0	0
	Elmis sp.	0	0	0	1	0	0
	Elodes sp	0	0	3	0	0	0
	Gyrinus sp.	0	0	0	0	0	0
	Hydrocyphon sp.	3	11	0	0	0	0
	Hydroporus palustris	0	0	0	1	0	6
	Hygrotus inequalis	0	0	0	0	0	0
	Limnius sp. Adult	1	2	1	5	2	0
	Limnius sp. Larvae	5	0	4	9	2	3
	Noterus sp.	0	0	0	0	0	0
	Oulimnius sp. Adult	0	0	0	8	0	0
	Oulimnius sp. Larvae	2	0	0	1	0	0
	Platambus sp.	0	0	3	2	0	0
	Potamonectes depressus	0	0	0	0	0	1
	Unidentified coleoptera	0	0	1	1	2	0
Diptera	*Antocha vitripennis*	5	1	0	1	0	0
	Ceratopogoninae	2	0	0	0	0	0
	Chelifera sp.	4	2	0	0	0	0
	Chironomus sp.	46	28	294	33	4	7
	Chironomus sp. (pupa)	9	2	1	1	1	0
	Dicranota sp.	1	2	2	0	0	0
	Dixa sp.	0	0	0	0	0	0
	Dixa sp. Adult	0	0	0	0	0	0
	Hexatoma sp.	3	0	1	2	0	0
	Limnophora sp.	2	1	0	0	1	0
	Orthocladiinae	24	13	5	12	13	20
	Pedicia sp.	1	0	0	0	0	1
	Podominae	3	5	22	11	1	4
	Simulidae larvae	11	27	1	6	15	1
	Simulidae pupae	2	0	0	0	0	0
	Tanypodinae	44	13	39	21	3	41
	Tipula sp.	4	4	15	31	2	8
	Wiedemannia sp.	3	1	0	0	1	0
Ephemeroptera	*Baetis scambus eaton*	0	0	0	0	0	0
	Baetis sp.	148	146	14	116	176	10
	Caenis horaria	62	68	63	23	7	0
	Centroptilum luteolum	0	0	0	0	0	19
	Ecdyonorus sp.	34	27	1	7	51	0
	Ecdyonorus sp.	0	0	0	0	2	0
	Electrogena lateralis	0	0	0	0	0	0
	Leptophlebia marginata	0	0	18	0	0	65
	Paraleptophlebia cincta	1	0	46	8	0	100
	Procloeon bifidum	0	0	0	0	0	23
	Rhithrogena sp.	22	50	0	4	68	0

Figure 4 Abundance of different taxa collected with a kick net in Little Gruinard River

Taxonomic Group	Taxa	Sites					
		1	2	3	4	5	6
Gastropoda	*Ancylus fluviatilis*	4	0	0	0	0	0
	Myxas glutinosahauteur	0	0	0	0	0	0
	Planorbidae	1	0	0	0	0	0
	Radix sp.	7	2	15	34	2	3
Heteroptera	*Velia sp.*	0	0	0	0	0	0
Hirudinea	*Glossiphonia complanata*	4	2	1	4	3	1
	Helobdella stagnalis	0	0	8	6	1	4
Lepidoptera	*Nymphula nympheata*	0	0	0	0	0	0
Megaloptera	*Sialis lutaria*	0	0	5	3	0	0
Nematoda	*Nematoda*	0	0	13	2	0	0
Nematomorpha	*Gordiacea*	0	2	0	1	1	1
Odonata	*Cordulegastera boltonii*	5	3	1	6	3	0
	Dugesia sp.	0	0	0	1	0	0
	Orthetrum sp.	0	0	0	0	0	1
Oligochaeta	*Lumbriculidae*	14	28	7	0	6	0
	Lumbriculidae	19	36	33	32	38	43
	Lumbriculidae	19	46	8	6	14	4
	Nais sp.	0	0	0	1	0	0
	Stylaria lacustris	0	0	0	0	0	18
Plecoptera	*Amphinemura sulcicollis*	116	116	36	133	136	0
	Brachyptera risi	0	0	0	0	6	0
	Capnia sp.	0	0	0	0	5	0
	Chloroperla tripunctata	15	16	6	12	35	0
	Dinocras cephalotes	12	3	0	0	0	0
	Isoperla grammatica	21	40	6	21	31	4
	Leuctra hippopus	82	93	2	82	182	0
	Nemoura sp.	12	55	4	3	76	3
	Perla bipunctata	2	6	0	0	3	0
	Perlodes microcephallus	1	0	2	3	0	1
	Protonemura meyeri	19	37	0	0	10	1
Trichoptera	*Rhyacophila sp.*	10	10	0	2	4	0
	Rhyacophila sp.	4	2	0	0	1	0
	Agapetus fuscipes	0	0	0	0	0	0
	Agrypnia obseleta	0	0	0	0	0	2
	Brachycentrus subnubilus	0	0	1	0	0	0
	Hydropsyche sp.	76	97	6	16	267	2
	Hydroptila sp.	46	1	4	0	3	0
	Lepidostoma hirtumtaille	19	8	9	0	4	0
	Limnephilini sp.	5	1	1	16	1	1
	Limnephilini sp.	3	1	26	10	3	3
	Limnephilus rhombicus	0	0	0	1	0	0
	Mystacides sp.	0	0	0	17	0	2
	Odontocerum albicorne	0	0	0	1	0	0
	Philopotamus montanus	3	0	0	0	0	0
	Polycentropus sp.	13	14	21	24	14	11
	Sericostoma personatum	0	2	14	3	1	0
	Unknow Case Trichoptera	28	6	6	30	13	3
	Unknown Caseless Trichoptera	1	0	0	0	0	1
Tubellaria	*Dugesia sp.*	0	0	0	0	0	0

Figure 4(cont.) Abundance of different taxa collected with a kick net in Little Gruinard River

Despite the high number of different taxons, six species contributed 45 % to the total number of invertebrates in the sample collected (Fig. 5);

- *Baetis* sp. (Ephemeroptera). It is the most common species of the river.
- *Amphinemura sulcicollis* (Plecoptera)
- *Hydropsyche* sp. (Trichoptera)
- *Leuctra hippopus* (Plecoptera)
- *Chironomus* sp. (Diptera)

Some taxons can be classified as "uncommon" or "rare" for this river because they were just recorded one time over the 6212 invertebrates.

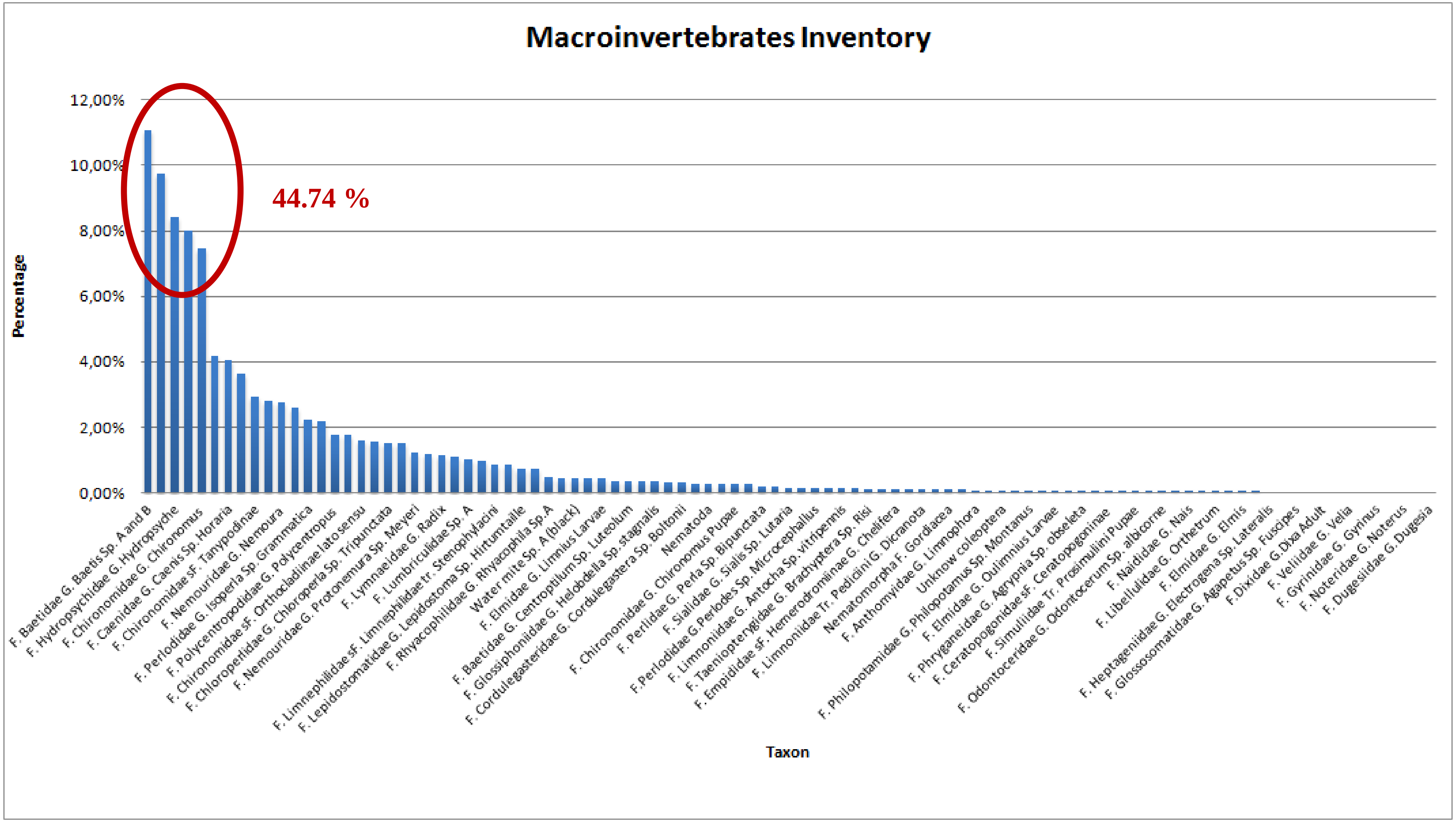

Figure 5 Macroinvertebrates inventory of Little Gruinard River (February-April 2014). N = 6212

2.3.2. Biodiversity and site comparison

Macroinvertebrates Density and Species Richness

Macroinvertebrate communities vary in abundance and taxa richness among the sites (Fig. 6). In fact, the invertebrates are not distributed evenly throughout the river. For example, some species were only recorded at the top of the river (e.g. *Electrogena lateralis*, *Stylaria lacustris* sp.). These species are usually found on loch and here it is a clue of the influence of the loch on the river biodiversity. Some other species like *Sialis lutaria* sp. are just present in the Lower Flats.

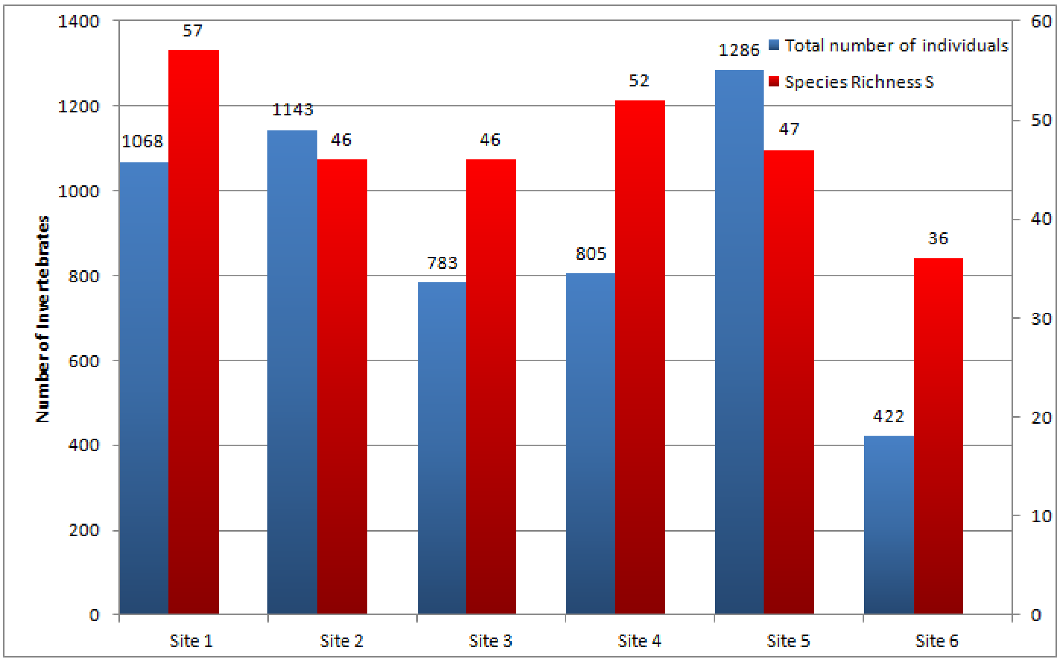

Figure 6 **Species richness and total number of invertebrates in the different sites**

Regarding the macroinvertebrates density, the site 5 (above the Upper Flats) has the maximum number of invertebrates and the site 1 (Garden Pool) has the most important taxa richness rather than the site 6 (Eye Pool) which has the lowest number for the two parameters (Fig. 6 & 7). The average macroinvertebrates density for the river is 230 invertebrates / m². Higher abundance and taxa richness appears to be associated with fast water (i.e. riffle and run).

Site	Density (#/m²)
Site 1 (1)	241,5
Site 1 (2)	292,5
Site 2 (1)	272,0
Site 2 (2)	299,5
Site 3 (1)	196,0
Site 3 (2)	195,5
Site 4 (1)	189,0
Site 4 (2)	213,5
Site 5 (1)	337,0
Site 5 (2)	306,0
Site 6 (1)	125,5
Site 6 (2)	85,5
All Sites	229,5

Figure 7 Macroinvertebrates Density

Biodiversity Index

The abundance and the taxa richness were used to calculate various population descriptors such as Shannon's Index, Simpson's Index and the Equitability Index (Fig. 8).

Site	Species Richness S	Ln (S)	Shannon's Index H	Simpson's Index D	Equitability J
1	57	4,043	3,265	0,941	0,807
2	46	3,829	3,039	0,935	0,794
3	46	3,829	2,661	0,837	0,695
4	52	3,951	3,130	0,927	0,792
5	47	3,850	2,675	0,894	0,695
6	36	3,584	2,669	0,888	0,745

Figure 8 Biodiversity Index

The Shannon diversity index (H) is commonly used to characterize species diversity in a community. The Shannon index ranges from 2.68 to 3.27 which is representative of a diverse and equally distributed community. Simpson's Index (D) is a measure of how individuals in a sample are concentrated into a few species. The value of this index ranges between 0 (no diversity) and 1 (infinite diversity). In the Little Gruinard River D is between 0.84 and 0.94. At last, Shannon's equitability (J) measures the evenness of a community. The value of this index ranges between 0 and 1 (complete evenness). It varies between 0.70 and 0.81 which is fairly good for the river.

In conclusion, the different indices show that the biodiversity of the river is quiet high. The site 1 which is a step/pool with riffle has the higher biodiversity rather than the site 3 which is a glide.

Dissimilarity/Similarity Index

A comparison among the sites was also conducted using the Bray-Curtis and Raup-Crick Index (Fig. 9 & 10). There are statistic index used to quantify the compositional dissimilarity/similarity between two different sites. The Bray-Curtis Dissimilarity Index is bound between 0 and 1, where 1 means the two sites have the same composition (that is they share all the species), and 0 means the two sites do not share any species (Bloom, 1981). The Raup-Crick Index has the same function than the previous one but it is a similarity index. The sites 1, 2, 5 seem to be similar regarding the composition of the invertebrates. It was expected because the three are riffles or runs. It also means that the elevation doesn't have a major effect on the macroinvertebrates repartition. The site 6 is very different from all others samples. It is likely due to the influence of the loch.

	1	2	3	4	5	6
2	0,237					
3	0,635	0,694				
4	0,359	0,433	0,606			
5	0,376	0,294	0,808	0,493		
6	0,796	0,839	0,645	0,749	0,865	

Figure 9 Table of the Bray-Curtis Index for the different sites

	1	2	3	4	5	6
2	0,001					
3	0,277	0,088				
4	0,906	0,336	0,018			
5	0,036	0,001	0,017	0,173		
6	0,952	0,913	0,683	0,607	0,742	

Figure 10 Table of the Raup-Crick Index for the different sites

2.3.3. Distribution by orders

In order to assess the composition of the macroinvertebrate populations, the invertebrates were sorted by orders. It hasn't been possible to weight the invertebrates during the survey because it requires a very accurate scale due to the low weigh of the invertebrates. However, all of the invertebrates were measured. Some length-weight relationships are now available on the web but only 40% of the invertebrates present on the river were found on previous studies. Moreover, the precision is not very high especially for the smallest taxon. Therefore, we just worked with the number of individual in the rest of this study.

The graphs of distribution by orders for each site and for the all river are shown below (Fig. 11 & 12). Plecoptera was the more prevalent of order on the river following by Ephemeroptera, Diptera, Trichoptera, and Oligochaeta. The glide at the Lower Flats is populated mainly by Diptera (*Chironomus* sp.) whereas Ephemeroptera (*Baetis* sp.) was the most important order in the Eye Pool.

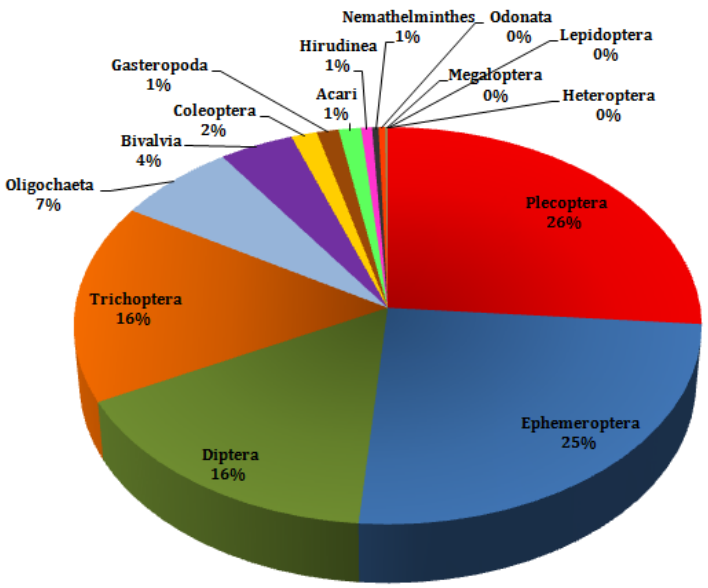

Figure 11 Composition of the macroinvertebrate population in Little Gruinard River

Moreover the most diverse orders were of Diptera (17 taxa), Trichoptera (16 taxa) Ephemeroptera (13 taxa) and Coleoptera (12 taxa) respectively.

Trichoptera, Plecoptera, and Bivalvia are mostly found on the riffles and the runs. Their body mass are quiet high rather than the other orders so they can represent an important source of food for the fish.

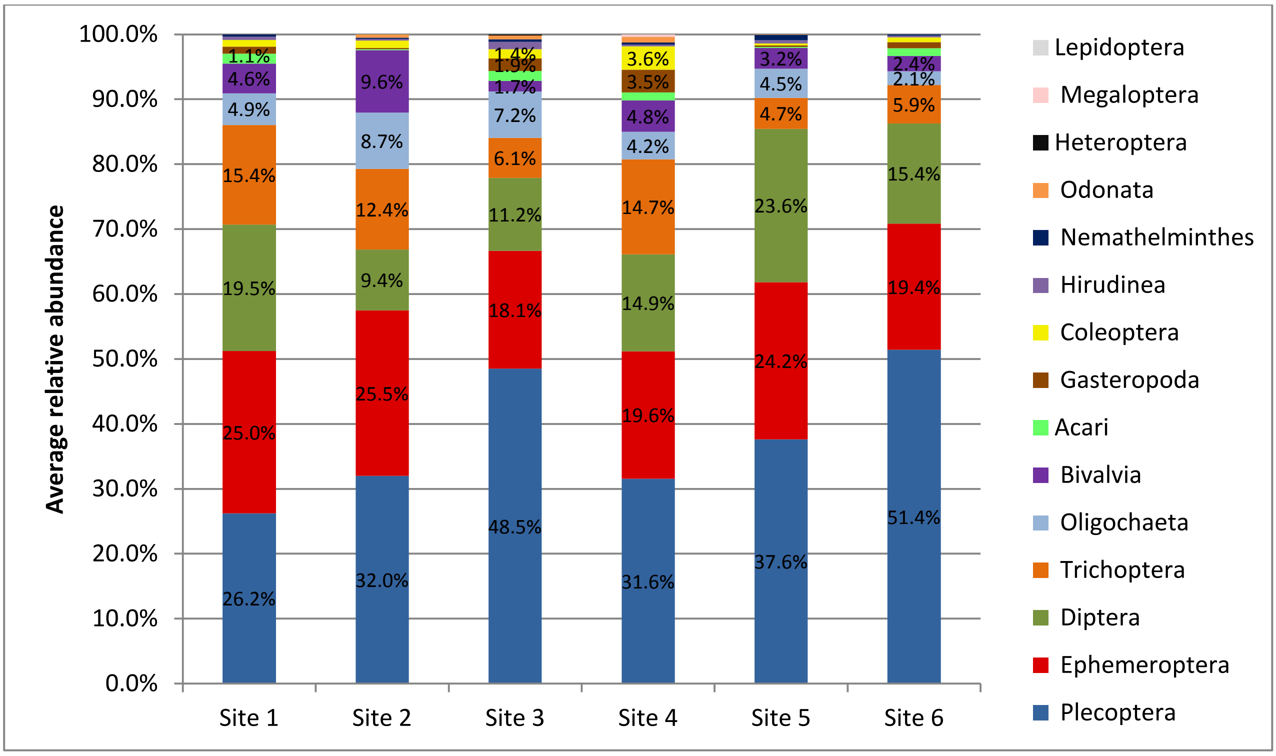

Figure 12 Composition of the macroinvertebrate population for each site

2.4. Discussion and conclusion

The Little Gruinard River has high biodiversity with much difference between the sites in terms of diversity and taxon. There is a habitat-specific distribution at different scales of resolution; large scale (e.g. pool/glide/run/riffle) and small scale (e.g. middle/bank side of the river). As expected the physical attributes play a considerable role in the macroinvertebrates diversity and distribution. Fast waters have the most important and diverse taxa. Also the elevation has no effect on the macroinvertebrates distribution whereas the loch at the top of the river has an important effect on the river. Trichoptera, Plecoptera, and Bivalvia are found mostly in fast water. Diptera and Oligochaeta taxa are more abundant in slow water. Regarding the Ephemeroptera taxa it mainly depends upon the species.

3. Stream ecology and community interactions

3.1. Introduction

There are four basic nutritional resource categories in river ecosystem available for the invertebrates; the Coarse Particulate Organic Matter 'CPOM', the Fine Particulate Organic Matter 'FPOM', the Periphyton and the Prey (Merritt, et al., 1996).

The CPOM is all of the particles greater than 1 mm in size. It is represented by litter accumulation (leaves, needles, bark...), plant parts and large woody debris (branches, logs...). The FPOM are the particles greater than 0.5 µm but less than 1 mm in size. It is composed of detrital materials and the result of the reduction and decomposition of CPOM. The Periphyton is the attached algae that can be found on rock, wood and plant surface. Finally, the prey is all invertebrates captured by predators.

The invertebrates have developed some morphological-behavioral adaptations depending on what they feed on. It is known as morphological-behavioral mechanisms of food acquisition. This feeding adaptation depends to the basic food resources categories. The macroinvertebrates are also classified into five different categories depending on the adaptation used to harvest nutritional resources (Cumins, 1973; Meritt, et al., 1996; Cummins, et al., 2005).

The shredders feed on CPOM. They break down large particles. They are either herbivores (eat live macrophytes) or detritivores (eat dead plat materials). Among this category, there are some Trichoptera (e.g. Limnephilidae sp., Odontoceridae sp...), Plecoptera (e.g. Nemouridae sp., Leuctridae sp....) but also Diptera (e.g. Tipulidae sp.). The collectors feed on FPOM. They collect fine particles. There are two different groups depending on the feeding mechanism:

- **The filterers or suspension feeders**. They use a 'nets' or body part to filter the water (e.g. Diptera: Simuliidae sp., Trichoptera sp., Hydropsychidae sp. and Philopotamidae sp., Bivalvia: Sphaeriidae sp.)
- **The gatherers or deposit feeders**. They move to gather the particles (e.g. most of the Ephemeroptera: Heptageniidae sp., Baetidae sp., Caeniidae sp., Leptophlebiida sp....)
- **The scrappers** feed on periphyton. They consume algae and associated material. This category is mainly composed by Gasteropoda (e.g. Lymnaeidae sp., Ancylidae sp., Planorbidae sp....), some Trichoptera (e.g. Glossosomatidae sp.) and Ephemeroptera (e.g. Heptageniidae sp.).

- **The predators** are carnivores and feed on prey. They are represented by the Odonata (e.g. Cordulegasteridae sp., Libellulidae sp.), most of the Plecoptera (e.g. Perlodidae sp., Perlidae sp....) and some Coleoptera.

From there, the researchers have developed the 'functional feeding group method' and some index and ratio in order to assess the trophic relations in a river (Cummins, et al., 1979; Cummins, et al., 1985). The aim of this study therefore, is to describe the general distribution of Function Feeding Groups in the river and to assess the ecological state of the Little Gruinard River.

3.2. Trophic relations of macroinvertebrates

All of the 6212 macroinvertebrates found on the river were categorized according to their feeding behaviour (Fig. 13). The 'collector-gatherers' (23 taxa) is the main group in the river following by the 'shredders' (14 taxa), 'predators' (38 taxa), 'collector-filterers' (4 taxa), the 'scrappers' (10 taxa), and the 'omnivores' (2 taxa). High numbers of *Chironomus* sp. contributed to the numerical dominance of the collector-gatherers at the site 3. *Baetis* sp. was the most important contributors to the collector-gatherers at the site 6. The riffle and run have a good homogeneity. The percentage of "collector-filterers" is very low in the glide, flat and pool. This is mainly due to the fact that the "collector-filterers" need a support like boulders and cobbles to live that are not present in these sites. At last, the Eye Pool is very different from all the others. It can be explained by the proximity of the loch but also due to habitat. It is a very particular habitat that is more similar to a loch than a river.

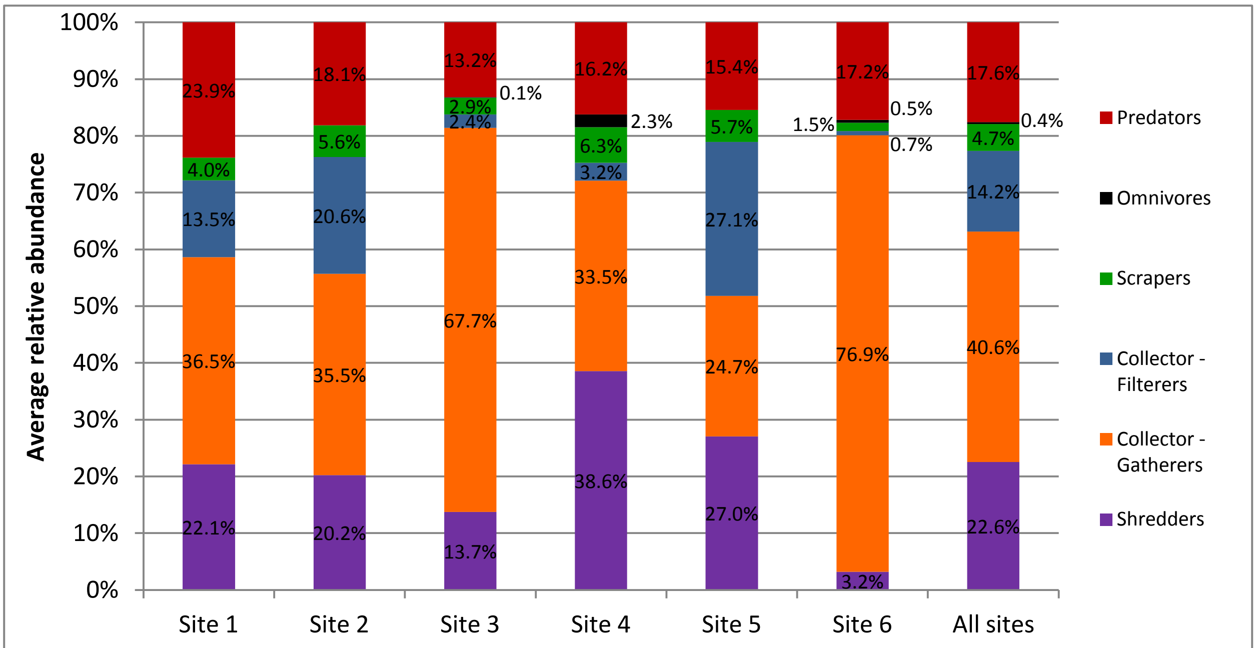

Figure 13 Relative abundance of the Functional Feeding Groups at studies sites

3.3. Functional Feeding Group Ratios

The data collected during the inventory were used to calculate the functional feeding group ratios (Fig. 14). These ratios are used as river ecosystem attributes.

Ecosystem Parameter	Symbols	Functional Feeding Group ratios	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Little Gruinard River	General Criteria ratio levels
Autotrophy to Heterotrophy Index or Gross Primary Production To community Respiration Index	Auto/Hetero or P/R	Scrapers to Shedders + Total Collectors	0,056	0,074	0,035	0,083	0,072	0,018	**0,06**	Autotrophic > 0.75
Coarse Particulate Organic Matter to Fine Particulate Organic Matter Index	CPOM/ FPOM	Shredders to Total Collectors	0,443	0,360	0,196	1,051	0,521	0,041	**0,41**	Normal shredder association linked to functioning riparian system; Fall-winter shredder populations > 0.50; Spring-summer shredder populations > 0.25
FPOM in Transport (suspended) to FPOM in Storage Sediments (deposited in benthos)	TFPOM/ BFPOM	Filtering Collectors to Gathering Collectors	0,370	0,579	0,035	0,095	1,096	0,010	**0,35**	FPOM transport (in suspension) enriched; unusual particulate loading > 0.5
Substrate (channel) Stability	Stable Channel	Scrapers + Filtering Collectors to Shredders + Gathering Collectors	0,299	0,470	0,065	0,131	0,634	0,028	**0,30**	Stable substrates (e.g bedrock, boulders, cobbles…) plentiful > 0.50
Top-Down Predator Control	Top-down control	Predators to Total of all other groups	0,313	0,222	0,152	0,194	0,182	0,208	**0,21**	Expected predator-prey balance = 0.10 – 0.20
Predictable Food Supply for Water Column Feeding Fish	Juvenile Salmonid Food Index	Filtering + Gathering Collectors to Scrapers+Shredders+Predators	1,000	1,275	2,339	0,580	1,077	3,473	**1,21**	Good food supply for water column feeding fish > 0.50
		Behavorial Drifter / Accidental Drifter	1,525	1,469	0,344	0,277	0,853	0,498	**0,83**	Good food supply for water column feeding fish > 0.50

Figure 14 Relative abundance of the Functional Feeding Groups at studies sites

The first ratio is an indicator of the relative importance of autotrophy to heterotrophy. The ratio indicates that the Little Gruinard River is very heterotrophic (Auto/Hetero = 0.6 < General criteria ratio levels = 0.75). It means that the river is dependent on allochthonous organic matter inputs (produced from the river-side or from the loch). The same results were obtained all along the river.

The second ratio represents the size categories and the relative amounts of coarse CPOM and FPOM in transport and storage. It indicates the availability of food resource for shredders, which relates to the riparian zone. The results underline the importance of shredder activity and indicate that the species depend mainly on slow processing rate of litter. It is a spring-summer shredder population (Cumins, et al., 1989). The site 4 seems to be different from the other one; it is likely due to important aquatic vegetation.

The third ratio is called 'substrate stability'. All of the sites except the riffle in the site 5 are under the general criteria (the Little Gruinard River 0.3 < General Criteria Level = 0.5) meaning that the channel stability for the river is poor. There are few attachment sites for the macroinvertebrates (e.g. coarse sediments in riffles, large wood, rooted aquatic vascular plants…).

The ratio FPOM in transport (suspended) to FPOM in storage in sediment (deposited in benthos) is particularly low for the river except in site 2 and 5 (the riffle). It is explained by the scarcity of stable substrates. In fact, there is a low abundance of filtering collectors, because they require such locations to set up their filtering stations.

The Top-Down Predator control indicates a typical predator to prey ratio. There is a balance between prey species with long and short-term life cycles.

Finally, the last ratio is called the Juvenile Salmonid Food Index. It can be calculated by two means. The first one is an estimation of the food available for the fish in the water column using the functional feeding group. The second one is calculated by using the data recorded during the drift net sampling. In the both method, it appears that there are a good food supply for the water column feeding fish.

3.4. Discussion

The Little Gruinard River is distinctly heterotrophic and dependent on allochthonous organic matter from the riparian zone, as indicated by the dominance of shredders and collectors that use detritus as a food resource. The significant numbers of shredders indicates that the system is a spring-summer shredder river. The shredders are dependent upon litter that requires a long conditioning time (time required for plant litter to be sufficiently colonized by stream microbes to render it a food resource usable by the invertebrates).

The results can change depending on the date of the survey. In fact some invertebrates change their feeding behavioural when they growth. Moreover, most aquatic invertebrates are not obligate feeders. This means that they are not restricted to one type of food or feeding strategy (i.e. they don’t exclusively fit into only one of the Functional Feeding Group categories).

In order to increase the productivity and the biodiversity of the river, one way is to improve the channel stability. In fact, by improving the channel stability, there will have more attachment sites for the macroinvertebrates so more prey for the predators and by consequences more food available for the fish. We can also think that the increase of food resource will affect either the density of fry/ parr and smolt or their growth. It is like a ‘cascade action’. The channel stability can be improved by adding large woody debris into the river. So, the project of planting trees along the river is one of the best long-term methods.

4. Physico-Chemical parameters and water quality of Little Gruinard River

4.1. Introduction

The aim of this study is to record the physical and chemical parameters of the water in order to assess water quality of the Little Gruinard River.

4.2. Methods

4.2.1. Temperature, pH and Conductivity

Temperature, pH and the conductivity were recording for each sampling site during the kick net sampling (Tester: Hanna Combo pH & E.C HI 98129). A Tinytag data logger which is an electronic device for monitoring temperature was set on the river at the Garden Pool. The temperature was recorded every hour from February 22th to April 12th.

4.2.2. Stream level

In order to avoid sampling during a flow or a very dry period, the stream level was recorded everyday with a graduated rule located below the garden pool.

4.2.3. Kick Netting and Biological Monitoring Working Party (BMWP) method

The macroinvertebrates can be used as an indicator to assess water quality. It is easier than the chemical method and presents a lot of advantages. In fact, the invertebrates are present all the time in the river and they are very sensitive to pollutants so any pollution will perturb them. To evaluate water quality using the invertebrates, we calculated a Biotic Index score. This index is based on the premise that pollution tolerance differs among macroinvertebrates. Therefore, researchers have classified all the invertebrates according to their tolerance to organic pollutants. Each invertebrate family found in a sample have a score from 1 (very tolerant to pollution) to 10 (very sensitive to pollution) based on its sensitivity to organic pollution. For example, some invertebrates such as Plecoptera are extremely sensitive to organic pollution and can only live in clean water, whilst some, such as Oligochaeta ('worms'), can tolerate or thrive in polluted conditions. In between these two extremes, other invertebrates show a range of sensitivities.

Scientists, fisheries managers and also anglers are now using a well known method through the UK which is called the Biological Monitoring Working Party 'BMWP' method (Water

Framework Directive - United Kingdom Advisory Group, 2008). The Biotic Index (i.e. BMWP score) is the sum of the tolerance value of each invertebrate found in the river. A higher BMWP score is considered to reflect a better water quality. Moreover, because the BMWP score depends to the family richness, it is fairly common to calculate the Average Score Per Taxon 'ASPT' by dividing the BMWP score by the number of scoring families (TAXA). The ASPT ranges from 0 to 10.

The BMWP score, ASPT, and number of different invertebrate families present (TAXA) are used to summarise whether the fauna present in a river is representative of clean or polluted conditions.

The sampling method consisted in 3 minutes (180 seconds) kick sampling in a riffle or a run. The three minutes were split proportionally according to the relative areas of the habitats identified. For example, riffles occupied 50 % of the site so they have been sampled for 90 seconds. All of the microhabitats were sampling during this three minutes. The sampling site was located at the Garden Pool. The invertebrates were then analysed and identified until the family level identification.

This method allows comparison in the time but also among the rivers in the UK. This method has never been carried out in the Little Gruinard River by the Scottish Environmental Protection Agency. However, this agency assessed the water quality in the closest rivers to the Little Gruinard (the Gruinard River, the Inverianvie River and the Allt Bad an Luig at Second Coast).

4.3. Results

4.3.1. Temperature, pH and Conductivity

The physical-chemical parameters of the river varied a lot both during the spring and also along the river (except for the conductivity) (Fig. 15). The temperature warmed very fast in April. Furthermore, the temperature difference between the top and the mouth of the river increased during the spring. On April 21th, the temperature difference was 2.2 °C (4 °F). It is likely due to the effects of the loch. In fact, it acts like a temperature controller because the temperature in the lock doesn't change as fast as in the river. Moreover, the water warms in flowing downstream to the sea due to the direct solar radiation. It is the greatest source of heat for the river. A diel temperature flux was also observed. For example, afternoon temperatures in late April reached 13 °C at the Garden Pool, whereas night temperatures approached 9 °C. Fluctuation in river temperature is very important both to the macroinvertebrates and to the salmon. Many organisms use temperature or temperature change as an environmental cue for emergence (e.g. macroinvertebrates) or spawning (e.g. fish) (Richard Hauer, et al., 1996).

The pH ranges from 6.7 and 8.3 and it decreases from the top of the river to the sea. It becomes more acidic near the sea. It is likely due to fact that the water flows through peatlands. Therefore the sphagnum moss acidifies water. Also a heavy rain can affect the pH of the water.

The conductivity was fairly stable. It ranged from 40 to 54 µS.

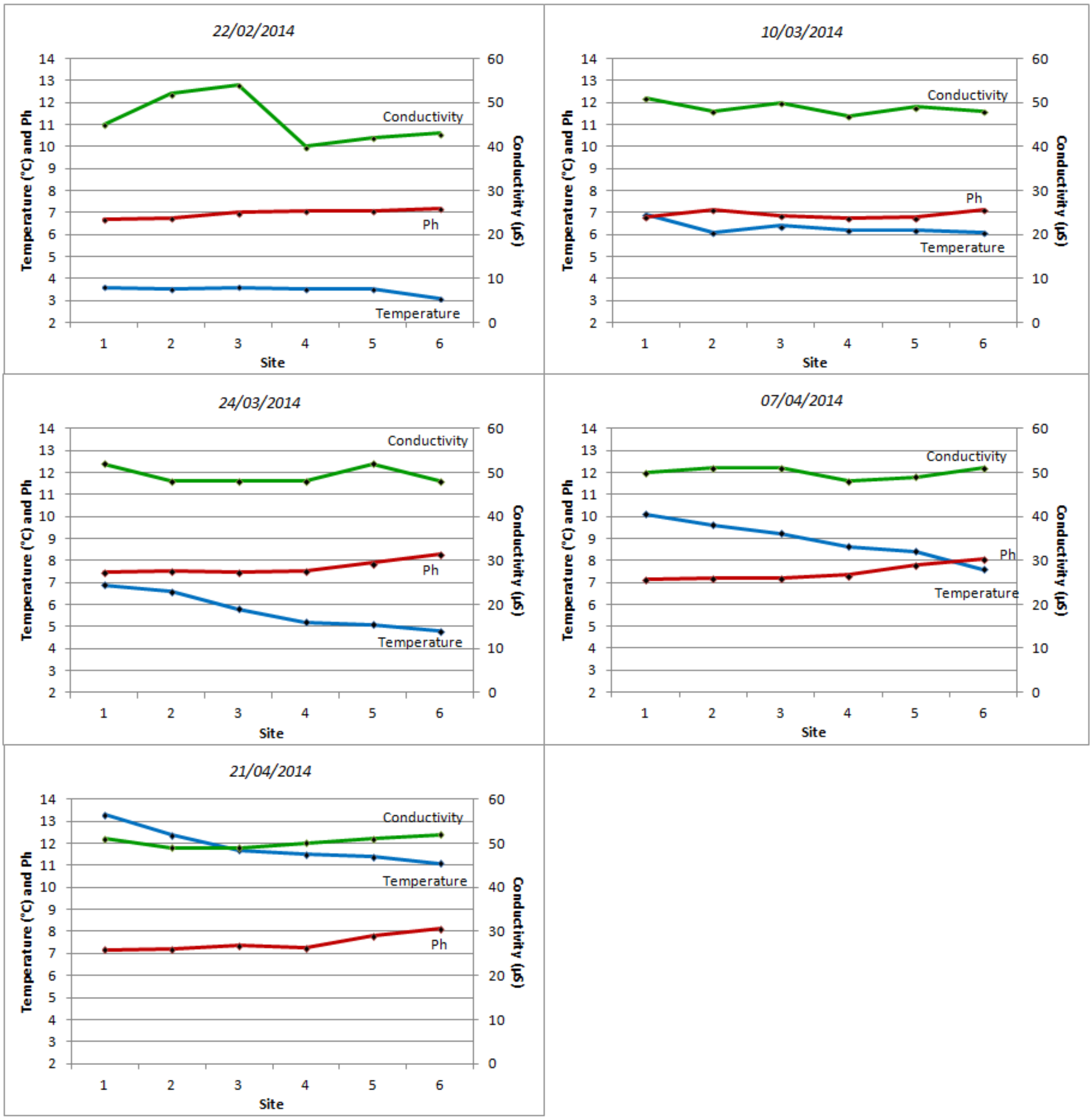

Figure 15 Physical-Chemical Parameters of Little Gruinard River

4.3.2. Stream level

The stream level varied a lot during the sample period with some very high peaks following by dry periods at the beginning of May (Fig. 16). With this graph, we can also notice how fast the stream level can be affected after a heavy and intense rain.

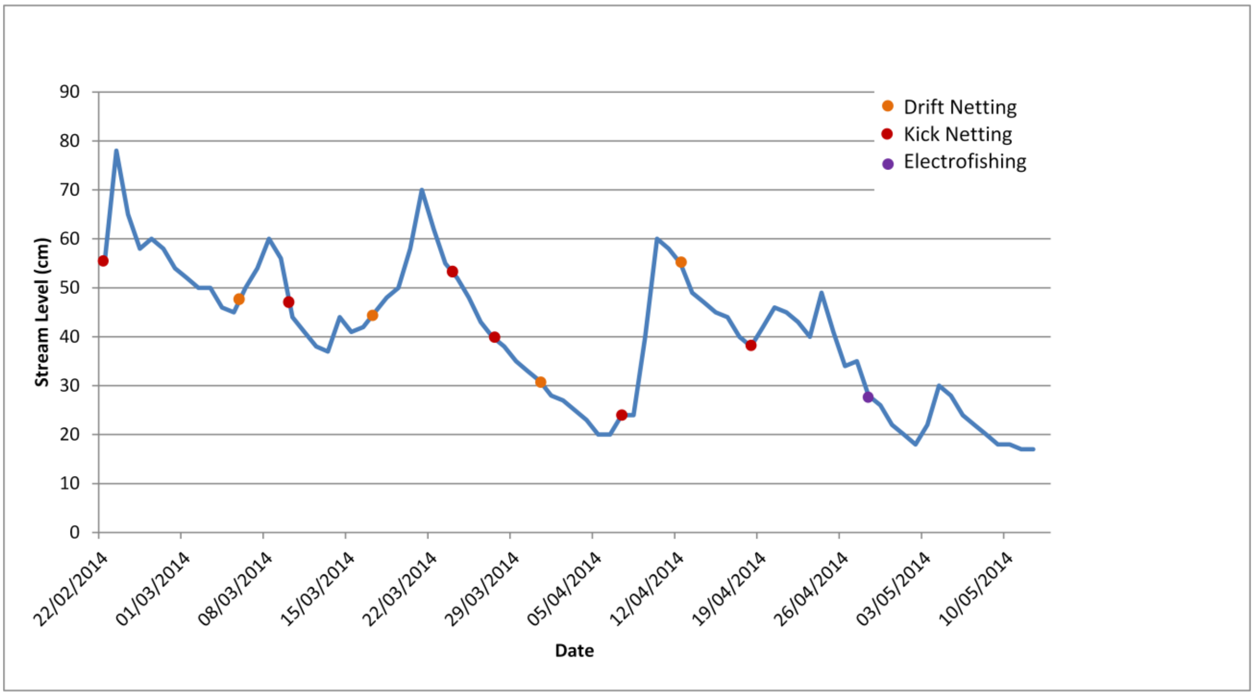

Figure 16 Stream Level of Little Gruinard River recorded at the Garden Pool

4.3.3. Environmental Quality

During the survey, 447 macroinvertebrates of 57 taxa were found (Fig. 19). The BMWP score reaches 159 which is higher than 100 (the general criteria for a very good quality) (Fig. 17 & 18). Moreover, the Average Species Per Taxon (ASPT) is 6.63 which means that water quality ranges from good to very good status.

Number of taxa	57
Total number of individuals	447
BMWP Score	159
# of BMWP taxa	24
ASPT	6,63

Figure 17 Environmental quality results

BMWP Score	Boilogical Quality	ASPT	Water Quality
Over 100	A. Very good biological quality	Over 7	Very good (natural)
71 – 100	B. Good biological quality	6.0 – 6.9	Good
41 – 70	C. Fair biological quality	5.0 – 5.9	Fair
11 – 40	D. Poor biological quality	4.0 – 4.9	Poor
0 – 10	E. Very poor biological quality	3.9 or less	Very poor

Figure 18 BMWP and ASPT score criteria

Taxonomic Group	Family	Taxa	# of Invertebrates	BMWP score
Plecoptera	Nemouridae	Protonemura meyeri	10	7
		Amphinemura sulcicollis	52	7
		Nemoura sp.	6	7
	Perlidae	Perla bipunctata	1	10
		Dinocras cephalotes	7	10
	Leuctridae	Leuctra hippopus	48	10
	Chloroperlidae	Chloroperla tripunctata	3	10
	Perlodidae	Isoperla grammatica	11	10
Ephemeroptera	Heptageniidae	Ecdyonorus sp.	17	10
		Rhithrogena sp.	20	10
		Baetis sp.	36	4
	Caenidae	Caenis horaria	31	7
Trichoptera	Rhyacophilidae	Rhyacophila sp.	2	7
		Rhyacophila sp.	1	7
	Limnephilidae	Limnephilini sp.	3	7
	Lepidostomatidae	Lepidostoma hirtumtaille	14	10
	Philopotamidae	Philopotamus montanus	3	8
	Hydroptipilidae	Hydroptila sp.	14	5
	Hydropsychidae	Hydropsyche sp.	38	5
	Polycentropodidae	Polycentropus sp.	7	7
		Unidentified Case Trichoptera	11	0
Oligochaeta	Lumbriculidae	Lumbriculidae sp.	7	0
		Lumbriculidae sp.	11	0
		Lumbriculidae sp.	9	0
Bivalvia	Sphaeriidae	Pisidium sp.	9	3
Diptera	Chironomidae	Orthocladiinae sp.	9	2
		Chironomus sp.	4	2
		Podominae sp.	1	2
		Tanypodinae sp.	23	2
	Ceratopogonidae	Ceratopogoninae sp.	2	0
	Tipulidae	Pedicia sp.	1	5
		Tipula sp.	3	5
	Limnoniidae	Hexatoma sp.	1	0
		Antocha vitripennis	4	0
	Empididae	Chelifera sp.	1	0
		Wiedemannia sp.	1	0
	Simuliidae	Prosimuliini sp.	6	5
Gasteropoda	Ancylidae	Ancylus fluviatilis	4	6
	Lymnaeidae	Radix sp.	2	3
Odonata	Cordulegasteridae	Cordulegastera boltonii	1	8
Coleoptera	Elmidae	Oulimnius sp.	2	5
Acari		Water mite sp. B (Yellow)	5	0
		Water mite sp. (Red)	1	0

Figure 19 Macroinvertebrates found during the BMWP study

4.4. Discussion and comparison

A previous study carried out in 1990 by Walker provides water quality data for the Little Gruinard River (Walker, et al., 1991). In 1990, the water was a little more acidic (pH 5.45 to pH 6.33). It can just be explained by the season of the measurements (beginning of spring in our study and summer in Walker's study). The conductivity seems to be the same (around 46 µS).

Regarding the biological quality, the Little Gruinard River BMWP score and the ASPT score are higher than the other rivers in the area (Gruinard River: BMWP 105 / ASPT 6.56, Inverianvie River: BMWP 99 / ASPT 6.6 and Allt Bad an Luig: BMWP 152 / ASPT 6.53). However, a fairly comparison is not available because the sampling have not been carried out the same year.

5. Invertebrate Drift

5.1. Introduction

The movement and the dispersal of invertebrates from one area to another is a well known phenomenon which is called 'Invertebrate Drift. It is an activity exhibited by most species. Although these organisms are benthic, they may enter in the water column and being transported downstream by the current. It is one of the most important mechanisms of colonization and dispersal. There are several explanations to the drift movements of invertebrates but they can be classified into two categories.

Firstly, there is the passive drift. Some invertebrates may passively drift by accidently being swept away by the current (Kovalek, 1979). Secondly, there is the active drift. This is known as drift behaviour. Some invertebrates drift intentionally in search of suitable resources such as food and substratum, to escape from predators or to hatch and emerge. At last, others drift to avoid unfavourable environmental conditions such as organic pollution (Smock, 1996).

Some Ephemeroptera such as *Baetis* sp. are well known for their drift behavior rather than others haven't been studied yet. It is interesting to focus on this phenomenon in order to understand the food resources available for juvenile salmon. In fact, juvenile salmon are known to feed both on benthos and on the water column and particularly on the drift food.

This study aims to answer the different following questions:

- Which invertebrates use to drift in the Little Gruinard River?
- Is there a difference between the day and the night in terms of drifting?
- Is there a drift pattern (e.g. sunrise, sunset, midday...)?

5.2. Method and site selection

There are different methods to collect the drift invertebrates. For this study we used two modified Surber sampler and a modified plankton net. Nets were set below the Garden Pool. The sampling site was representative to the river and closer to our accommodation in order to allow samples every three hours over a 26-h period.

Nets were set in a shallow area at about 5 cm above the river bottom in order to avoid collecting the invertebrates that are crawling under the cobbles. Drift nets were positioned in the middle of the river in a transect (Fig 20 & 21). The nets were set between 6:00 and 7:00 am (just before the sunrise) and they were collected every three hours over a 26-h period. In order to record the difference during the spring, the study was carried out every two weeks (4 times) from March 6th 2014 to April 12th 2014. The water velocity was recorded by the Velocity-Area method using a float. The invertebrates were analyzed within 48 hours after the sampling.

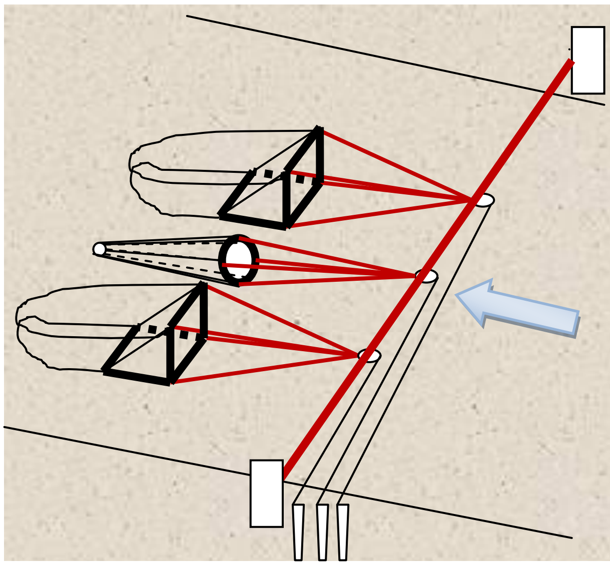

Figure 20 Diagram of the drift net sampling

Figure 21 Drift Net sampling. Photo: Geoffrey Billier

In order to compare the data, the “Drift Density” was calculated using the number of invertebrates captured by the nets per volume of water passing through the nets during the sampling period. Drift density (# invertebrates / 100 m^3) was calculated using the following equation (Smock, 1996):

$$\text{Drift Density} = \frac{(N)(100)}{(t)(W)(H)(V)(3600s/h)}$$

N represents the number of invertebrates in a sample, t the time that the net was set (h), W the net width (m), H the mean height of water column in the net mouth (m), and V the velocity ($m.s^{-1}$).

Comparisons of the species, drift densities and average size of invertebrates were performed between day and night and over a 26-h period.

At last, statistical analyses (e.g. T-test, Man-Whitney Test, Anova…) haven’t been performed due to the short time of the study.

5.3. Results

5.3.1. Species composition of drifting macroinvertebrates

Overall, 4267 invertebrates were identified and 69 different species were found in the Little Gruinard River (Fig. 22). The *Baetis* sp. and *Chironomus* sp. were by far the most present. Terrestrial insects were found in the samples. They are likely fall from the bank sides onto the water. Moreover some adults Ephemeroptera and Plecoptera were observed at the beginning of April. A lot of Coleoptera were found in the last sample (12/04/2014). This is probably due to the warmer water.

A difference between the day and the night were observed and developed in the following paragraph.

5.3.2. Behaviourally drifting invertebrates

We compared the invertebrates captured in the drift nets to the others collected during the kick net sampling in the Garden Pool in order to determinate which invertebrates are drift behavior and accidental drifter (Fig. 22). For example, a species can be absent from the drift nets but being very common in the sampling area and conversely. There was a significant correlation between the drift rate and benthic density of only 32 of the 69 taxa. Therefore, we can conclude than 32 species are behavioral drifter in the Little Gruinard River.

Taxa	# of Invertebartes	Percentage	Behavorial Drifting
Baetis sp.	1656	38,81%	Behavorial Drifter
Chironomus sp. Adult	796	18,66%	Behavorial Drifter
Other Adult Diptera	279	6,54%	Behavorial Drifter
Amphinemura sulcicollis	193	4,52%	Behavorial Drifter
Protonemura meyeri Larvae	190	4,45%	Behavorial Drifter
Rhithrogena sp.	153	3,59%	Behavorial Drifter
Leuctra hippopus Adult	119	2,79%	Behavorial Drifter
Prosimuliini sp. Larvae	91	2,12%	Behavorial Drifter
Chloroperla tripunctata	69	1,62%	Behavorial Drifter
Isoperla grammatica	68	1,59%	Behavorial Drifter
Ecdyonorus sp.	64	1,50%	Behavorial Drifter
Baetis rhodani Adult	61	1,43%	Behavorial Drifter
Protonemura meyeri Adult	60	1,41%	Behavorial Drifter
Prosimuliini sp. Adult	60	1,41%	Behavorial Drifter
Hydropsyche sp.	46	1,08%	Behavorial Drifter
Leuctra sp. Larvae	43	1,01%	Behavorial Drifter
Dixa sp. Adult	41	0,96%	Behavorial Drifter
Chironomus sp. Pupae	39	0,91%	Behavorial Drifter
Nemoura sp.	33	0,77%	Behavorial Drifter
Prosimuliini sp. Pupae	28	0,66%	Behavorial Drifter
Tanypodinae sp.	22	0,52%	Behavorial Drifter
Rhyacophila sp.	18	0,42%	Behavorial Drifter
Terrestrial insect	14	0,33%	Behavorial Drifter
Diptera sp. Adult	10	0,23%	Behavorial Drifter
Paraleptophlebia cincta	9	0,21%	Behavorial Drifter
Dixa sp. Larvae	8	0,19%	Behavorial Drifter
Unidentified Invertebartes	8	0,19%	Behavorial Drifter
Tipula maxima Adult	7	0,16%	Behavorial Drifter
Dinocras cephalotes	6	0,14%	Behavorial Drifter
Brachyptera risi	5	0,12%	Behavorial Drifter
Water spider	5	0,12%	Behavorial Drifter
Orthocladiinae sp.	4	0,09%	Accidental Drifter
Caenis horaria	3	0,07%	Accidental Drifter
Lepidostoma hirtumtaille	3	0,07%	Accidental Drifter
Polycentropus sp.	3	0,07%	Accidental Drifter
Water mite sp.	3	0,07%	Accidental Drifter
Coleoptera sp. A	2	0,05%	Accidental Drifter
Coleoptera sp. B	2	0,05%	Accidental Drifter
Diptera sp. Adult	2	0,05%	Accidental Drifter
Capnia sp.	2	0,05%	Accidental Drifter
Carabidae sp.	2	0,05%	Accidental Drifter
Ceratopogoninae sp.	2	0,05%	Accidental Drifter
Chironomus sp.	2	0,05%	Accidental Drifter
Podominae sp.	2	0,05%	Accidental Drifter
Nymphula nympheata	2	0,05%	Accidental Drifter
Hygrotus inequalis Adult	2	0,05%	Accidental Drifter
Oulimnius sp.	2	0,05%	Behavorial Drifter
F. Heptageniidae G. Ecdyonorus Sp.B	2	0,05%	Accidental Drifter
Leptophlebia marginata	2	0,05%	Accidental Drifter
Lumbriculidae sp. C	2	0,05%	Accidental Drifter
Elodes sp.	2	0,05%	Accidental Drifter
Velia sp.	2	0,05%	Accidental Drifter
Unidentified Lepidoptera Adult	2	0,05%	Accidental Drifter
Coleoptera sp. C Larvae	1	0,02%	Accidental Drifter
Coleoptera sp. D Adult	1	0,02%	Accidental Drifter
Coleoptera sp. D Larvae	1	0,02%	Accidental Drifter
Procloeon bifidum	1	0,02%	Accidental Drifter
Elmis sp.	1	0,02%	Accidental Drifter
Limnius sp. Larvae	1	0,02%	Accidental Drifter
Chelifera sp.	1	0,02%	Accidental Drifter
Gyrinus sp.	1	0,02%	Accidental Drifter
Hydraena sp.	1	0,02%	Accidental Drifter
Limnephilini sp.	1	0,02%	Accidental Drifter
Stenophylacini sp.	1	0,02%	Accidental Drifter
Lumbriculidae sp. B	1	0,02%	Accidental Drifter
Noterus sp.	1	0,02%	Accidental Drifter
Planorbidae sp.	1	0,02%	Accidental Drifter
Gordiacea sp.	1	0,02%	Accidental Drifter
Unidentified Case Trichoptera	1	0,02%	Accidental Drifter

Figure 22 Invertebrates collected during the Drift net sampling

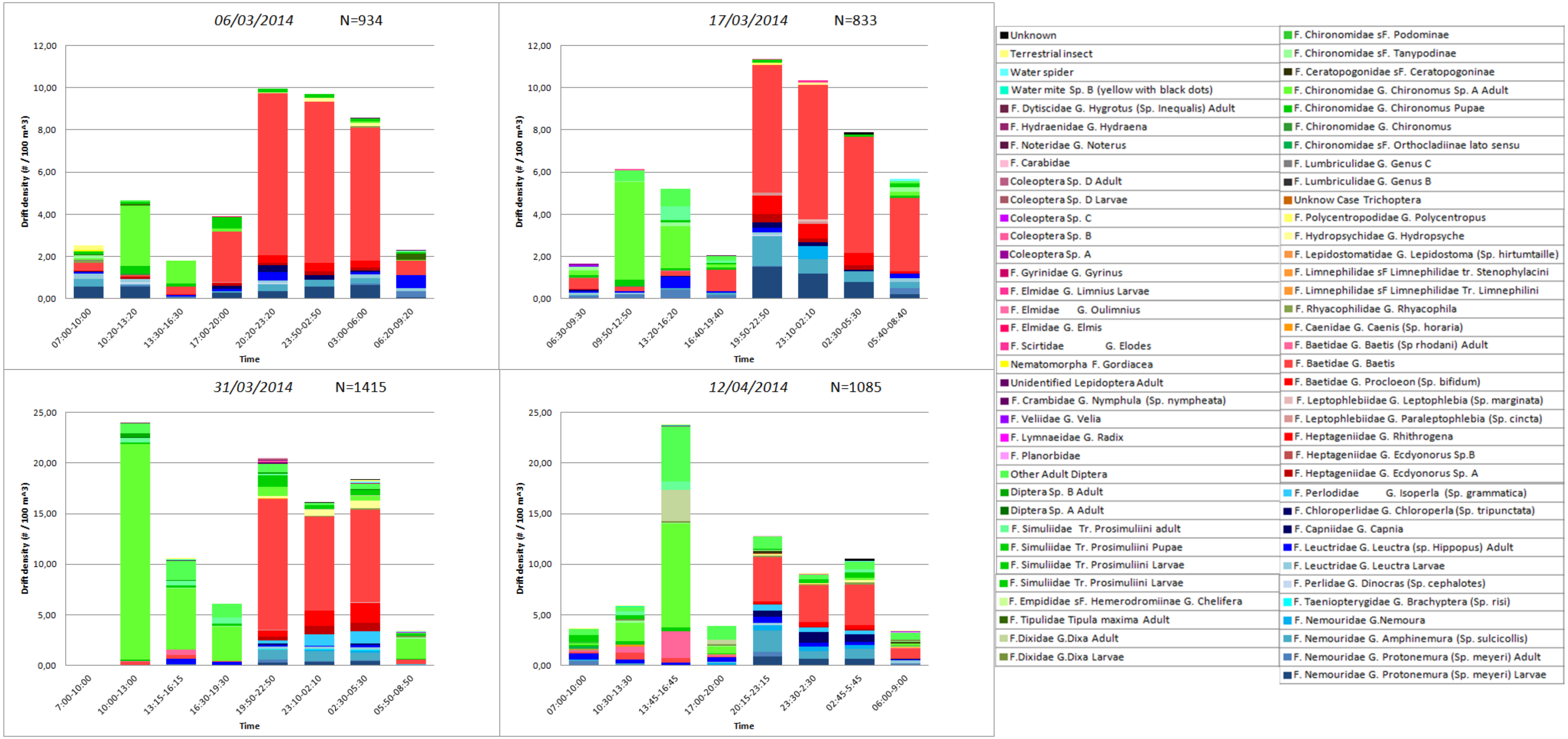

Figure 23 Drift density of the different taxa by sample date

5.3.3. Diel periodicity drift pattern

The Drift density is 56% higher at night than during the day (Fig. 24). One of the main reasons of this difference is the adaptation of invertebrates to fish predation. In fact, drifting during the day increases the risk of capture by fish. Juvenile salmon and Brown Trout are mostly visual feeders, needing to see their prey to capture them. Therefore by drifting at night invertebrates are less vulnerable to fish predation because they are less visible for the fish. This is particularly true for Plecoptera and Ephemeroptera which mostly drift at night (Fig. 23). Moreover, larger invertebrates (e.g. Perlidae sp., Ecdyonorus sp.) were collected more often at night than during the day. It is likely due to the fact that they are more readily visible than small individuals. Therefore, drifting at night is an adaptation to decrease the risk of fish predation.

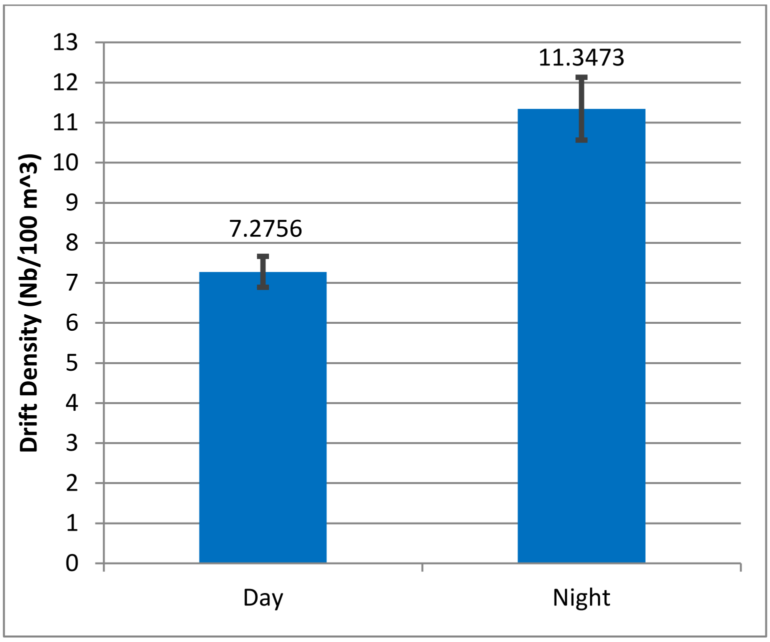

Figure 24 Day vs. Night

Conversely, Diptera and Coleoptera seem to drift during the day and not at night (Fig. 23). The reasons here are different. In fact, most of them drift because there are hatching. The maximum drift density was between 10:00 am and 14:00 am.

At last, we didn't observe a peak at the sunrise or at the sunset. The sample interval (3 hours) can explain this observation. In fact, it is not enough accurate to record the drift density during a very short event such as a sunrise or a sunset. Moreover, it is also likely that the peaks at the sunrise and the sunset are not as important during the beginning of spring as in the middle of the summer.

5.4. Discussion

This study shows that 32 species are behavioral drifter in the Little Gruinard River. There is also an important difference during the day and the night in terms of species and number. It would had been interesting to do the same study at the top of the river to compare the results with the mouth in order to understand which invertebrates are drifting from the loch to the river.

Furthermore, the day light hours varies a lot in Wester Ross during the year. This parameter may have affected the results (Fig. 25).

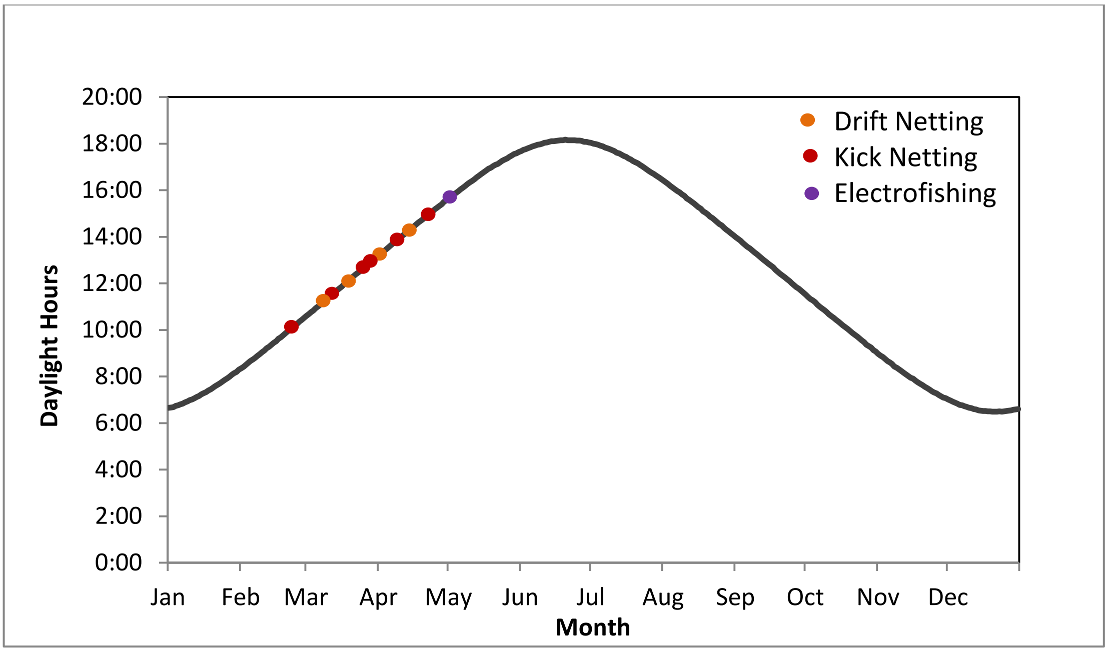

Figure 25 Daylight hours in Wester Ross

Finally the effects of the moonlight upon drifting behavior were not considered in this study although some studies have shown that a full moon can depress the invertebrate drift (Anderson, 1966).

6. Atlantic Salmon's feeding

6.1. Introduction

These days a lot of studies have focused on Atlantic salmon's feeding but most of them have reported different results (Aas, et al., 2013). It is mainly due to the conditions of the studies (e.g. location, size of river, water temperature, time of the year, and invertebrates' population present in the river) that are different.

Here, we focused on the first stage of salmon (i.e. fry, parr and smolt) in order to understand what they are feeding in the Little Gruinard River. The date of the survey was chosen in order to focus on salmon smolt. In fact, few studies exist of the food of smolt during their downstream migration.

This study aims to answer the different following questions:

- What are the young salmon feeding on?
- Does the diet composition change with fish size (fry, parr, and smolt)?
- Are the juvenile salmon selective in terms of prey types (taxon) and prey sizes?
- Is there a difference between the day and the night?
- Are the juvenile salmon drift feeder or benthic feeder?

6.2. Methods and site selection

An electrofishing survey was carried out in the Garden Pool on April, the 28th 2014 to collect juvenile salmon and especially smolt before they come to sea (Fig. 26). Previous studies have shown that the gut evacuation rate for the Atlantic salmon varies with the water temperature. At 10 °C (50 °F), the gut evacuation rate for Atlantic salmon is around 12 hours although a high proportion of meal remained in the stomach. So, in order to study the day-night pattern we electrofished the river two times, at 6:00 am (for the night diet) and at 18:00 pm (for the day diet) the same day.

Figure 26: Electrofishing survey at Little Gruinard River. Photo: Geoffrey Billier

We caught 6 fry, 6 parr and 5 smolt at 6:00 am and 5 fry, 6 parr and 4 smolt at night. The fish were measured, weighted, and scales were preserved for further analysis. We couldn't use a non lethal method to analyse the stomach content because the fish were too small. So the young salmon were killed to take off the stomach. Then, the stomachs contents were analysed and the invertebrates were identified until the maximum level (family and genus level) (Fig. 27).

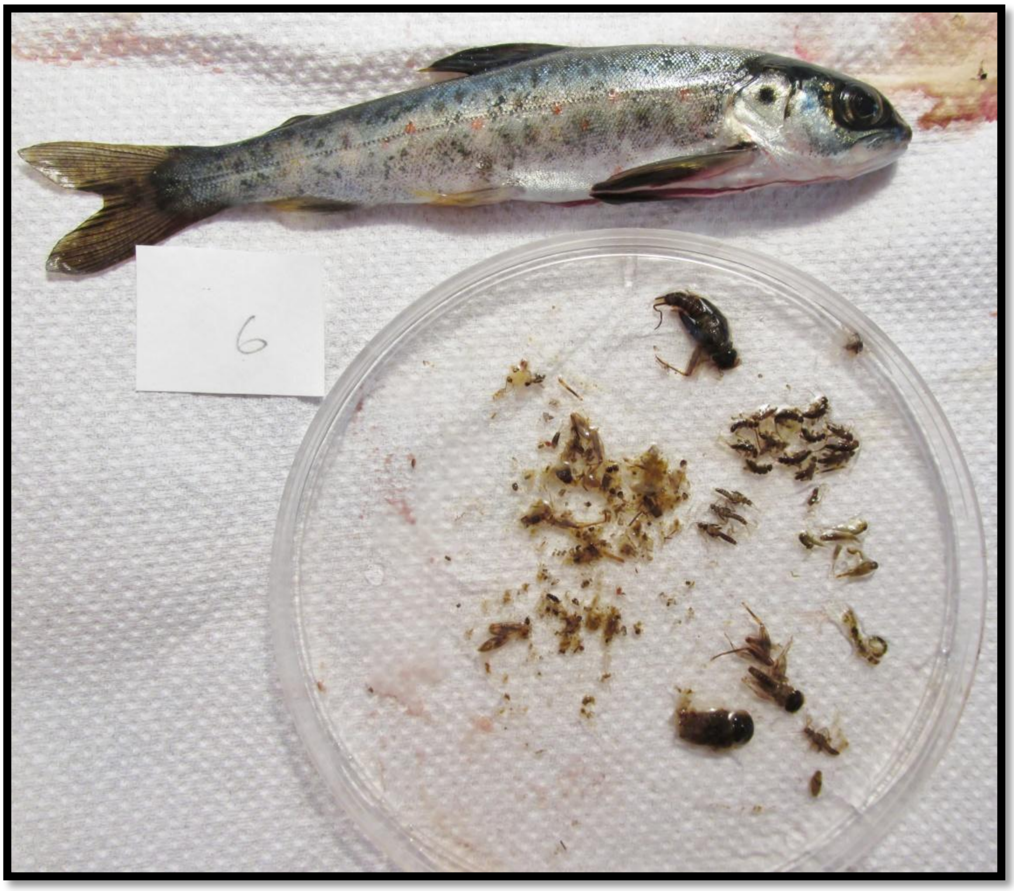

Figure 27 **Stomach content of a salmon smolt. Different taxa are recognizable on the picture (*Amphinemura sulcicollis*, *Baetis* sp, *Ecdyonurus* sp., *Dinocras cephalotes*...). Photo: Geoffrey Billier**

6.3. Results

6.3.1. Atlantic Salmon

The average length of the salmon smolt is 109.5 mm (average weight = 13.41 g) which is relatively low rather than the salmon smolt caught on the others rivers in this area (Cunningham, 2011) (Fig. 28 & 29). Regarding salmon parr and salmon fry the average length (and weight) are 83.41 mm (6.27 g) and 55.55 mm (1.63 g) respectively. Only 4 salmon smolt were caught during the night electrofishing session.

Figure 28 Juvenile salmon captured at Little Gruinard River. The upper is a salmon smolt identifiable by the silver colour. In the middle, it is a parr, easily identifiable by the black 'parr' marks on the side of the body. The lower one is a salmon fry. Photo: Geoffrey Billier

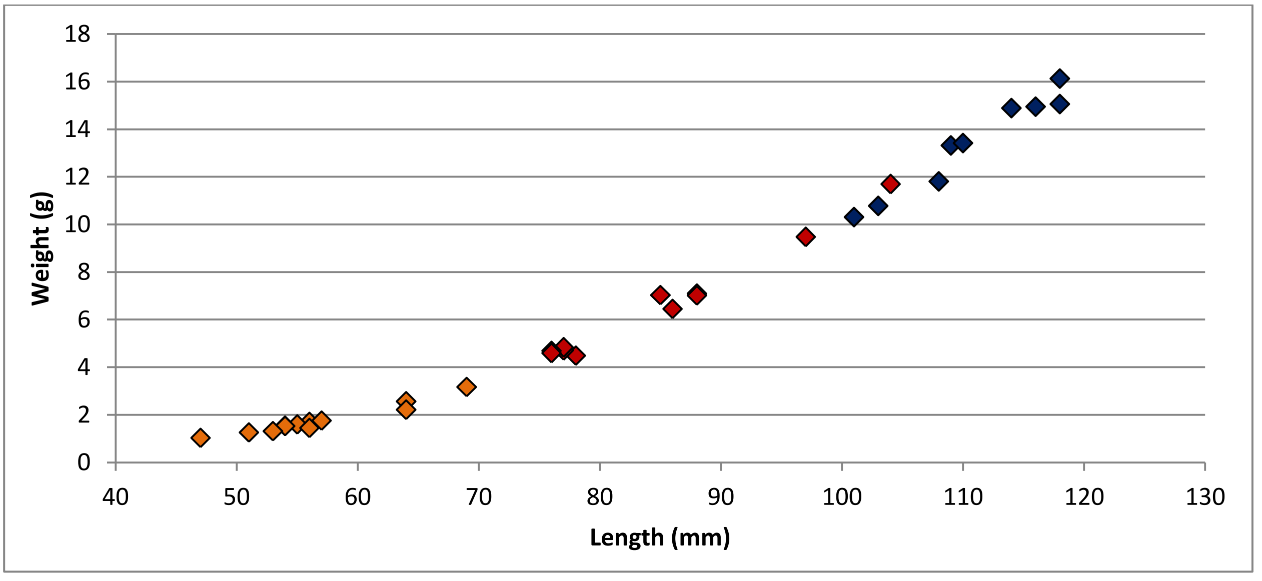

Figure 29 Length-Weight relation for juvenile Atlantic salmon. (Blue dots = Smolt, red dots = parr, orange dots = fry). N= 32

6.3.2. Diet selectivity and ontogenetic changes in diet

The analysis of the stomach reported 38 different taxons and 477 invertebrates were identified (Fig. 30). All the salmon stomachs were full.

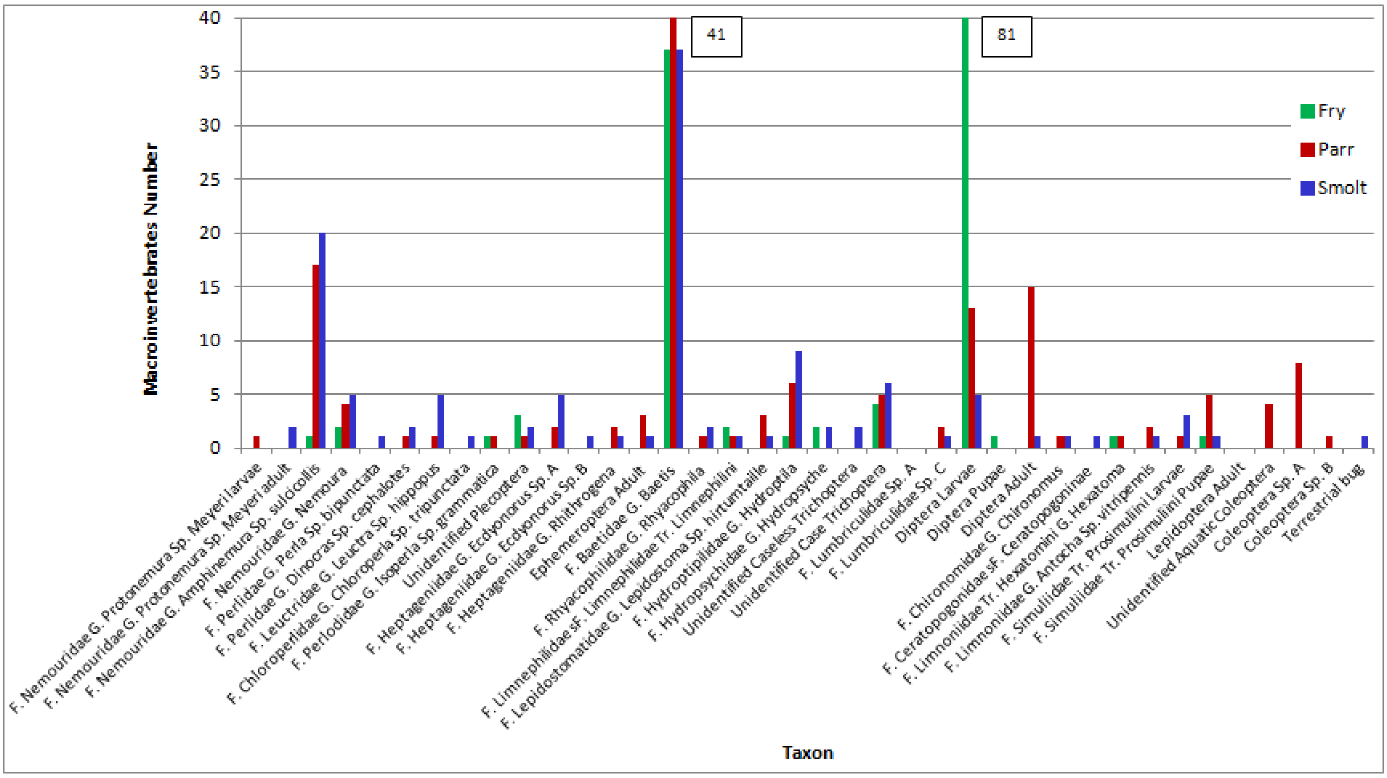

Figure 30 Juvenile salmon diet by stage (fry, parr, smolt) N=32

The comparison between the different salmon stages indicates that on the one hand they don't feed exactly on the same invertebrates and on the other hand they don't eat the same prey sizes although all the young salmon feed on *Baetis* sp. in good proportion (Fig. 30 & 31 & 32). Salmon smolt feed on the larger *Baetis* sp. and the fry on the smaller individuals.

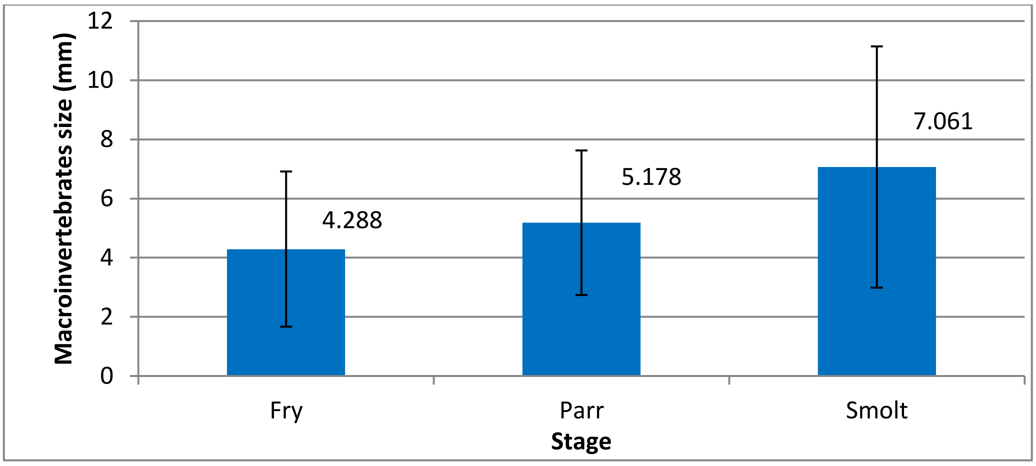

Figure 31 Relation between the salmon stage and the prey size N=32

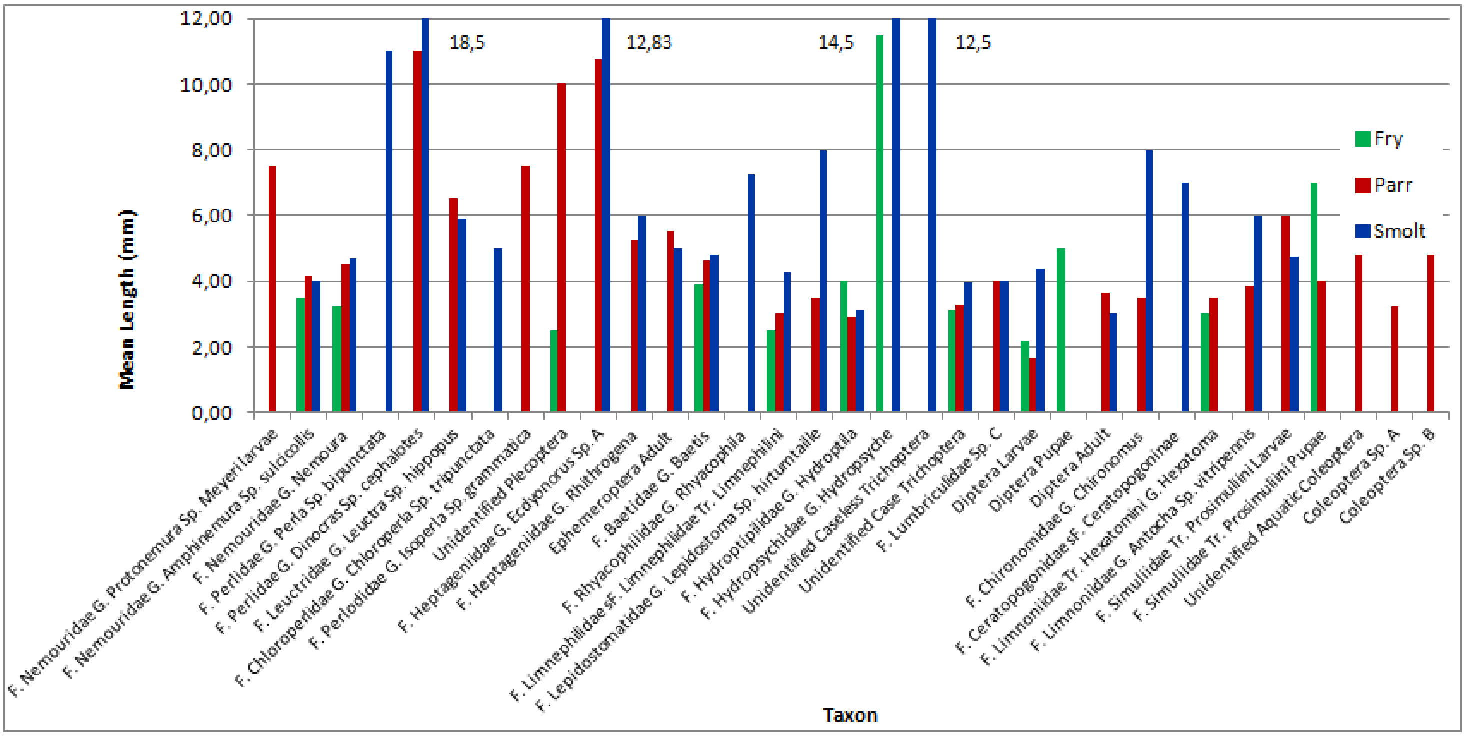

Figure 32 Average prey size by salmon stage. N=32

Salmon smolt seem to be prey selective and they feed mostly on Plecoptera, Trichoptera and Ephemeroptera. They feed on the larger individuals (*Perla Bipunctata*, *Ecdyonorus* sp., *Hydropsyche* sp...).

Salmon parr feed on every taxon. The diet reflected the food availability, they can be considered as opportunistic feeders. Moreover, salmon parr are the only one to feed one Coleoptera. Regarding the size of prey, they feed on larger invertebrates than salmon fry but smaller than the smolt. Larger parr seem to feed more frequently at the surface than the smaller one.

As for salmon fry, Diptera larvae and small species of Trichoptera dominated their diet. The average size of their prey is 4.3 mm which is 65 % smaller than salmon smolt (7.06 mm).

6.3.3. Temporal feeding patterns: Day vs. Night

Salmon smolt feed mainly at night (Fig. 33). Moreover, 81% of the food is drifting invertebrates. They eat almost two times less during the day than at night.

Salmon parr eat 31 % more at night than during the day. They also feed mainly on drift food (68% of the food resources are drift invertebrates at night and 64.5 % for the day).

Salmon fry are very different from the two previous stages. In fact, they feed two times more during the day than the night. Also, they are benthic feeders (87.5 % of the invertebrates that they eat during the day were benthic food). The results are more uncertain for the day but it seems that they feed more on drift invertebrates.

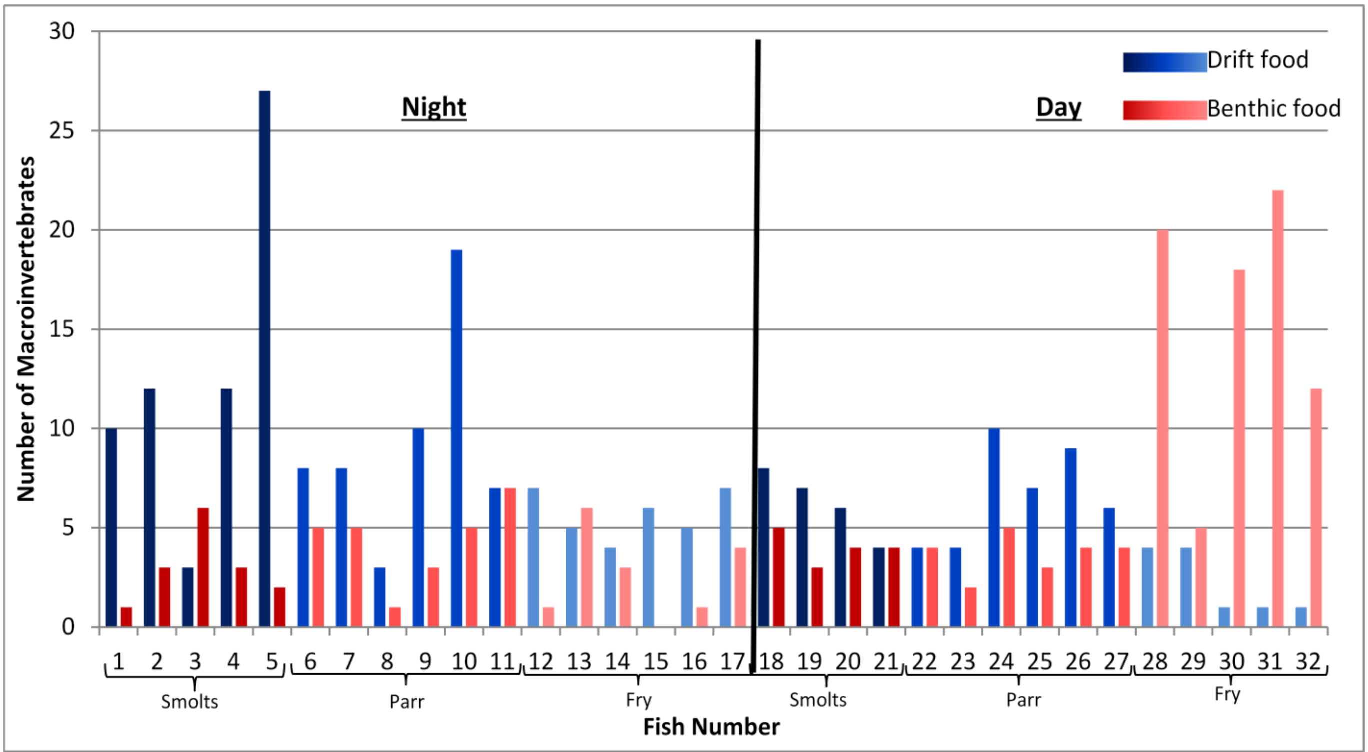

Figure 33 Temporal feeding pattern of juvenile salmon: day vs. Night. N=32

6.4. Discussion

Salmon fry, parr and smolt feed on different invertebrates both in terms of species and size. Juvenile salmon are selective in terms of prey size; the larger fish eating the larger invertebrates. The young salmon are mostly drift-feeders at night. During the day, salmon fry which live under the gravel feed mainly on benthic food and the smaller invertebrates. Salmon parr are more versatile being able to feed during the day and at night and both on drift and benthos food. It is likely due to the competitions (with smolt and between them also). At last, salmon smolt are manly drift feeders and feed preferentially at night.

As explained in introduction, the proportion of food remaining in the stomach after a meal is quiet high meaning that during the day diet analysis some invertebrates ate by the fish at night may have affected the results. At last, another important factor that deserves consideration is the relatively small sample size (N = 31) represented by these data. Therefore the results presented in this report are just a preliminary answers to the questions formulated in the introduction.

Conclusion

Overall, 10956 invertebrates were identified during this project providing a good information base on the current aquatic macroinvertebrate assemblage of the Little Gruinard River. During the macroinvertebrates inventory study, 93 different taxon and 56 families were found on the river. Six species contributed 49 % to the total number of invertebrates.

The physical attributes, especially substratum, depth and velocity dictated the diversity and abundance of invertebrates. Higher abundance, taxa richness and diversity appeared to be associated with fast water (i.e. riffle and run). The Fionn Loch at the top of the river also played a considerable role both on the macroinvertebrates composition and the physical chemical parameters of the water. Elevation above sea level didn't seem to have a major effect on the river.

The analysis of the Functional Feeding Group ratio reported that the Little Gruinard River was very heterotrophic depending mainly on allochthonous organic matter inputs. The others ratio indicated that the river was healthy although the 'channel stability' might be improved. The project of planting trees in the catchment area is one of the best long-term measures to improve the channel stability, the diversity and therefore the productivity of the river.

Water quality of the Little Gruinard River was very good according to the BMWP and ASPT score. Moreover, the river has one of the best water qualities in the area compare to Gruinard River, the Inverianvie River and the Allt Bad an Luig at Second Coast.

The drift net study reported that 32 species were behavioral drifters in the Little Gruinard River. It is a very good food supply for the juvenile salmon. Important differences were recorded between the day and the night in terms of species and numbers. The invertebrates drifted mostly at night to avoid fish predation.

Finally, the diet composition of juvenile salmon was different according to the size of the fish and the day/night. Juvenile salmon were mainly selective both in terms of prey types and average prey sizes. Salmon smolt were drift feeder, eating mostly during the night. Large-sized prey types were usually being preferred by the smolt. Salmon parr fed a little more at night and mostly on drift invertebrates. At last, salmon fry were benthic feeder, feeding mostly during the day.

Overall, this study provides a sound background for future study.

Data request

All the data collected during this project were not presented in this report. However, the data are available upon request from Wester Ross Fisheries Trust (info [at] wrft.org.uk) and Geoffrey BILLIER (geoffrey.billier [at] gmail.com)

References

Aas, Øystein, et al. 2013. *Atlantic Salmon Ecology.* 2013.

Anderson, N. H. 1966. *Depressant effect of moonlight on activity of aquatic insects.* 1966.

Bloom, S.A. 1981. *Similarity indices in community studies: Potential Pitfalls.* 1981.

Cumins, K. W. and Wilbach, M. A. 1989. *Shredders and riparian vegetation.* 1989.

Cumins, K. W. 1973. *Trophic relations of aquatic insects.* 1973.

Cummins, K. W. and Wilzbach, M.A. 1985. *Field Procedures for the Analysis of Functional Feeding Groups in Stream Ecosystems.* 1985.

Cummins, K. W., Merritt, R.W. and Andrade, P.C.N. 2005. *The use of invertebrate functional groups to characterize ecosystem attributes in selected streams and rivers in south Brazil.* 2005.

Cummins, K.W. and Klug, M.J. 1979. *Feeding ecology of stream invertebrates.* 1979.

Cunningham, Peter D. 2011. *Little Gruinard River Fisheries Management Plan 2011.* 2011.

Hynes, H.B.N. 1970. *Te Ecology of Running Waters.* 1970.

Kovalek, W. P. 1979. *Day-night changes in stream benthos density in relation to current velocity.* 1979.

Meritt, R. W. and Cumins, R. W. 1996. *An introduction to the Aquatic Insects of North America.* 1996.

Merritt, Richard W. and Cumins, Kenneth W. 1996. *Methods in Stream Ecology. Trophic Realtions of Macroinvertebrates.* 1996.

Richard Hauer, F. and Lamberti, Gary A. 1996. *Methods in Stream Ecology.* 1996.

Richard Hauer, F. and Resh, Vincent H. 1996. *Methods in Stream Ecology. Benthic Macroinvertebrates.* 1996. Benthic Macroinvertebrates.

Smock, L.A. 1996. *Macroinvertebrate movements: drift, colonization, and emergence.* 1996.

Smock, Leonard A. 1996. *Methods in Stream Ecology. Macroinvertebrate Movements: Drift, Colonization, and Emergence.* 1996.

Walker, A. F. and Walker, A. M. 1991. *The Little Gruinard Salmon catch and release experiment.* 1991.

Water Framework Directive - United Kingdom Advisory Group. 2008. *UKTAG RIVER ASSESSMENT METTHODS BENTHIC INVERTEBRATE FAUNA (RIVER INVERTEBRATE CLASSIFICATION TOOL°.* 2008.

Appendix

Annex A: Example of sampling site

Sampling site: Site 1(Below Garden Pool)

Localization:

Distance from de mouth: 399 m

Mean elevation: 5 m

GPS location (British grid): NG: 94564 BNG: 89927 Point: 88

Length of the sample site: 36 m

Description of the site sample and the environment:

Stream reaches classification: Step-Pool with Riffle and Run

Mean Velocity: 93.16 cm/s (16/03/2014), 55.98 cm/s (14/04/2014)

Wide of the stream (water): 12 m

Wide of the stream (to the sides):

Mean depth of the stream: 70 cm

Percentage of sun: 100%

Substratum and abundance of each (%):

Site 1: Side	Site 2: middle of the stream
- Silt/Clay 0%	- Silt/Clay 0%
- Sand 20%	- Sand 10%
- Pebble/Gravel 20%	-Pebble/Gravel Cobbles 20%
-Cobble/Boulder 60%	- Cobble/Boulder 70%

Presence of vegetation:

Sides: grass, thorns, fern…

Site 1: Weeds on boulders

Site 2: Weeds on boulders

Number of microhabitats:

-Pool

-Dammed pool

-Plunge pool

- Riffle

-Run

Annex B: Macroinvertebrates inventory of Little Gruinard River (February-April 2014)

Phylum	Class	Order	Family	Subfamily	Tribu	Genus	Taxon identification	Taxon level
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae			Glossiphonia	Glossiphonia complanata	Species
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae			Helobdella	Helobdella stagnalis	Species
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae				Lumbriculidae	Family
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae				Lumbriculidae	Family
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae				Lumbriculidae	Family
Annelida	Oligochaeta	Tubificida	Naididae			Nais	Nais	Genus
Annelida	Oligochaeta	Tubificida	Naididae			Stylaria	Stylaria lacustris	Species
Arthropoda	Arachnida	Acari					Acari	Order
Arthropoda	Arachnida	Acari					Acari	Order
Arthropoda	Arachnida	Acari					Acari	Order
Arthropoda	Insecta	Coleoptera	Carabidae				Carabidae	Family
Arthropoda	Insecta	Coleoptera	Dytiscidae	Colymbetinae		Platambus	Platambus sp.	Genus
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae		Hydroporus	Hydroporus palustris	Species
Arthropoda	Insecta	Coleoptera	Dytiscidae			Hygrotus	Hygrotus inequalis	Species
Arthropoda	Insecta	Coleoptera	Dytiscidae			Potamonectes	Potamonectes depressus	Species
Arthropoda	Insecta	Coleoptera	Elmidae			Elmis	Elmis sp.	Genus
Arthropoda	Insecta	Coleoptera	Elmidae			Limnius	Limnius sp.	Genus
Arthropoda	Insecta	Coleoptera	Elmidae			Oulimnius	Oulimnius sp.	Genus
Arthropoda	Insecta	Coleoptera	Gyrinidae			Gyrinus	Gyrinus sp.	Genus
Arthropoda	Insecta	Coleoptera	Helodidae			Elodes	Elodes sp	Genus
Arthropoda	Insecta	Coleoptera	Noteridae			Noterus	Noterus sp.	Genus
Arthropoda	Insecta	Coleoptera	Scirtidae			Hydrocyphon	Hydrocyphon sp.	Genus
Arthropoda	Insecta	Diptera	Anthomyidae			Limnophora	Limnophora sp.	Genus
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae			Ceratopogoninae	Subfamily
Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae		Chironomus	Chironomus plumosus	Species
Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae		Chironomus	Chironomus sp.	Genus
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			Orthocladiinae	Subfamily
Arthropoda	Insecta	Diptera	Chironomidae	Podominae			Podominae	Subfamily
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			Tanypodinae	Subfamily
Arthropoda	Insecta	Diptera	Dixidae			Dixa	Dixa sp.	Genus
Arthropoda	Insecta	Diptera	Empididae	Clinocerinae		Wiedemannia	Wiedemannia sp.	Genus
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae		Chelifera	Chelifera sp.	Genus
Arthropoda	Insecta	Diptera	Limnoniidae		Hexatomini	Hexatoma	Hexatoma sp.	Genus
Arthropoda	Insecta	Diptera	Limnoniidae		Pediciini	Dicranota	Dicranota sp.	Genus
Arthropoda	Insecta	Diptera	Limnoniidae			Antocha	Antocha vitripennis	Species
Arthropoda	Insecta	Diptera	Simumidae				Simumidae	Family
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae		Pedicia	Pedicia sp.	Genus
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae		Tipula	Tipula maxima	Species
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae		Tipula	Tipula sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Baetidae			Baetis	Baetis rhodani	Species
Arthropoda	Insecta	Ephemeroptera	Baetidae			Baetis	Baetis scambus eaton	Species
Arthropoda	Insecta	Ephemeroptera	Baetidae			Baetis	Baetis sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Baetidae			Baetis	Baetis sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Baetidae			Centroptilum	Centroptilum luteolum	Species
Arthropoda	Insecta	Ephemeroptera	Baetidae			Procloeon	Procloeon bifidum	Species
Arthropoda	Insecta	Ephemeroptera	Caenidae			Caenis	Caenis horaria	Species
Arthropoda	Insecta	Ephemeroptera	Heptageniidae			Ecdyonorus	Ecdyonorus sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae			Ecdyonorus	Ecdyonorus sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae			Electrogena	Electrogena lateralis	Species
Arthropoda	Insecta	Ephemeroptera	Heptageniidae			Rhithrogena	Rhithrogena sp.	Genus
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae			Leptophlebia	Leptophlebia marginata	Species
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae			Paraleptophlebia	Paraleptophlebia cincta	Species
Arthropoda	Insecta	Heteroptera	Veliidae			Velia	Velia sp.	Genus
Arthropoda	Insecta	Lepidoptera	Crambidae			Nymphula	Nymphula nympheata	Species
Arthropoda	Insecta	Megaloptera	Sialidae			Sialis	Sialis lutaria	Species
Arthropoda	Insecta	Odonata	Cordulegastridae			Cordulegastera	Cordulegastera boltonii	Species
Arthropoda	Insecta	Odonata	Libellulidae			Orthetrum	Orthetrum sp.	Genus
Arthropoda	Insecta	Odonata	Platycnemididae			Platycnemis	Platycnemis pennipes	Species
Arthropoda	Insecta	Plecoptera	Capniidae			Capnia	Capnia sp.	Genus
Arthropoda	Insecta	Plecoptera	Chloroperlidae			Chloroperla	Chloroperla tripunctata	Species
Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctrinae		Leuctra	Leuctra hippopus	Species
Arthropoda	Insecta	Plecoptera	Nemouridae			Amphinemura	Amphinemura sulcicollis	Species
Arthropoda	Insecta	Plecoptera	Nemouridae			Nemoura	Nemoura	Genus
Arthropoda	Insecta	Plecoptera	Nemouridae			Protonemura	Protonemura meyeri	Species
Arthropoda	Insecta	Plecoptera	Perlidae			Dinocras	Dinocras cephalotes	Species
Arthropoda	Insecta	Plecoptera	Perlidae			Perla	Perla bipunctata	Species
Arthropoda	Insecta	Plecoptera	Perlodidae			Isoperla	Isoperla grammatica	Species
Arthropoda	Insecta	Plecoptera	Perlodidae			Perlodes	Perlodes microcephallus	Species
Arthropoda	*Insecta*	*Plecoptera*	*Taeniopterygidae*			*Brachyptera*	*Brachyptera risi*	*Species*
Arthropoda	*Insecta*	*Trichoptera*	*Brachycentridae*			*Brachycentrus*	*Brachycentrus subnubilus*	*Species*
Arthropoda	Insecta	Trichoptera	Glossosomatidae			Agapetus	Agapetus fuscipes	Species
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae		Hydropsyche	Hydropsyche sp.	Genus
Arthropoda	Insecta	Trichoptera	Hydroptipilidae	Hydroptilinae		Hydroptila	Hydroptila sp.	Genus
Arthropoda	Insecta	Trichoptera	Lepidostomatidae			Lepidostoma	Lepidostoma hirtumtaille	Species
Arthropoda	Insecta	Trichoptera	Leptoceridae			Mystacides	Mystacides sp.	Genus
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilidae	Limnephilini	Limnephilus	Limnephilus rhombicus	Species
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilidae	Limnephilini		Limnephilini sp.	Tribu
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilidae	Stenophylacini		Stenophylacini	Tribu
Arthropoda	Insecta	Trichoptera	Odontoceridae			Odontocerum	Odontocerum albicorne	Species
Arthropoda	Insecta	Trichoptera	Philopotamidae			Philopotamus	Philopotamus montanus	Species
Arthropoda	Insecta	Trichoptera	Phryganeidae			Agrypnia	Agrypnia obseleta	Species
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropodinae		Polycentropus	Polycentropus sp.	Genus
Arthropoda	Insecta	Trichoptera	Rhyacophilidae			Rhyacophila	Rhyacophila sp.	Genus
Arthropoda	Insecta	Trichoptera	Rhyacophilidae			Rhyacophila	Rhyacophila sp.	Genus
Arthropoda	Insecta	Trichoptera	Sericostomadidae			Sericostoma	Sericostoma personatum	Species
Mollusca	Bivalvia	Veneroidea	Sphaeriidae	Pisidiinae		Pisidium	Pisidium sp.	Genus
Mollusca	Gastropoda	Basommatophora	Ancylidae			Ancylus	Ancylus fluviatilis	Species
Mollusca	*Gastropoda*	*Basommatophora*	*Lymnaeidae*	*Lymnaeinae*		*Myxas*	*Myxas glutinosahauteur*	*Species*
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Lymnaeinae		Radix	Radix sp.	Genus
Mollusca	Gastropoda	Basommatophora	Planorbidae				Planorbidae	Family
Nematoda							Nematoda	Phylum
Nematomorpha	Gordiacea						Gordiacea	Class
Platyhelminthes	*Tubellaria*	*Tricladida*	*Dugesiidae*			*Dugesia*	*Dugesia sp.*	*Genus*