HORIZON NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

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Wylfa Newydd Project

Horizon Nuclear Power Wylfa Limited

Entrapment of Marine Organisms at the Existing Power Station

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2	19/10/2017	Updated report to reflect latest dietary equivalent assessment information	H Young	A Charalampopoulou	Rachel Wilson

Contents

Executive Summary

Jacobs UK Limited (Jacobs) was commissioned by Horizon Nuclear Power Wylfa Limited (Horizon) to undertake a full marine ecological survey programme to inform various applications, assessments and permits to be submitted for approval to construct and operate the Wylfa Newydd Project. Part of the work programme involved surveys at the existing Magnox power station (referred to as the Existing Power Station hereon in) cooling water intake to understand the current rates of impingement and entrainment of fish, including their eggs and larvae (ichthyoplankton) within the CWS, a process termed "entrapment". This report details the findings of the entrapment surveys undertaken in 2011 and 2012 on the site of the Existing Power Station.

A total of 55 24-hour surveys were completed between March 2011 and July 2012 inclusive. Impingement surveys monitored the fish taxa caught on the cooling water drum screens (10 mm mesh) and also recorded macroalgae and invertebrate taxa. Entrainment surveys sampled cooling water from tap-off points on each of the four drum screens by running a known volume of water through a 500 µm mesh net. This sample was then analysed for ichthyoplankton.

The impingement rates of fish were lower in biomass but higher in number than those recorded previously in the late 1980s (Spencer, 1990). Extrapolation of the data for the Existing Power Station estimated the annual catch at the maximum abstraction rate of 70 m^3/s to be approximately 79,450 fish with a biomass of approximately 1.8 tonnes. This compares with an annual biomass impingement estimation of 2.4 tonnes during the late 1980s.

Impingement of fish peaked during the winter when higher numbers of sprat, herrings, dragonets, sea scorpions and lesser-spotted dogfish were impinged. Increased numbers of juvenile gadoids (particularly whiting) are impinged between May and July. Ninety-five percent of all fish species impinged during the present study had a standard length equal to or less than 18 cm. The smallest minimum landing size for a fish species, as stipulated by the Council Regulation (EC) No. 850/98, is 11 cm which is based on pilchard (*Sardina pilchardus*). Very few fish of any commercial value were impinged with 87% of all fish being 11 cm or less. Impingement of fish at the Existing Power Station is very low; it remains lower than at other UK power stations and is considered to not pose any threat to commercial stocks.

The main bulk of all impinged material was composed of marine macroalgae and invertebrates. Increased impingement of material was found to be approximately correlated to periods of strong north-westerly winds. Impingement of lobsters was low with an estimate of approximately 65 impinged per year. Impacts on the local lobster fishery are considered to be negligible.

The peak season for larval entrainment was between February and June in both years when sampling was completed. This peak season coincided with peak abundances recorded from coastal ichthyoplankton surveys. Entrainment samples contained a similar species complement to coastal plankton samples although a number of species including snake pipefish, lumpsucker, goldsinny wrasse and topknot, were recorded in entrainment samples only. The overall abundance of larvae in the entrained samples was often only around 10% - 20% of that recorded from the coastal samples. The position of the present intake close to shore and on the seabed, is the likely reason for these differences.

Entrapment catches of sea bass, whiting, plaice, sprat, herring, clupeids (assuming these are either sprat or herring), Dover sole, solenette, dab, sandeel, goldsinny wrasse, corkwing wrasse, dragonet and gobies[1] were extrapolated to the maximum abstraction rate of the Existing Power Station (70 m^3/s) and assessed using the Equivalent Adult Value (EAV) concept. Annual entrapment EAVs of commercial fish species (sea bass, whiting, plaice, sprat, herring and Dover sole) each represented between 0.0005% and 0.09% of adult fish removed by commercial fishing efforts within the Irish Sea. The number of dab equivalent adults entrapped represented 0.01% of population estimates for the eastern Irish Sea.

Sandeel and clupeids are known to be principle prey species of Sandwich, common and Arctic terns. The biomass of sandeel and clupeids entrapped at the Existing Power Station during the breeding season (1st April

[1] EAVs for gobies were only applied to the entrained fraction owing to their size and the variable life histories demonstrated by goby species.

to 31st July) represents 0.4 - 0.7% of that which would be required to sustain the tern populations of the Anglesey Terns/Morwenoliaid Ynys Môn SPA (calculations assume a five year mean population size: 1992 - 1996 for Arctic and common terns and 1993-1997 for Sandwich terns). Entrapment of fish species known to be prey of grey seal equated to the annual diet of one average sized adult.

1. Introduction

1.1 Overview

Horizon Nuclear Power Wylfa Limited (Horizon) is currently planning to develop a new nuclear power station in north Anglesey as identified in the *National Policy Statement for Nuclear Power Generation (EN-6)* (Department of Energy and Climate Change, 2011). The Wylfa Newydd Project (the Project) comprises the proposed new nuclear power station, including the reactors, associated plant and ancillary structures and features, together with all of the development needed to support its delivery, such as highway improvements, worker accommodation and specialist training facilities. The Project will require a number of applications to be made under different legislation to different regulators. As a Nationally Significant Infrastructure Project under the *Planning Act 2008*, the construction and operation must be authorised by a Development Consent Order.

Jacobs UK Limited (Jacobs) was commissioned by Horizon to undertake a full ecological survey programme within the vicinity of the proposed new nuclear power station on Anglesey (the Wylfa Newydd Generating Station). This work has included the gathering of baseline data to inform the various applications, assessments and permits that will be submitted for approval to construct and operate the Power Station and Associated Development[2]. Part of the work programme involved surveys at the existing Magnox power station (referred to as the Existing Power Station hereon in) cooling water intake to understand the current rates of impingement and entrainment of fish and their eggs and larvae (ichthyoplankton) within the Cooling Water System (CWS), a process termed “entrapment” (see Section 1.5 for further explanation of terminology).

This report details the findings of the entrapment surveys undertaken in 2011 and 2012 on the site of the Existing Power Station.

This report uses a number of technical terms and abbreviations. It also makes reference to legislation that was in force at the time of publication. Key terms are capitalised and explained with their acronyms within the text.

1.2 The Wylfa Newydd project

The Project includes the Wylfa Newydd Generating Station and Associated Development. The Wylfa Newydd Generating Station includes two UK Advanced Boiling Water Reactors to be supplied by Hitachi-GE Nuclear Energy Limited, associated plant and ancillary structures and features. In addition to the reactors, development on the Power Station Site would include steam turbines, control and service buildings, operational plant, radioactive waste storage buildings, ancillary structures, offices and coastal developments. The coastal developments would include a CWS intake and breakwater, and a Marine Off-Loading Facility (MOLF).

1.3 The Wylfa Newydd Development Area

The Wylfa Newydd Development Area (the indicative areas of land and sea, including the Power Station Site, the Wylfa NPS Site[3] and the surrounding areas that would be used for the construction and operation of the Power Station) covers an area of approximately 409 ha. It is bounded to the north by the coast and the Existing Power Station. To the east, it is separated from Cemaes by a narrow corridor of agricultural land. The A5025 and residential properties define part of the south-east boundary, with a small parcel of land spanning the road to the north-east of Tregele. To the south and west, the Wylfa Newydd Development Area abuts agricultural land, and to the west it adjoins the coastal hinterland.

The Wylfa Newydd Development Area includes the headland south of Mynydd-y-Wylfa candidate local wildlife site. There are two designated sites for nature conservation within the Wylfa Newydd Development Area: the

[2] Development needed to support delivery of the Power Station is referred to as ‘Associated Development’. This includes highway improvements along the A5025, Park and Ride Facilities for construction workers, Logistics Centre, Temporary Workers’ Accommodation, specialist training facilities, Horizon’s Visitor Centre and media briefing facilities.

[3] The site identified on Anglesey by the *National Policy Statement for Energy EN-6* (Department of Energy and Climate Change, 2011) as potentially suitable for the deployment of a new nuclear power station.

Tre'r Gof Site of Special Scientific Interest (SSSI) and the Anglesey Terns/Morwenoliaid Ynys Môn Special Protection Area. There is also a candidate Special Area of Conservation (cSAC) that has been submitted to the European Commission, but not formally adopted (North Anglesey Marine/Gogledd Môn Forol cSAC). The Wylfa Newydd Development Area is within 1 km of the Cae Gwyn SSSI and Cemlyn Bay Special Area of Conservation (SAC) and SSSI[4].

1.4 Study aims and objectives

The CWS methodology to be adopted at the Wylfa Newydd Generating Station has yet to be determined but the preferred option for maximising plant efficiency is direct cooling, which will require seawater extraction from the local environment. Marine fauna and flora in the vicinity of the new intake would be at risk from entrapment into the CWS.

The aim of the entrapment surveys was to sample the fish entrained and impinged at the Existing Power Station. At the same time, the opportunity to record the invertebrates and macroalgae impinged on the screens was also taken.

The objective was to develop an up-to-date and robust understanding of the site-specific impingement and entrainment rates at the Existing Power Station for the purpose of quantifying losses to the marine ecosystem. This dataset will be used to estimate the magnitude of losses from the operation of the proposed Wylfa Newydd Generating Station and inform appropriate best practice in terms of design to reduce entrapment within the CWS, and ensure maximum survival and return of organisms to the marine environment. This information will be used within the Environmental Statement and other supporting documents which will be required as part of the application process for the Wylfa Newydd Project.

The sampling programme was designed in accordance with guidelines developed by the British Energy Estuarine and Marine Studies Expert Panel (BEEMS) (2010a; 2010b). The surveys aimed to provide fish impingement and entrainment data comparable to those obtained previously (Dempsey and Rogers, 1989; Spencer, 1990). Following BEEMS guidance, entrapment data was assessed using the Equivalent Adult Value (EAV) concept to determine the commercial significance of catches in relation to fishing statistics (BEEMS, 2010a). This method was expanded to determine the ecological significance of catches of non-commercial species, where applicable, in relation to population estimates and natural predation.

1.5 Terminology

The following terminology is used in this report.

- Entrapment – the process by which any organism, irrespective of its size, is drawn into the CWS intake. The term implies the organism is unable to resist capture; this may be owing to no or poor swimming ability or failing to detect the intake structure.
- Impingement – entrapped organisms that are too big to pass through the fine mesh on the CWS drum screens. These are removed from the screenwell by collection buckets on the drum screen and then washed free by a water jet system to a trash channel. Examples include adult and juvenile fish, macroinvertebrates (e.g. crabs, jellyfish) and macroalgae.
- Entrainment – organisms small enough to pass through the fine mesh of the CWS drum screens including phytoplankton, zooplankton and ichthyoplankton. These organisms pass through the entire CWS and are subjected to biocides, mechanical stresses and changes in pressure and temperature.

1.6 Cooling water intake arrangement

The CWS intake structure of the Existing Power Station is located between Wylfa Head and Porth-y-pistyll (blue circle in Figure 1.1). It comprises two submerged vertical intakes sited to either side of a short jetty. The intake pipes sit just proud of the seabed and consist of a vertical shaft approximately 20 m in height with an 8.6 m^2

[4] Note that the format of names for designated and conservation sites are consistent with JNCC guidance.

cross-section. The subsequent tunnel leading to the forebay is approximately 210 m long with an 11.9 m^2 cross-section before rising up vertically into the forebay (Figure 1.2).

The structures resemble a modern velocity cap design, drawing water horizontally through circumferential apertures protected by a coarse screen formed of drop-in vertical steel rods at 380 mm spacing with 455 mm pitch. The central part of each cap can be lowered to plug the down shaft, but this dual use necessitates eight guide slots of approximately 5 m^2 total area in the cap. These permit ingress of fish, invertebrates and seaweed.

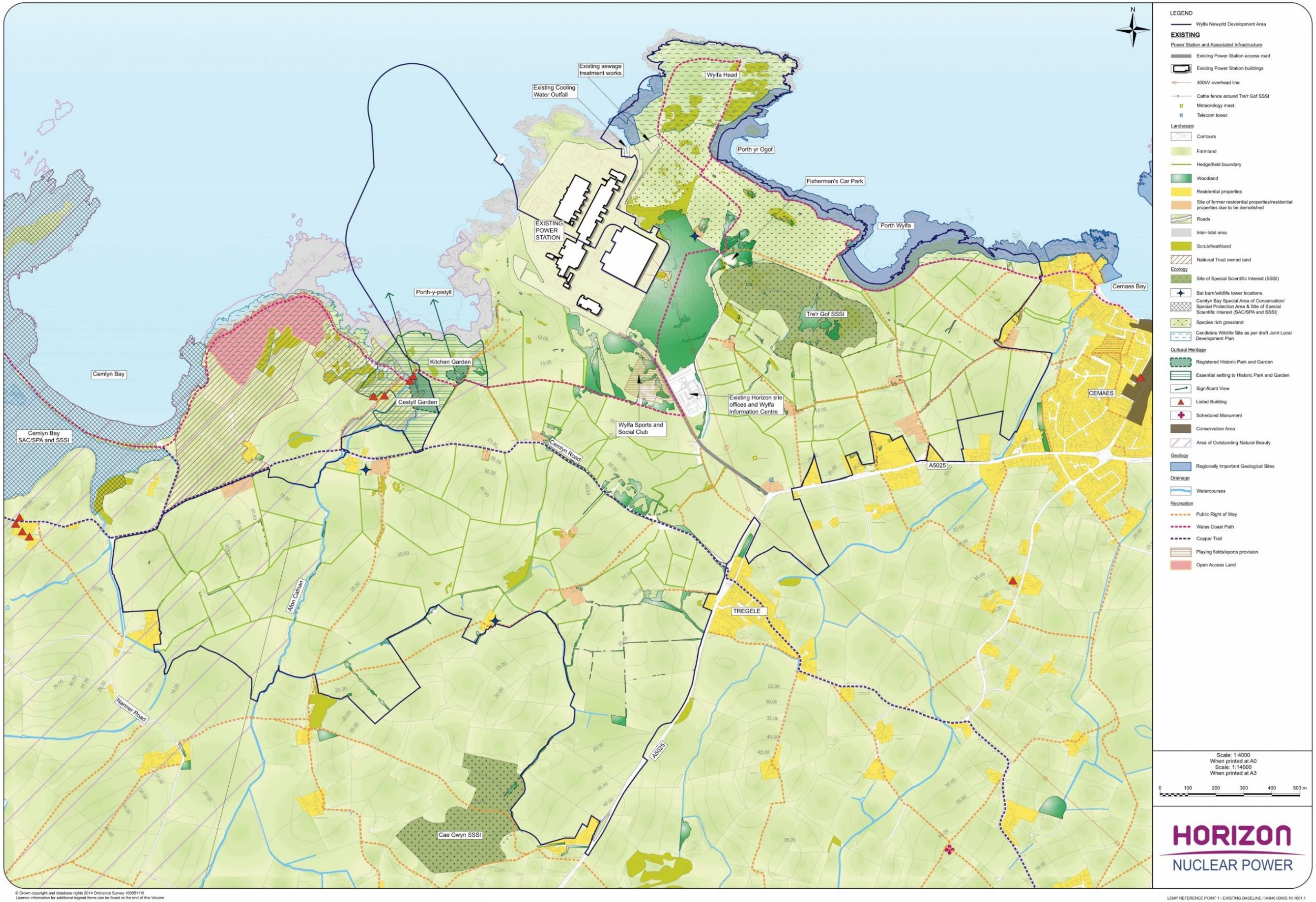


Figure 1.1: The location of the CWS intake (overlaid blue circle) for the Existing Power Station on north Anglesey.

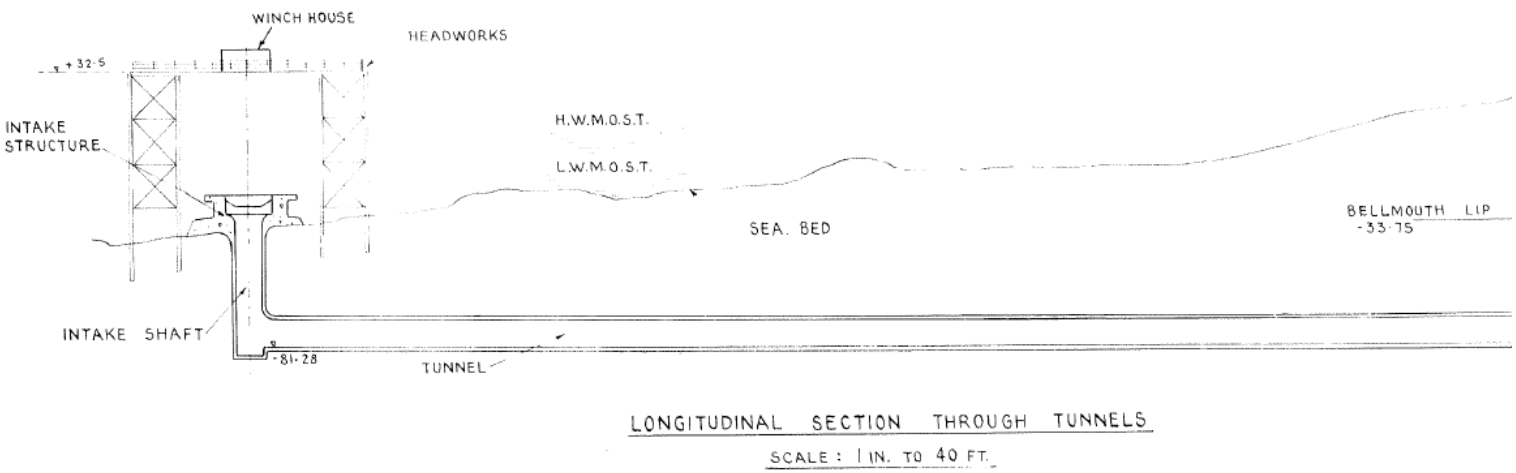


Figure 1.2: Schematic of the CWS intake at the Existing Power Station (taken from Technical Drawing No. 51321 (1968)

2. Impingement

2.1 Methodology

A total of 55 impingement surveys were completed at the Existing Power Station between 22nd March 2011 and 31st July 2012. Surveys were scheduled on a random basis to avoid tidal bias. The dates of all the surveys conducted are provided in Appendix A.

Netlon™ baskets with a 5 mm mesh were constructed around thin (2.5 mm) steel frames designed to provide a tight fit into the drum screen wash-off channels. The baskets were approximately 1 m long and filled the entire cross-section of each channel, approximately 0.1 m^2. In this way, all debris, macroalgae, invertebrates and fish removed from the screens were sampled in the baskets (Figure 2.1).

Figure 2.1 : An impingement-sampling basket about to be deployed (left) and a basket sampling in the drum screen wash channel (right).

At the start of each 24-hour survey, the Netlon™ baskets were placed into the wash-off channels and the time noted; most often, this was early to mid-morning between 08:00 and 10:00. Often the baskets were emptied and replaced at the end of the first day after six to seven hours and the catch analysed. Overnight, periodical checks were made of the sampling baskets by station staff. If the baskets became too full, the catch would be emptied into buckets and held for processing and the baskets replaced.

At the end of each sampling period, the baskets were removed from the wash-off channels and the time noted. The entire catch was then processed. The total volume (in litres) of the catch was recorded and an assessment made of the percentage composition of macroalgae, invertebrates and fish.

Dominant macroalgae species were recorded and the presence of other species noted. Mobile invertebrates were enumerated whilst the presence of sessile and colonial organisms was recorded simply as 'present'. All individual fish were identified to the lowest possible taxonomic level, measured (standard length) and weighed to the nearest gram. Records were also made as to whether a fish was dead or alive and of any apparent exterior physical damage.

2.1.1 Data analysis

Impingement data were analysed to identify the species assemblage and life stages most frequently impinged at the Existing Power Station. Seasons of peak impingement were identified as were environmental conditions considered to influence the rate of impingement.

On 20 sampling occasions, the volume of material coming through the screens was so great that the baskets could not be left unattended as they clogged rapidly, causing water and debris to spill over into the screenwell area. On these occasions, the survey was either cut short and a note made of the time, or re-scheduled for another day. Furthermore, the four abstraction pumps were not always operating at full capacity during the impingement surveys. Consequently, the volume (m^3) of cooling water abstracted by the Existing Power Station during each survey was not consistent (see Appendix B). To compare catches between surveys and to identify temporal trends in impingement, the number and biomass of marine flora and fauna has been standardised to 10^6 m^3 of seawater abstracted. This has been calculated by dividing raw abundances and biomass by the volume of seawater abstracted (m^3) during the survey period and then multiplying by 10^6.

2.1.1.1 Extrapolations

To estimate the abundance and biomass of fish impinged annually at the Existing Power Station, data from the impingement monitoring programme was extrapolated to the maximum permissible abstraction velocity of 70 m^3/s. Raw abundance and biomass data sampled during surveys carried out within a given month were summed and then divided by the volume of water abstracted during the corresponding period to yield estimates per m^3 of cooling water abstracted. These values were then multiplied by the volume of water abstracted (m^3) during each month (assuming a constant abstraction velocity of 70 m^3/s) to give extrapolated monthly impingement estimates. Summation of these values provides an annual estimate of impingement.

2.2 Results

2.2.1 Overall

Although the primary reason for the impingement surveys was to monitor the fish impinged on the CWS screens, the vast majority of material impinged comprised invertebrates and macroalgae (seaweed). The total volume (litres) of invertebrates and fish (fauna) as well as macroalgae (flora) impinged on the screens was estimated for each survey (Figure 2.2). Overall, the volume of marine flora and fauna impinged was greatest between May and June in both years with the exception of a number of isolated peaks during the autumn and winter months. Anecdotal evidence suggests that wind direction influences impingement rates, particularly when it blows strongly from the north-west (290° - 310°) during and preceding the surveys. This was particularly apparent during October 2011 and January 2012 when the wind was gusting to force eight and above[5]. Although winds from a north-west direction did not coincide exactly with peaks observed in May 2011 and June 2011, the wind had been blowing from this direction at around a force six during the preceding one to two days. The influence of wind speed and direction is believed to be an important factor affecting the impingement of marine flora and fauna on the CWS screens at the Existing Power Station.

[5] The Beaufort Scale is an empirical measure (Force 0-12) for describing wind intensity based on observed sea conditions.

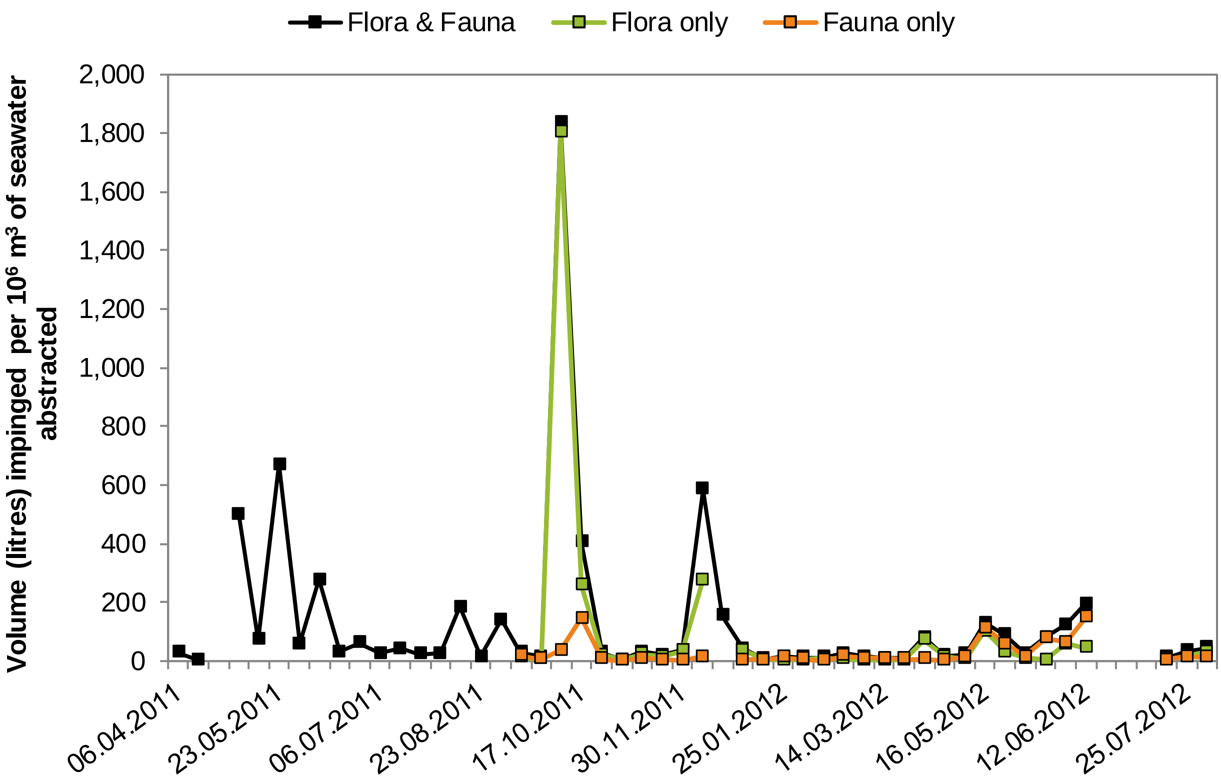


Figure 2.2 : Total volumes (litres) of marine fauna (fish and invertebrates) and flora (macroalgae) impinged during each survey at the Existing Power Station between April 2011 and July 2012 inclusive. Values have been scaled to 10^6 m^3 of seawater abstracted to permit comparison. Macroalgae and invertebrates were not consistently separated during the first few months of survey work so are not displayed separately prior to September 2011.

2.2.2 Fish

In total, 5,081 fish weighing a total of 143.9 kg and representing 65 species were sampled over the 55 surveys (Table 2.1). The most numerous species sampled was sprat (*Sprattus sprattus*) and the species that represented the highest total biomass sampled was the lesser-spotted dogfish (*Scyliorhinus canicula*).

Table 2.1 : Total numbers and biomass (g) of fish taxa impinged on the CWS screens at the Existing Power Station during 55 surveys between March 2011 and July 2012. Data are shown in order of abundance. Shaded taxa were within the 95th percentile of total abundance. (* Note: specimens were too small or damaged to weigh hence biomass not recorded.)

Taxa	Common name	Numbers	Biomass (g)
Sprattus sprattus	Sprat	1,946	2,918
Atherina presbyter	Sand smelt	486	1,376
Merlangius merlangus	Whiting	356	1,505
Clupea harengus	Herring	274	1,575
Taurulus bubalis	Long-spined sea scorpion	184	2,971
Agonus cataphractus	Pogge	181	2,056
Echiichthys vipera	Lesser weever	147	654
Scyliorhinus canicula	Lesser-spotted dogfish	146	68,836
Ciliata mustela	Five-bearded rockling	143	3,175

Taxa	Common name	Numbers	Biomass (g)
Callionymus lyra	Common dragonet	139	777
Pollachius pollachius	Pollack	133	11,079
Spinachia spinachia	Fifteen-spined stickleback	82	301
Callionymus sp.	Dragonet	78	115
Gadidae	Cod family	74	120
Ammodytes tobianus	Lesser sandeel	71	409
Syngnathus acus	Greater pipefish	60	391
Limanda limanda	Dab	52	1,515
Trisopterus minutus	Poor cod	49	667
Labrus bergylta	Ballan wrasse	37	6,930
Pleuronectes platessa	Plaice	35	1,585
Clupeidae	Herring family	33	44
Symphodus melops	Corkwing wrasse	29	1,032
Ammodytes sp.	Sandeel	28	324
Indeterminate	Indet.	25	31
Lipophrys pholis	Shanny	23	146
Pollachius virens	Saithe	19	1,750
Gadus morhua	Cod	18	2,698
Scyliorhinus stellaris	Nurse hound	16	5,840
Gobiidae	Goby family	14	13
Arnoglossus laterna	Scaldfish	12	122
Callionymus reticulatus	Reticulated dragonet	12	135
Entelurus aequoreus	Snake pipefish	12	149
Ctenolabrus rupestris	Goldsinny wrasse	11	136
Gaidropsarus vulgaris	Three-bearded rockling	11	1,341
Pholis gunnellus	Butterfish	10	88
Syngnathidae	Pipefish family	10	15
Centrolabrus exoletus	Rock cook	8	34
Trisopterus luscus	Pouting	8	176
Gobius paganellus	Rock goby	7	48
Myoxocephalus scorpius	Short-spined sea scorpion	7	196
Pomatoschistus minutus	Sand goby	7	12
Eutrigla gurnardus	Grey gurnard	6	8
Zeus faber	John Dory	6	84
Chelon labrosus	Thick-lipped grey mullet	5	6,356
Cyclopterus lumpus	Lumpsucker	5	2,858
Raja clavata	Thornback ray	5	58

Taxa	Common name	Numbers	Biomass (g)
Dicentrarchus labrax	Sea bass	4	3,065
Pomatoschistus sp.	Goby sp.	4	5
Buglossidium luteum	Solenette	3	7
Ciliata septentrionalis	Northern rockling	3	15
Gobiusculus flavescens	Two-spot goby	3	3
Parablennius gattorugine	Tompot blenny	3	42
Raniceps raninus	Tadpole fish	3	256
Callionymus maculatus	Spotted dragonet	2	7
Chelidonichthys cuculus	Red gurnard	2	29
Conger conger	Conger eel	2	3,400
Cottidae	Sea scorpion family	2	2
Liparis liparis	Striped sea snail	2	13
Liparis montagui	Montagu's sea snail	2	8
Platichthys flesus	Flounder	2	438
Solea solea	Dover sole	2	512
Thorogobius ephippiatus	Leopard-spotted goby	2	6
Aphia minuta	Transparent goby	1	1
Blenniidae	Blenny family	1	1
Gasterosteus aculeatus	Three-spined stickleback	1	2
Labridae	Wrasse family	1	1
Labrus mixtus	Cuckoo wrasse	1	70
Lampetra fluviatilis	River lamprey	1	29
Liparidae	Sea snail family	1	4
Liza aurata	Golden grey mullet	1	933
Maurolicus muelleri	Pearlside	1	1
Melanogrammus aeglefinus	Haddock	1	3
Molva molva	Ling	1	1
Mugilidae	Grey mullet family	1	1,420
Pomatoschistus microps	Common goby	1	1
Raja montagui	Spotted ray	1	980
Scophthalmidae	Topknot sp.	1	6
Scyliorhinus sp.	Dogfish family	1	2
Syngnathus rostellatus	Nilsson's pipefish	1	1
Trachurus trachurus	Horse mackerel	1	5
Triglidae	Gurnard family	1	1
Trisopterus sp.	Poor cod family	1	2
Totals	**65 species**	**5,081 fish**	**143.92kg**

The number of species recorded in samples increased rapidly at first as the more common species were impinged (Figure 2.3). Incidences of new species began to plateau after around 16 surveys before increasing again after 35 surveys. This second sharp rise in the number of species sampled was a seasonal variation occurring in mid to late winter and may have been related to movements of some species inshore.

Of the 65 species recorded over the impingement monitoring programme, six (10%) were classed as either pelagic (living in the water column) or pelagic-neritic (living within the water column within shallow coastal waters), five (8%) were reef-associated species, 45 (71%) were demersal (living and feeding near or on the bottom) and nine (14%) were bentho-pelagic (living and feeding near the bottom as well as in midwaters or near the surface). Classifications have been derived from the FishBase database (FishBase, 2015 and references herein).

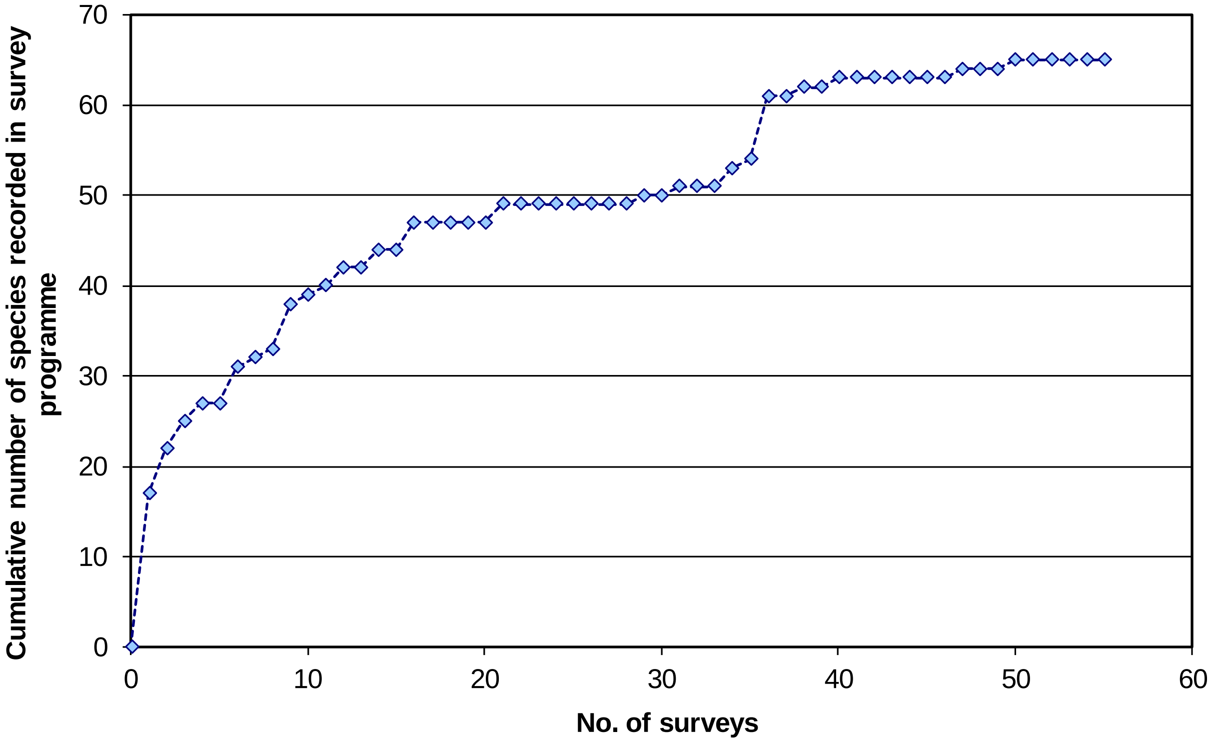


Figure 2.3 : Cumulative number of fish species recorded on the CWS screens at the Existing Power Station with number of surveys conducted.

Fish with specific conservation designations are cited in Table 2.2. Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, known as the EC Habitats Directive, is the means by which the European Union meets its obligations under the Bern Convention. Annex II, IV and V of the Habitats Directive list species and sub-species of conservation importance; Appendix II and III of the Bern Convention list protected fauna species. Section 7 of *The Environment (Wales) Act 2016* refers to Species of Principal Importance in Wales. The International Union for the Conservation of Nature (IUCN) Red List comprises species considered to be at risk of decline or extinction. The Convention for the protection of the marine environment of the north-east Atlantic (OSPAR) has created a list of threatened and / or declining species and habitats.

Of the species with conservation designations, whiting (*Merlangius merlangus*) and herring (*Clupea harengus*) were the most frequently encountered with 356 and 274 fish impinged over the 16-month sampling period, respectively. A total of 12 *Pomatoschistus* spp. (includes common goby and sand goby) were impinged during the sampling period. All other fish with conservation designations were caught at rates of seven or less per survey with only single records for river lamprey (*Lampetra fluviatilis*), ling (*Molva molva*), haddock (*Melanogrammus aeglefinus*), spotted ray (*Raja montagui*) and horse mackerel (*Trachurus trachurus*).

Table 2.2 : Conservation designations of fish species sampled on the CWS screens at the Existing Power Station. *Note: Vulnerable = considered to be facing a high risk of extinction in the wild; Near threatened = may qualify for a threatened category in the near future; Least concern = widespread and abundant. **Note: Thornback ray is only listed as under threat or in decline in the Greater North Sea, not the Irish Sea.

Common name	EC Habitats Directive Annex II, V	Section 7 Environment (Wales) Act	OSPAR	IUCN Red List *	Bern Convention Appendix III
Common goby	-	-	-	-	✓
Sand goby	-	-	-	-	✓
Herring	-	✓	-	Least concern	-
Cod	-	✓	✓	Vulnerable	-
Whiting	-	✓	-	-	-
Plaice	-	✓	-	Least concern	-
Ling	-	✓	-	-	-
Dover sole	-	✓	-	-	-
Horse mackerel	-	✓	-	-	-
Thornback ray	-	✓	✓**	Near threatened	-
Spotted ray	-	-	✓	Least concern	-
Sea bass	-	-	-	Least concern	-
Haddock	-	-	-	Vulnerable	-
River lamprey	✓	✓	-	Least concern	✓

Impingement samples were dominated by fish smaller than 18 cm (95th percentile), although larger specimens were sampled on occasion; these included conger eels (*Conger conger*), nurse hounds (*Scyliorhinus stellaris*), lesser-spotted dogfish and rays (*Raja clavata* and *Raja montagui*) (Figure 2.4). The large number of smaller fish impinged was composed mainly of sprat, sand smelt (*Atherina presbyter*), whiting and numerous other small species and unidentified juvenile fish (too damaged to identify). The small peak in numbers at around 600 mm is mainly owing to lesser-spotted dogfish dominating this size range.

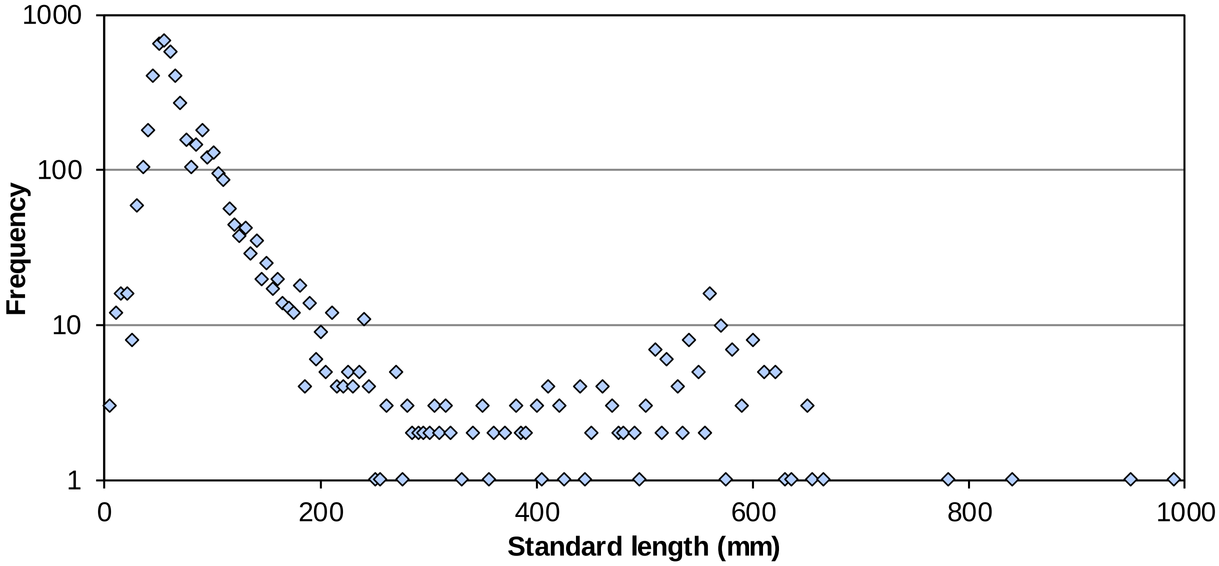


Figure 2.4: Length-frequency distribution (standard length) of fish species impinged at the Existing Power Station between March 2011 and July 2012 (n = 5,080 (a single sand smelt was not measured)).

The numbers, biomass and species of fish impinged on the CWS screens varied both on a daily basis and with season (Figure 2.5). Peak impingement in terms of number occurred between late December 2011 and early March 2012 when increased numbers of sprat, herring, dragonets (Callionymidae), long-spined sea scorpion (*Taurulus bubalis*) and lesser-spotted dogfish were recorded on the screens; overall, biomass was consistently high during the same period. A second small increase in impingement numbers occurred between May and July in 2011 and to a lesser extent in 2012; this was owing to increased numbers of juvenile whiting entering the CWS.

The highest peaks in biomass were recorded in May 2011 and October 2011. The first peak in May 2011 was due to higher numbers of lesser-spotted dogfish being recorded during a single survey. The peak in October 2011 coincided with strong north-westerly winds which may have increased the quantity of material impinged at the CWS screens including numbers and biomass of fish (see Figure 2.2 and Figure 2.5).

The number of sprat impinged peaked during the winter months between early December 2011 and mid-March 2012. Sand smelt were present sporadically during the survey period although numbers peaked during winter, the exception being a large number impinged on 21st November 2011. Whiting numbers peaked between May and July 2011 with fewer individuals recorded during the corresponding months in 2012, the majority being juveniles less than 80 mm standard length; during autumn and winter, larger fish were sampled (90 – 275 mm) though in much lower numbers. Finally, the number of herring impinged peaked between January 2012 and March 2012 and consisted of individuals ranging from 60 mm to 230 mm, with the majority of individuals in the 80 - 120 mm size range.

Extrapolation of the data suggests that in a single year, assuming maximum operating conditions (an abstraction rate of 70 m^3/s); the Existing Power Station impinges around 79,450 fish with a biomass of 1.8 tonnes. This equated to 36 fish per 10^6 m^3 and 0.82 kg per 10^6 m^3 of water abstracted, respectively. The number of fish impinged was generally found to be highest during the winter months with 62% of annual impingement occurring between December and February. The impingement of fish biomass at the Existing Power Station was highest during the winter and spring months, with 39% of annual impingement occurring between December and February whilst a further 26% occurred between March and May, respectively.

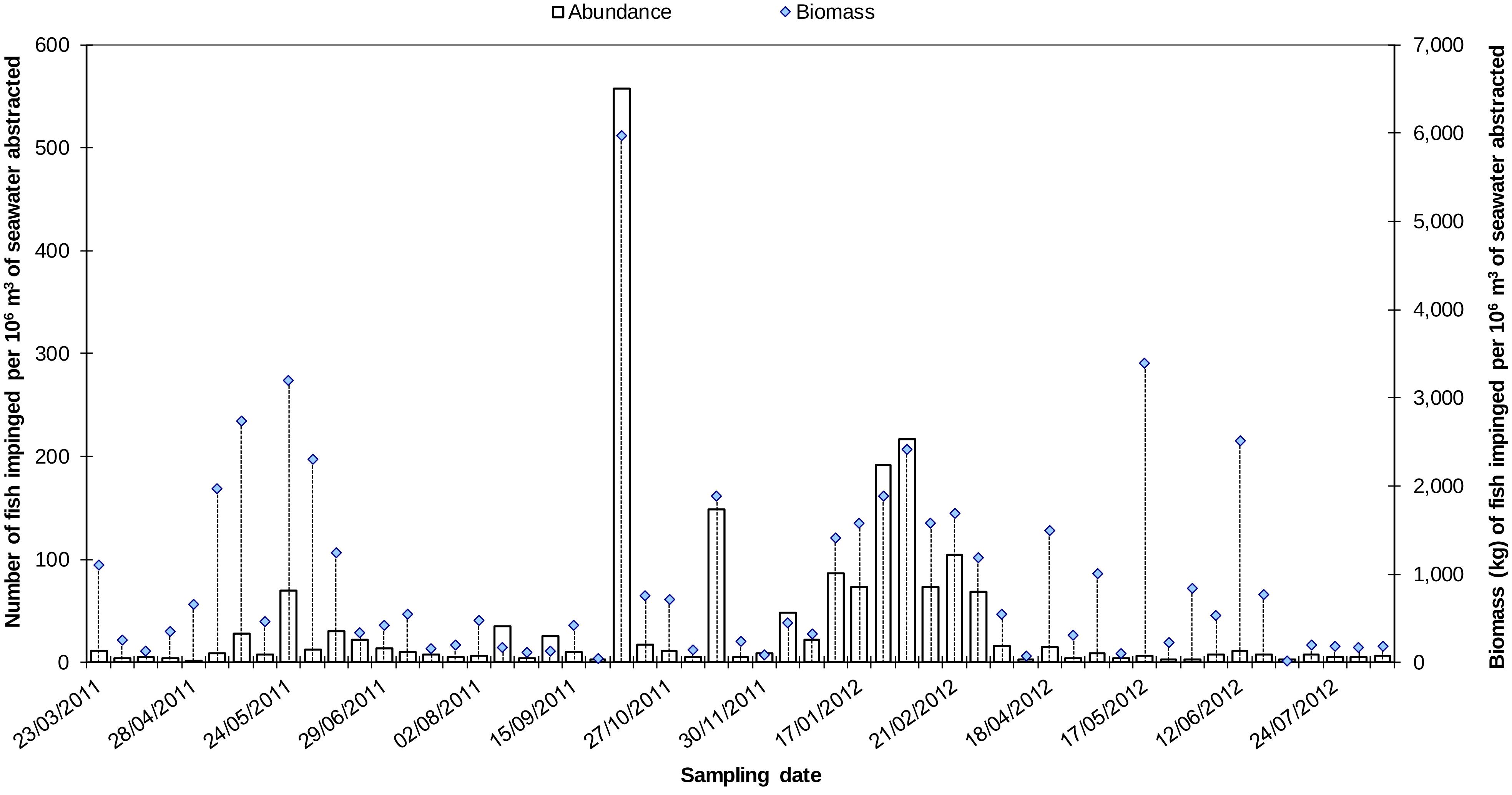


Figure 2.5 : Total numbers and total biomass (kg) of fish impinged during 24-hour periods at the Existing Power Station between March 2011 and July 2012.

2.2.3 Invertebrates

Over 150 invertebrate taxa were recorded from the impingement samples between March 2011 and July 2012 (Appendix C). A large proportion of the organisms impinged were sessile fauna. This suggests either they had been dislodged from the seabed in the surrounding sea area by periods of strong wave action or they were growing within the CWS intake itself; a combination of the two is most likely.

Quantifying the total invertebrates in terms of numbers is problematic as colonial, sessile organisms cannot be readily counted as individuals. Therefore, the estimated total volume of invertebrates per survey has been presented in Figure 2.6. The data show two peaks in the impingement of invertebrates during autumn 2011 and winter 2012 that can be attributed to the strong north-westerly winds at the time of survey. Increased volumes during spring and early summer are a result of blooms of ctenophores (comb jellies) and jellyfish during these seasons that become entrained in large numbers.

Certain invertebrate species were counted without issue during the surveys, allowing the loss of particular species to be considered in greater detail. Both edible crab (*Cancer pagurus*) and lobster (*Homarus gammarus*) have commercial value for local inshore fisheries and the total numbers impinged per survey were monitored.

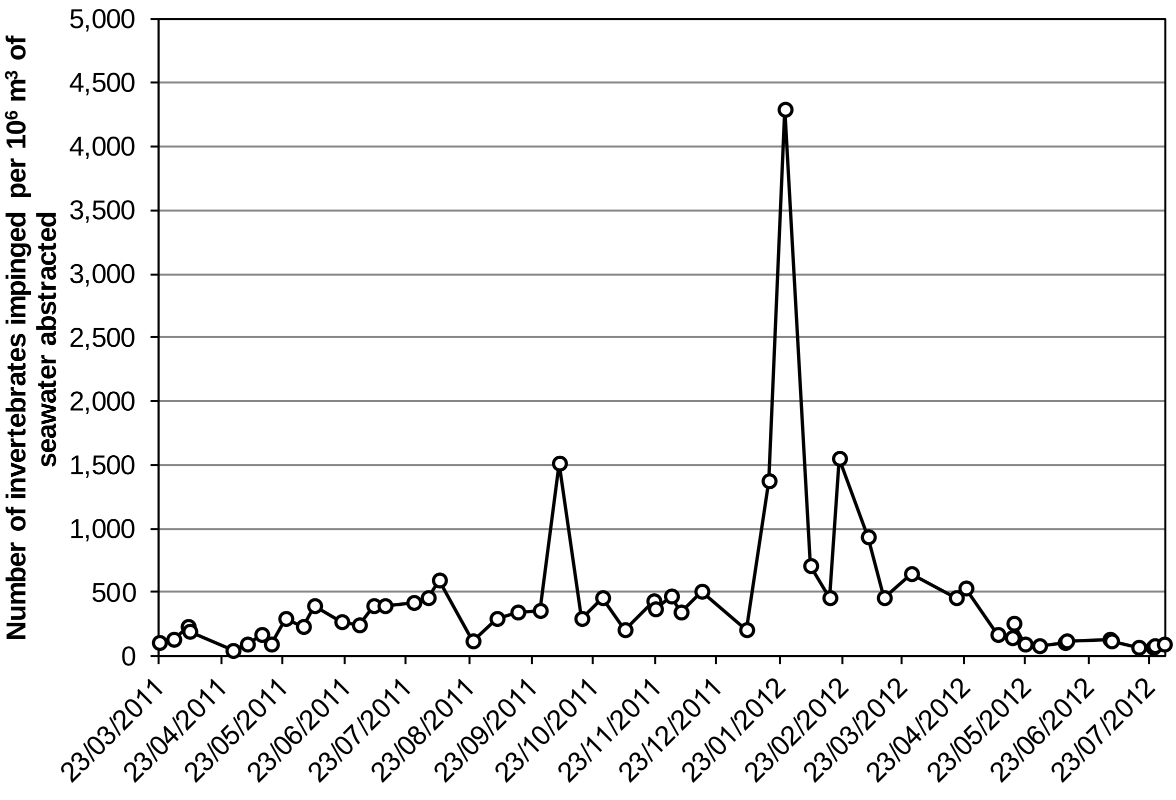


Figure 2.6: The number of invertebrates impinged during each survey standardised to 10^6 m^3 of seawater abstracted. This only includes taxa for which enumeration is feasible and excludes organism which are sessile or colonial. Note the data is presented on a log scale.

In total, over the 55 surveys, a median value of 26 edible crabs per 10^6 m^3 per of seawater abstracted per survey was recorded. On 10 sampling occasions, the impingement rate of edible crabs exceeded 100 per 10^6 m^3 per of seawater abstracted, with a maximum impinged rate of 248 edible crabs per 10^6 m^3 per of seawater abstracted recorded in a single survey (6th July 2011). This variability indicates that there is a significant degree of seasonality in the impingement of this species (Figure 2.7). Between late May 2011 and early August 2011, the numbers of edible crab impinged increased dramatically before dropping back down to less than 180 per 10^6 m^3 per of seawater abstracted per survey thereafter. This pattern was not repeated in 2012 and it might be that 2011 was simply a strong recruitment year for edible crab. The individual carapace width of crabs was not recorded (this was beyond the project scope) but anecdotal evidence suggests that the vast majority (more than 90%) of the crabs impinged during spring and summer 2011 were less than 50 mm in width.

Impingement of lobsters was an uncommon occurrence with only a total of seven recorded over all 55 surveys which equates to a mean of 0.03 per 10^6 m^3 of seawater abstracted. This figure, although low, is probably realistic as periodic inspections of the trash baskets and skips on site revealed very little evidence of large numbers of lobsters being impinged.

There was also a sharp increase in the numbers of shrimps (*Palaemon serratus*, *P. elegans*, *Pandalus montagui*, *Pandalina brevirostris* and *Pasiphaea sivado*) impinged during the winter months. Figure 2.8 shows the variations in the numbers impinged over the sampling period. For the most part, numbers of shrimps remained at around 1 – 110 individuals per 10^6 m^3 per of seawater abstracted per survey, with the exception of the sharp spike from January 2012 to March 2012 inclusive. The spike preceding this in October 2011 coincided with strong north-westerly winds during the survey period.

Similar seasonal peaks existed for several other species. For example, higher numbers of curled octopus (*Eledone cirrhosa*) were observed between January 2012 and April 2012 (1 - 20 per day) whilst numbers of little cuttlefish (*Sepiola atlantica*) peaked between August 2011 and October 2011 (sometimes in excess of 100 individuals per day) and again between January 2012 and May 2012.

It is known that jellyfish can cause issues for a power station's CWS if they are present in large quantities. Although increased abundances of jellyfish impinged caused some issues with the sampling programme, they were not present in large enough quantities to cause any issues for the power station operation. The main species of jellyfish recorded were the lion's mane (*Cyanea capillata*) and moon jelly (*Aurelia aurita*). Blue jellies (*Cyanea lamarckii*) and compass jellies (*Chrysaora hysoscella*) were frequently recorded though in noticeably lower numbers. The large barrel jelly (*Rhizostoma pulmo*) was recorded infrequently. Figure 2.9 describes the seasonal peak in jellyfish impingement at the Existing Power Station between March 2011 and March 2012. Data are not provided for the 2012 season as during this time jellyfish were recorded as present or absent only; however, it should be noted that the jellyfish season in each year was of the same duration and considered to be of a similar magnitude.

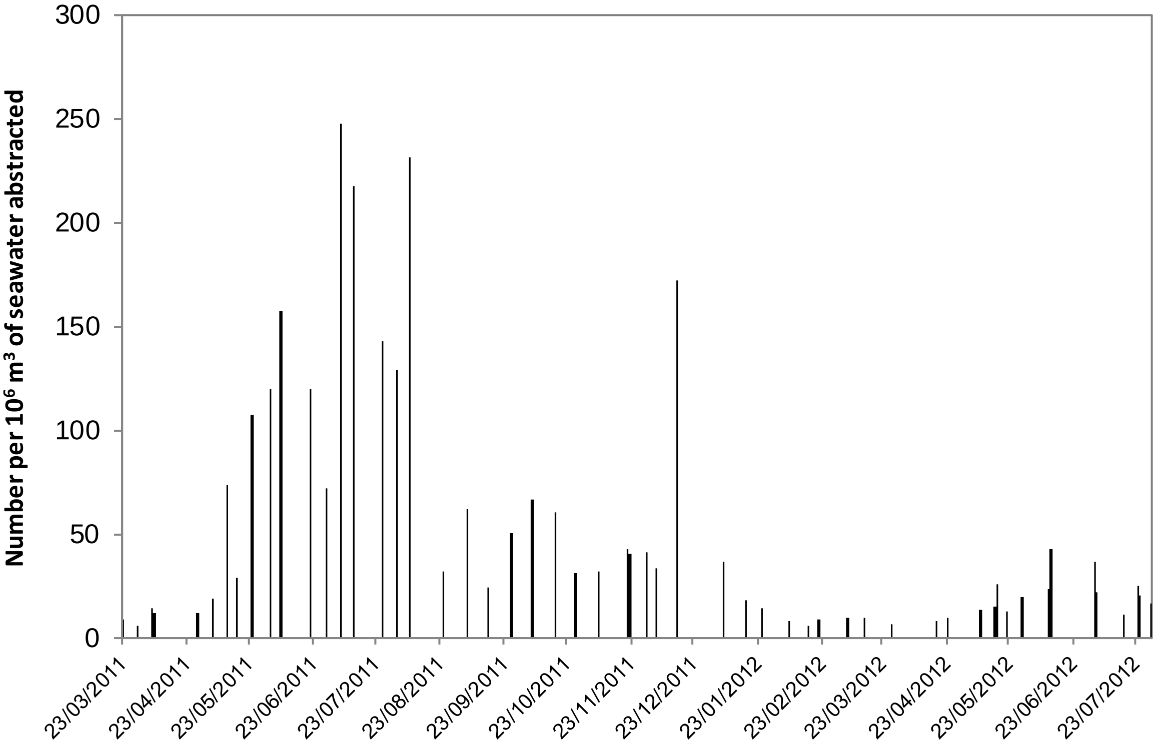


Figure 2.7: The number of edible crabs (*Cancer pagurus*) impinged during each survey on the CWS screens at the Existing Power Station between March 2011 and July 2012 expressed per 10^6 m^3 of seawater abstracted.

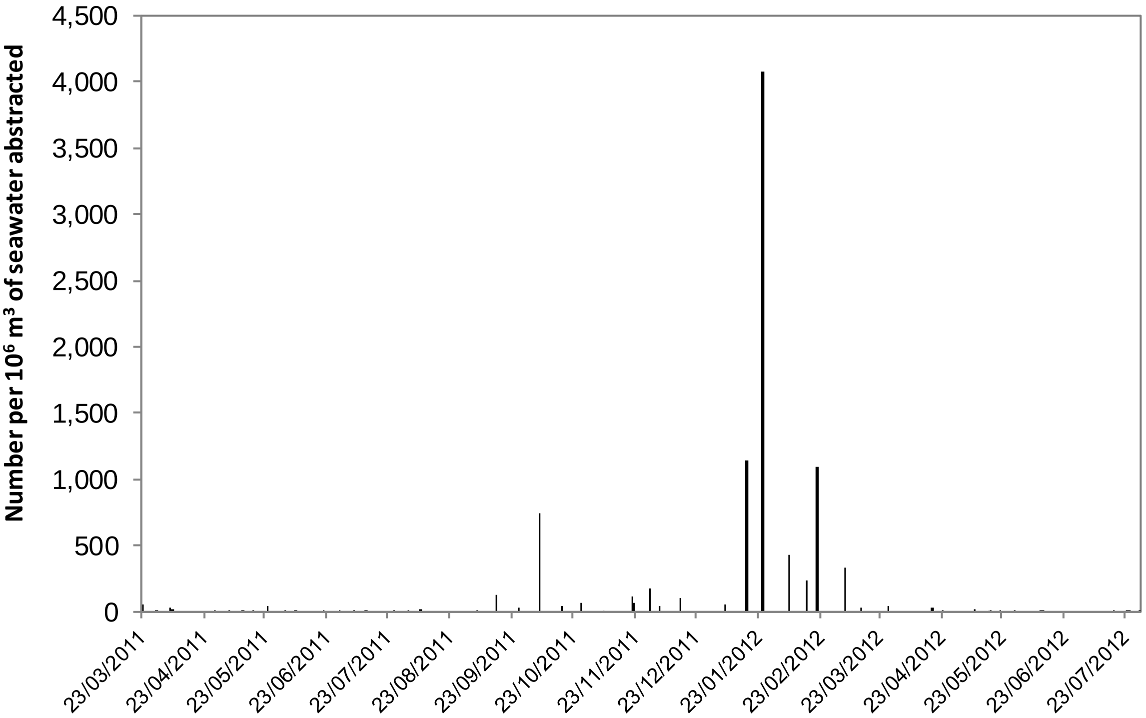


Figure 2.8: Frequency of shrimps (*Palaemon* spp., Pandalidae and *Pasiphaea sivado*) impinged during each survey on the CWS screens at the Existing Power Station between March 2011 and July 2012 expressed per 10^6 m^3 of seawater abstracted.

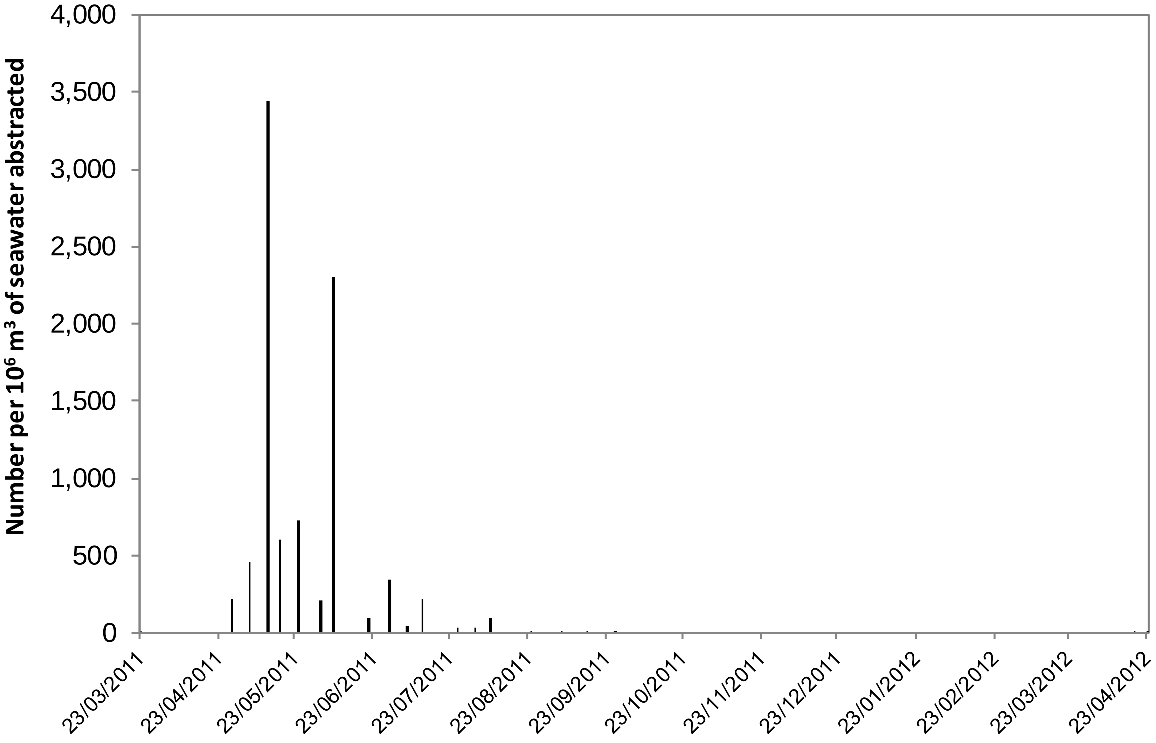


Figure 2.9: Frequency of jellyfish (lion's mane, moon, blue, compass and barrel) impinged per survey on the CWS screens at the Existing Power Station between March 2011 and March 2012 expressed per 10^6 m^3 of seawater abstracted. The data do not include counts of ctenophores (sea gooseberries / comb jellies).

Ctenophores (comb jellies) were recorded in samples throughout all seasons. Although present in low abundances throughout autumn and winter, numbers began to increase in February with a few hundred recorded per survey. By late March, numbers reached more than 1000 per survey with tens of thousands being recorded by late May and throughout June.

2.2.4 Macroalgae

During most surveys, a major constituent of impinged matter on the CWS screens was marine macroalgae (seaweed). As macroalgae becomes dislodged from the seabed it drifts along the coastline and is drawn into the CWS as it passes by. Wherever possible, the species of macroalgae impinged were noted as 'present'. The full species list is provided in Appendix D. During each survey, the total quantity of macroalgae was recorded by assessing the volume in litres in the collection buckets into which the impingement samples were emptied; the dominant species of macroalgae were also recorded.

Figure 2.2 in Section 2.2.1 shows the recorded volumes of macroalgae over the survey period. The greatest volume recorded during any single survey period was more than 5000 L on 6th October 2011 which equates to 1,801 L per 10^6 m^3 of seawater abstracted. On this occasion, the survey had to be suspended owing to the quantities of macroalgae impinged. On this day with a strong (force 8) north-westerly wind, the screen-wash channels were being constantly manned by station staff shovelling the macroalgae clear to prevent the CWS screens from becoming blocked.

The dominant macroalgal species varied with month and season. Common species included:

- kelps and wracks (*Laminaria* spp. and fucoids);
- foliose species such as dulse (*Palmaria palmata*), sea lettuce (*Ulva* spp.), fine-veined crinkle weed (*Cryptopleura ramosa*) and sea beech (*Delesseria sanguinea*); and
- filamentous species such as cock's comb (*Plocamium cartilagineum*) and siphoned feather weed (*Heterosiphonia plumosa*).

These algal species form many of the dominant infralittoral (shallow subtidal) habitats along the north Anglesey coast, so their dominance of the impingement samples suggests a local origin.

2.2.5 Marine mammals

One live, young seal (species unconfirmed but likely to be a grey seal (*Halichoerus grypus*) was observed in one of the collecting skips on 5th December 2011; the RSPCA arrived on site to collect the animal before setting it free further along the coast. At least another two young seals were then recorded up until 15th December 2011; it is unclear whether either of these young seals was the same individual observed on 5th December 2011. It is considered that strong winds during this period may have played a role in the entrapment of these young seals. During a survey on 11th June 2012, a seal was observed in the screenwells by survey staff but it did not exit via the screens during the survey period.

2.3 Discussion

The operation of the Existing Power Station during the period of the surveys was typical of normal operations. There was an outage of one reactor between late August 2011 and December 2011, which is part of an annual maintenance programme whereby each reactor is serviced alternately every year. As a result, the data are considered to provide a realistic estimate of annual impingement.

2.3.1 Fish

2.3.1.1 Species impinged

The overall catch of fish on the screens at the Existing Power Station is characterised by low numbers (less than approximately 6 fish per hour) and low biomass (less than approximately 0.15 kg per hour), but a relatively high diversity, comparable with data obtained over 25 years previously (Spencer, 1990). Spencer (1990) recorded impingement at the Existing Power Station between 1985 and 1987 at rates of less than 5 fish and less than 0.3 kg per operating hour.

Of the 66 species recorded by Spencer (1990) at the Existing Power Station, 53 were recorded in this survey. Thirteen species recorded in the late 1980s were not recorded in the present survey, these were:

- blonde ray (*Raja brachyura*);
- European eel (*Anguilla anguilla*);
- black goby (*Gobius niger*);
- thickback sole (*Microchirus variegatus*);
- Norwegian topknot (*Phrynorhombus norvegicus*);
- topknot (*Zeugopterus punctatus*);
- smooth sandeel (*Gymnammodytes semisquamatus*)’
- Raitt’s sandeel (*Ammodytes marinus*);
- Corbin’s sandeel (*Hyperoplus immaculatus*);
- tub gurnard (*Chelidonichthys lucernus*);
- Atlantic salmon (*Salmo salar*);
- hake (*Merluccius merluccius*); and
- shore rockling (*Gaidropsarus mediterraneus*).

Each of these species was recorded by Spencer (1990) in an abundance of less than 23 individuals over the two-year sampling period with the majority recorded as less than 10 individuals. Of these, all except Norwegian topknot, smooth sandeel, Corbin’s sandeel, salmon, hake and shore rockling have been recorded in other coastal or freshwater surveys (Jacobs, 2013a; Jacobs, 2013b). Thickback sole, Norwegian topknot, smooth sandeel and Raitt’s sandeel have been all recorded during entrainment surveys on site of the Existing Power Station (see Section 3.2).

Some fish recorded during the impingement monitoring programme in 2011 - 12 are likely to have included representatives of the species listed above but are unconfirmed as these individuals could not be identified to the necessary taxonomic level owing to the damage caused during impingement or sampling. For example, topknot was recorded but not to species level.

There were also 13 species recorded in 2011-12 that were not recorded by Spencer (1990):

- reticulated dragonet (*Callionymus reticulatus*);
- spotted dragonet (*Callionymus maculatus*);
- scaldfish (*Arnoglossus laterna*);
- leopard-spotted goby (*Thorogobius ephippiatus*);
- rock cook (*Centrolabrus exoletus*);
- tompot blenny;
- red gurnard (*Chelidonichthys cuculus*);
- spotted ray;
- golden grey mullet (*Liza aurata*);
- horse mackerel;
- haddock (*Melanogrammus aeglefinus*);
- transparent goby (*Aphia minuta*); and
- rock goby (*Gobius paganellus*).

Again, all these species were recorded by Jacobs in low numbers (all less than 13 individuals) over 16 months with eight of the species recorded as only one or two individuals.

Of the 65 species of fish impinged at the Existing Power Station between 2011 and 2012, 19 accounted for 95% of the total number of fish recorded over the 16 months (Table 2.1). The dominant species showed seasonal variation with many peaking during the winter months between December and mid-March.

Overall, impingement rates were higher during the winter months compared with the summer. This may be a result of both increased incidences of inclement weather during the winter but also spatial and temporal changes in habitat and resource use by local fish species. One example of this is the increase in sprat numbers recorded during the winter, which also coincides with observed increased in sprat numbers recorded from subtidal trawl surveys around Wylfa Head (Jacobs *et al*., 2013b). Another example is the peak in lumpsuckers (*Cyclopterus lumpus*) between late autumn and early spring as they move inshore to spawn during this time.

The most unusual fish recorded in the present surveys was the pearlside (*Maurolicus muelleri*). This species is a deepwater, pelagic species growing to no more than 8 cm. The fish has four rows of pale blue, light emitting organs along its ventral surface and normally lives at depths of between 200 m and 500m. Whilst no waters this deep exist off Anglesey, pearlsides do occasionally enter the upper 30m of the water column and are susceptible to being washed ashore during periods of heavy weather; indeed, strong winds were present at the time the single pearlside was recorded. The species had previously been recorded by Spencer (1990) and, although a rarity, should not be considered too unusual for the area.

Another rarity reported from previous years by station staff is the ocean sunfish (*Mola mola*). The sunfish is a southern species, frequenting UK waters during the summer months as it follows its prey, jellyfish. A specimen is reported to have been impinged approximately two or three years previously. They are not thought to be particularly abundant in the Irish Sea with previous estimates of abundance given at 0.98 individuals per 100 km^2 (Houghton *et al*., 2006).

2.3.1.2 Comparison of impingement impacts with other studies

Summary data from impingement studies conducted in the 1980s at other UK and French power stations are presented in Figure 2.10. Although the data are over two decades old, the numbers are still relevant as some of these stations are still running and, like the Existing Power Station, they do not have fish deterrent systems to reduce the numbers impinged. Together with the data from the present survey, they show that the catches on the CWS screens at the Existing Power Station are the lowest of all the power stations surveyed.

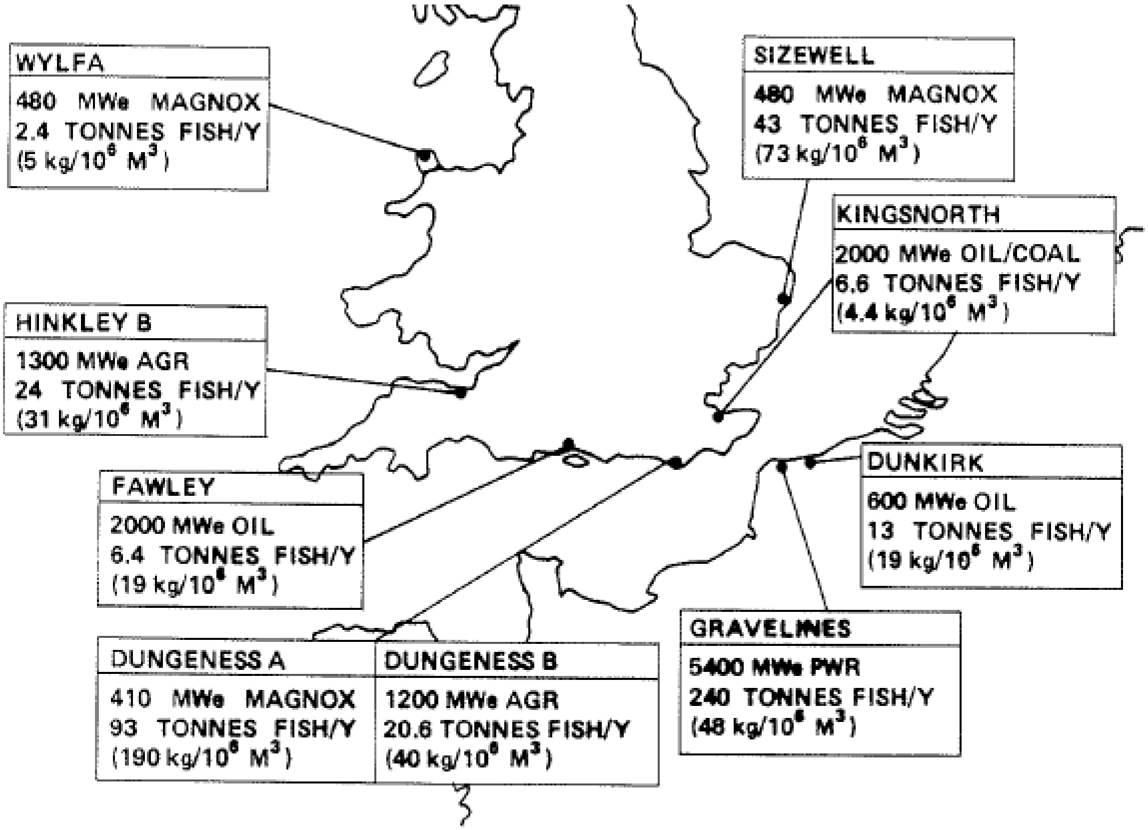


Figure 2.10 : Estimated annual fish catches at UK and French power stations (Spencer, 1990).

Some of the other impingement studies have been ongoing and, although some data are not yet publically available, those for Hinkley Point B are. Recent studies at Hinkley Point B conducted between February 2009 and February 2010 comprised 41 24-hour samples (Environment Agency, 2012). Sixty-four fish species were sampled over the year with the most common species being sprat, whiting, Dover sole (*Solea solea*), cod (*Gadus morhua*) and thin-lipped grey mullet (*Liza ramada*). Despite the similarities in the datasets (with respect to sprat and whiting being among the most abundant species), the main differences between the two stations are the numbers involved.

Over the 41 surveys at Hinkley Point B, nearly 80,000 sprats and over 45,000 whiting were impinged, compared with 1,946 and 356, respectively, over 55 surveys at the Existing Power Station. For all fish species recorded, the total predicted annual impingement at Hinkley Point B was 2.7 million fish with a total weight of 28 tonnes: over 15 times greater than at the Existing Power Station. This more recent estimate of 28 tonnes for Hinkley Point B also compares well with those made over two decades previously for an annual impingement of 24 tonnes (Figure 2.10).

To put the numbers of impinged fish at the Existing Power Station into further context, they can be compared with UK commercial landings. In 2011, UK commercial finfish landings were recorded as 442,000 tonnes (Elliott *et al*., 2011). The total biomass of fish impinged annually at the Existing Power Station (assuming a constant abstraction rate of 70 m³/s) equates to 0.0004% of this figure whilst the impingement of commercial finfish at the Existing Power Station was even less, at 0.00008% of the UK 2011 catch. The Existing Power Station does not operate a fish return system but the losses are not considered to pose a threat to commercial stocks. The present impingement rates at the Existing Power Station are extremely low when compared with losses from other coastal power stations or from commercial landings.

2.3.2 Invertebrates and macroalgae

Invertebrates and macroalgae formed the main bulk of the impinged material at the Existing Power Station, more often comprising more than 95% of the total catch. The species recorded (algae and invertebrates) were representative of those forming the infralittoral habitats along the north Anglesey coast and can therefore be considered of local origin.

The amount and type of material impinged often varied widely between each screen and depended on which screens were running. Screens three and four often contained most of the impinged algal matter whilst screen one usually yielded the most mussels (presumably dislodged from the intake tunnel) which were both dead and alive.

As described in the Results section, wind speed and direction is believed to have played a large role in determining the quantities of material impinged. This was originally noted by Spencer (1990) who also recorded increased catches of macroalgae during and immediately following periods of strong north-westerly winds. Entrapment of macroalgae into the CWS rarely caused an issue for station operation during the survey period and any issues that did arise were dealt with swiftly by operations staff ensuring that power generation was not affected. Figure 2.11 demonstrates the exposure of the Existing Power Station site during severe onshore north-westerly winds which can drive material inshore toward the intake, thus increasing the quantities impinged.

As well as macroalgae, the other factor that can cause blockage problems at the CWS screens is jellyfish. The jellyfish season at north Anglesey is clearly defined (Figure 2.9) between late April and late August, reaching its peak in mid-June. Moon jellies comprised the bulk of the records with a significant contribution from lion's mane jellyfish. Whilst the jellyfish caused some problems clogging the sampling baskets, they were not considered to be in numbers high enough to be detrimental to power station operation. Shutdowns have occurred at other power stations as a result of high jellyfish numbers, e.g. Torness nuclear power station in Scotland was temporarily shutdown in June 2011.

Figure 2.11 : The sea wall at the Existing Power Station over topping during high north-westerly winds in the 1980s (Source: Wylfa 'B' pre-application studies, 1980s).

Of the invertebrate species recorded from the CWS screens, lobster has the highest value to local fisheries. However, this species was impinged in very small numbers, estimated to total approximately 65 individuals per year; these losses are therefore not considered to present a significant loss to the local fishery.

Edible crabs were impinged in much higher numbers than lobster. The total number impinged per year is estimated at approximately 123,550. However, this high estimate may not be typical of every year as the high numbers recorded per survey between May 2011 and July 2011 were not repeated in 2012 (Figure 2.7). Whether 2011 was an exceptional recruitment year, or if 2012 was unusually low, is unknown, but it is clear that the numbers of edible crab existing locally are subject to very high variation. Most crab, lobster and other crustaceans impinged were alive and active suggesting good potential for survival following impingement.

2.3.3 Survivability

Aside from the presence of coarse screens (380 mm spaced vertical steel bars), the Existing Power Station has no fish protection measures in place and therefore any fish and invertebrates impinged would have been transferred to trash collecting skips resulting in 100% mortality. Although, the Environment Agency (2010) considers direct cooling using seawater to be the Best Available Technique (BAT) for large, coastally sited thermal plant; the BAT definition can only be considered appropriate if best practice fish protection measures designed to minimise the mortality of fish and other biota is followed. The CWS intake system for the Wylfa Newydd Generating Station will therefore be required to incorporate best practice guidance for fish protection system design and management.

A design options assessment has been carried out for the Wylfa Newydd Generating Station to identify a suite of solutions which will achieve the optimal fish protection, when balanced with performance in other areas of power station design and operation (Jacobs, 2016a). Although the exact specification of this is still to be decided, fish protection measures are likely to include 'fish friendly' fine mesh screens and a fish recovery and return (FRR) system.

The survival of fish and invertebrate species impinged on fine mesh intake screens and subsequently returned to the marine environmental via a FRR system varies owing to factors such as morphology (e.g. small scales, mucous covering and/or spiny armature). Survivability surveys have been carried out at a power station possessing fish protection measures similar to those expected to be installed at the Wylfa Newydd Generating Station. The complement of species vulnerable to impingement is also considered broadly similar for the two power station sites. The results of these surveys are presented in Table 2.3.

Robust epibenthic taxa (e.g. gobies, rockling and shrimps) generally exhibit high survival rates (>80%), whilst demersal taxa (e.g. gadoids) demonstrated moderate survival rates (~65%). Pelagic species such as clupeids (sprat and herring) generally exhibit extremely low survival rates when they come into contact with screens owing to factors such as scale loss and stress.

Table 2.3: Survival rates of fish and invertebrate taxa observed 24-hours after impingement (Jacobs, 2016b)

Common name	24-hour survival rate (%)
Sea bass	38%
Clupeids	0%
Gadoids	66%
Gobies	84%
Sand smelt	30%
Crab	81%
Spider crabs	100%

Common name	24-hour survival rate (%)
Prawn	86%
Shrimp	99%

The results of this study demonstrated good agreement with published survival rates observed at other power station sites although the exact fish protection measures installed may have differed (Travade and Bordet, 1982; Muessig *et al*., 1988; Seaby, 1994; Allen *et al*., 2012). However, it is evident that, had greater fish protection measures been in place at the Existing Power Station, a notable proportion of individuals belonging to the taxa outlined in Table 2.3 would have been returned to the sea alive. It can therefore be concluded that the addition of fish protection measures such as 'fish friendly' fine mesh screens and a FRR system within the CWS arrangement of the Wylfa Newydd Generating Station is likely to reduce the mortality of fish and invertebrates due to impingement.

2.3.4 Marine mammals

Entrapment of marine mammals at the Existing Power Station appears to be limited to single figures of grey seals in any given year and is therefore considered to be a relatively infrequent occurrence. Most seals survive the experience, and are rescued and returned to the sea away from the station.

The proposed CWS intake arrangement at the Wylfa Newydd Generating Station will include coarse screens with a much smaller spacing than those currently installed at the Existing Power Station. For example, a bar spacing of around 90 mm – 100 mm is likely to prevent entry by mammals. Consequently, with coarse screens such as this in place, impingement of marine mammals at Wylfa Newydd Generating Station is considered to be highly unlikely as there would be no aperture larger enough to permit entry of even small individuals such as grey seal pups.

3. Entrainment

3.1 Methodology

Entrainment surveys were completed for 24-hour periods at the CWS drum screens at the Existing Power Station at a rate of 40 surveys per annum. Surveys were scheduled on a random basis to avoid tidal bias. In total, 55 surveys were completed between 22nd March 2011 and 31st July 2012.

Ichthyoplankton was sampled from the drum screen jet-wash system that uses the same seawater as that extracted for the purposes of cooling. Prior to survey work commencing, checks were made to confirm that the system was not subject to any secondary filtration that could reduce the quantity of plankton sampled; it was confirmed by engineers at the Existing Power Station that this was not the case.

Hoses (4 inches in diameter) were secured to pre-existing fire hydrant valves on the screen wash system. One hose was set up at each of the four CWS screens. When the water was turned on, flow rates were measured by recording the time taken to fill a 74 L plastic drum; three replicate measurements were made at each tap-off point and the mean flow rate calculated. The flow rate for each tap-off point was set between approximately 5 - 8 L s^{-1}. Therefore, the total flow rate (summed over all the screens) often exceeded the minimum guidelines set by BEEMS (2010b) for entrainment studies of 10 - 25 L s^{-1}. The valves were not adjusted for the duration of the 24-hour sampling period.

The sampling water was then filtered through a 280 µm mesh plankton net and a note made of the start time. Each net was contained within a large blue drum that directed the filtered water back into the screenwells (Figure 3.1 and Figure 3.2). The apparatus was left to sample for 24 hours.

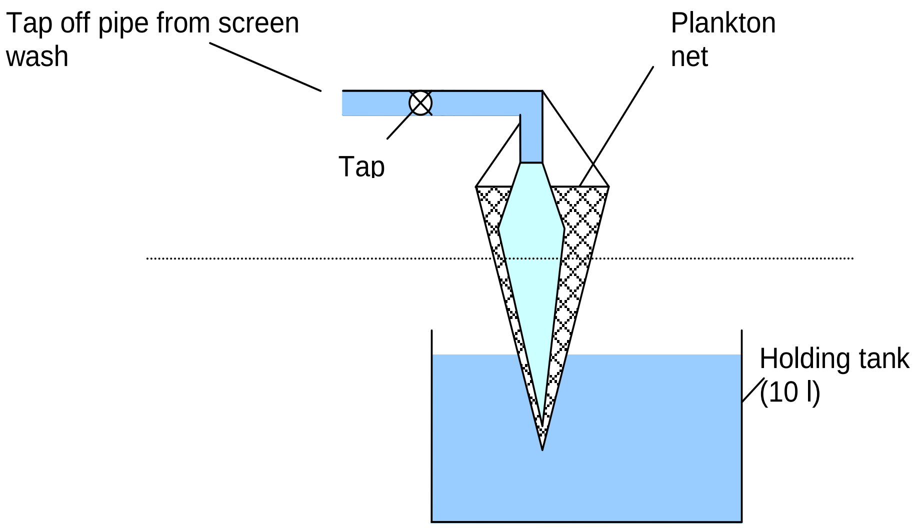


Figure 3.1 : Schematic diagram of the ichthyoplankton entrainment sampling setup.

Figure 3.2 : Photograph showing the operation of ichthyoplankton entrainment sampling.

At the end of the 24-hour sampling period, each hose was removed from the nets and a note made of the time. The water supply was not turned off until a further three replicate readings were taken of the flow rate at each tap-off point. The plankton samples were rinsed gently from the nets, placed into separate 1 L plastic buckets (one per net), preserved in 4% formalin and labelled with date, time, contents and screen number.

On occasions, not all the CWS screens were running owing to maintenance being carried out either at the screens or elsewhere on the power station. When sampling was restricted to fewer screens, the flow rates on the remaining screens was increased to ensure that the minimum BEEMS guidelines for sampling volumes continued to be met.

Samples were analysed in the laboratory using taxonomic guides including Russell (1976).

3.2 Data analysis

Numbers of fish and eggs per m^3 sampled were extrapolated to numbers per 10^6 m^3 of water abstracted. This standardisation allows direct comparison of data between surveys. Larval numbers are often standardised on a "'per 10^6 m^3" basis to allow meaningful statistical comparison. Numbers are standardised to such a high volume so that the numbers are rarely presented as fractions of fish and are also more relevant in terms of actual CWS abstraction volumes.

A multivariate statistical analysis of entrainment catches was carried out to assess temporal differences in community composition and to compare to coastal samples. The multivariate statistical approach adopted treated each taxon as a separate variable, enabling an assessment of complex community patterns within large-scale datasets. Multivariate statistics were carried out using PRIMER 6™ (v. 6.0) (Clarke and Gorley, 2006). In contrast to univariate analyses, which concentrate complex ecological data into a single metric, multivariate analysis compares differences between all taxa and their relative abundances between samples. The analysis therefore allows identification of samples with similar/dissimilar communities.

To assess differences in entrainment and coastal samples, a one-way Analysis of Similarity (ANOSIM) test was used to test for *a priori* differences in the structure of the community between sampling sites. This test was carried out on a square root transformed Bray-Curtis matrix.

To visually present differences in communities, non-metric Multi-dimensional Scaling (MDS) (50 restarts, Kruskal fit) was carried out on the square root transformed Bray Curtis resemblance matrices. MDS constructs a pictorial representation of the samples whose distances reflect statistically tested 'true' differences between the samples. Put simply, the closer a sample is to another sample on the MDS plot; the more similar the samples are to each other.

Due to the loss of key identification features in fragile specimens and/or their small size preventing certainty in speciation, for accurate statistical assessment, species data were amalgamated to family level. In some cases, poor specimen condition and the general difficulty in identifying larval fish prevented identification to family level. In these instances, individuals were classified as indeterminates. This group was removed from the data set prior to analysis in PRIMER, as this group is likely to contain multiple taxa which may exhibit different temporal and seasonal patterns in abundance. This being the case, inclusion could distort differences between factors making it difficult to identify statistical trends.

3.3 Results

The dates of all the 24-hour surveys are provided in Appendix A. The dates shown cover the start and end of each 24-hour survey period.

In total, over the course of 55 surveys, 5,973 fish larvae and 61,796 eggs were sampled at the CWS screens. The mean volume of water sampled during each survey was 2,011 m^3 ± 455 (standard deviation). Figure 3.3 presents the number of fish and eggs sampled per 10^6 m^3 of seawater abstracted. The data suggest that the period of highest abundance of entrained fish larvae and eggs is between early February and late August in any given year. The lowest abundances occurred over autumn/winter with 17 surveys from 23rd August 2011 to 7th February 2012 resulting in less than 6,500 fish larvae per 10^6 m^3 entrained per survey; this includes six surveys from 21st November 2011 to 6th January 2012 where no fish larvae were recorded during any surveys.

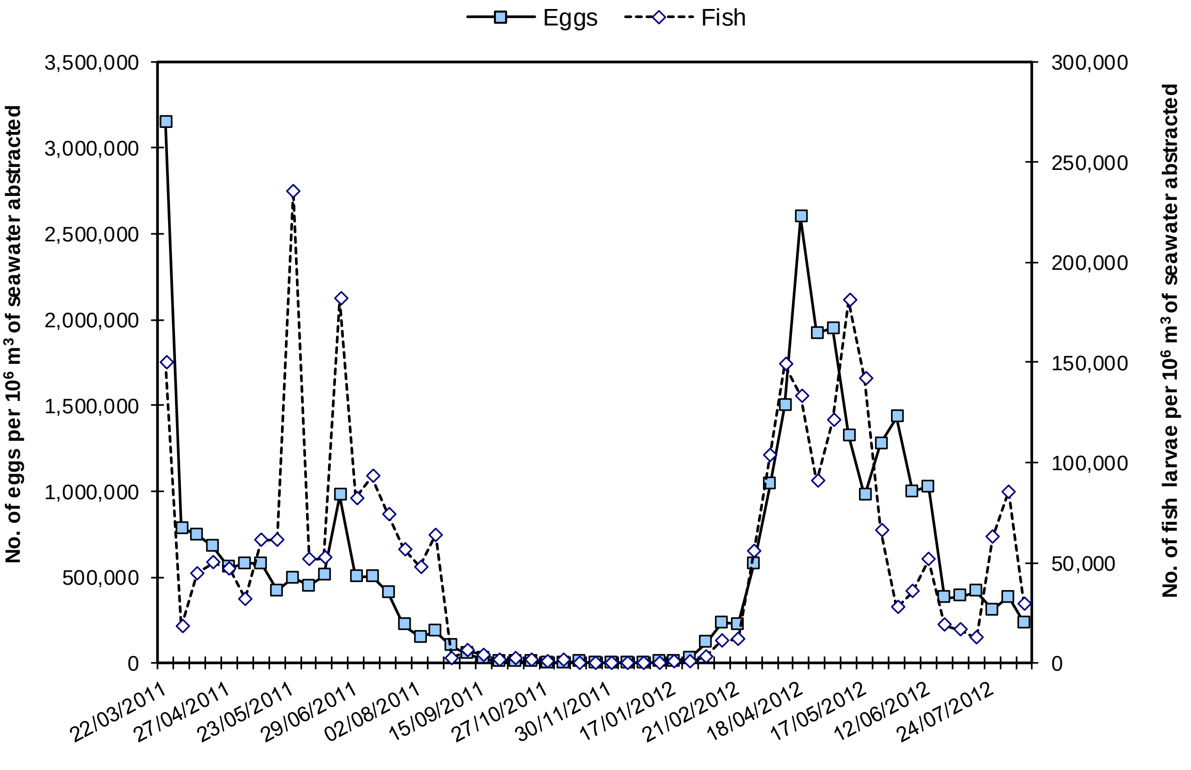


Figure 3.3 : Number of fish larvae and eggs entrained per 10^6 m^3 of seawater abstracted at the Existing Power Station between March 2011 and July 2012.

The timing of the peaks in larval abundance was similar in 2011 and 2012. The maximum peak in larval abundance was similar in both years with approximately 235,700 larvae per 10^6 m^3 recorded on 23rd May 2011 and 180,750 larvae per 10^6 m^3 recorded on 16th May 2012. Smaller peaks occurred in June and July in both years following the main peaks. During each spring/summer survey season, the mean abundance of larvae entrained at the Existing Power Station was 74,050 and 76,750 fish larvae per 10^6 m^3 in 2011 and 2012 respectively. The species responsible for each peak were largely similar in both spring/summer sampling seasons and this is examined further below.

The abundance of eggs followed a similar trend to that of fish larvae with the lowest abundances occurring over the winter period. In each of the 12 surveys from 26th September 2011 to 17th January 2012, less than 11,250 eggs per 10^6 m^3 were recorded. In the 2011 surveys, egg numbers were highest on 22nd March at approximately 3,149,650 per 10^6 m^3, and in 2012 egg numbers peaked on 18th April at approximately 2,593,150 per 10^6 m^3.

3.3.1 Species entrained

In total, 49 distinct fish taxa (species) were sampled over the 55 surveys (Table 3.1). The most numerous taxon sampled was the goby family (Gobiidae). There were no unusual species entrained during the survey period, i.e. all species would be expected within this biogeographical region.

Table 3.1 : Fish larvae species sampled at the Existing Power Station between 22nd March 2011 and 30th July 2012 and the total abundance over the whole survey period. Shaded taxa were within the 95th percentile of total abundance.

Taxa	Common name	Numbers
Gobiidae	Goby family	752
Callionymus lyra	Common dragonet	578
Indeterminate	Unidentifiable	578
Limanda limanda	Dab	508
Callionymus sp.	Dragonet family	441
Parablennius gattorugine	Tompot blenny	409
Blenniidae	Blenny family	337
Ammodytes spp.	Sandeel family	301
Pleuronectidae	Right-sided flatfish	301
Taurulus bubalis	Long-spined sea scorpion	273
Cottidae	Sea scorpion family	193
Buglossidium luteum	Solenette	136
Agonus cataphractus	Pogge	92
Callionymus reticulatus	Reticulated dragonet	92
Platichthys flesus	Flounder	84
Pomatoschistus microps	Common goby	74
Ammodytes marinus	Raitt's sandeel	70
Pomatoschistus minutus	Sand goby	67
Lipophrys pholis	Shanny	59
Soleidae	Unidentifiable sole	55
Aphia minuta	Transparent goby	54
Symphodus melops	Corkwing wrasse	52
Echiichthys vipera	Lesser weever	39
Labridae	Wrasse family	35

Taxa	Common name	Numbers
Myoxocephalus scorpius	Short-spined sea scorpion	34
Solea solea	Dover sole	34
Pholis gunnellus	Butterfish	31
Diplecogaster bimaculata bimaculata	Two-spotted clingfish	30
Pleuronectes platessa	Plaice	25
Liparis montagui	Montagu's sea snail	22
Clupeidae	Herring family	17
Ctenolabrus rupestris	Goldsinny wrasse	17
Liparis liparis liparis	Common sea snail	17
Ammodytes tobianus	Lesser sandeel	14
Liparidae	Sea snail family	14
Entelurus aequoreus	Snake pipefish	13
Syngnathus acus	Greater pipefish	13
Sprattus sprattus	Sprat	11
Chirolophis ascanii	Yarrell's blenny	10
Gadidae	cod family- unidentifiable	10
Hyperoplus lanceolatus	Greater sandeel	9
Labrus bergylta	Ballan wrasse	9
Lotidae	Rockling family	9
Merlangius merlangus	Whiting	9
Gymnammodytes semisquamatus	Smooth sandeel	8
Syngnathus rostellatus	Nilsson's pipefish	5
Clupea harengus	Herring	3
Cyclopterus lumpus	Lumpsucker	3
Microchirus variegatus	Thickback sole	3
Ciliata mustela	Five-bearded rockling	2
Nerophis lumbriciformis	Worm pipefish	2
Pollachius pollachius	Pollack	2
Scophthalmus rhombus	Brill	2
Spinachia spinachia	Fifteen-spined stickleback	2
Syngnathidae (juv.)	Juvenile pipefish	2
Triglidae	Gurnard family	2
Arnoglossus laterna	Scaldfish	1
Belone belone	Garfish	1
Blennius ocellaris	Butterfly blenny	1
Eutrigla gurnardus	Grey gurnard	1
Gobius paganellus	Rock goby	1

Taxa	Common name	Numbers
Gobiusculus flavescens	Two-spotted goby	1
Phrynorhombus norvegicus	Norwegian topknot	1
Pomatoschistus spp.	Sand/common goby	1
Zeugopterus regius	Eckstrom's topknot	1

Of those species listed in Table 3.1, the only species known to have conservation designations include herring, whiting, plaice, Dover sole and Raitt's sandeel. With the exception of Raitt's sandeel, which was not recorded in the impingement surveys, the conservation designations of these species are outlined in Table 2.2. Raitt's sandeel is listed on *Section 7 of The Environment (Wales) Act 2016.* Dover sole and plaice were the most frequently entrained with 34 and 25 fish larvae recorded, respectively over the 16-month sampling period. Of the other species of importance for conservation, there were 14 Raitt's sandeels, nine whiting and three herring entrained during the 55 entrainment surveys completed between 22nd March 2011 and 31st July 2012.

The species contributing the greatest to total abundance were grouped into their respective families to assess the proportion of their contribution to total abundance over the 16-month sampling period (Figure 3.4). In 2011, the fish sampled during the initial survey contained high numbers of sea scorpion (Cottidae) and sandeels (Ammodytidae) and right-eyed flatfish (Pleuronectidae). The greatest peak in fish larvae abundance in 2011 occurred on 23rd May and comprised 55% dragonet (Callionymidae) larvae and 22% right-eyed flatfish (Pleuronectidae, i.e. plaice, flounder, dab) larvae. A secondary peak in abundance on 20th June was dominated by blenny (Blenniidae) and goby families comprising 40% and 33% of the total abundance respectively. The two smaller, later peaks in July and August 2011 were also dominated by goby and blenny larvae.

The two main peaks in abundance in 2012 showed similar timing to peaks observed in 2011. The initial peak on 27th March 2012 was due to a peak in abundance of sandeels and sea scorpion which comprised 54% and 24% of the total abundance respectively; this closely resembled the results of the initial survey in 2011. The second peak in 2012 was on 16th May and resulted from a peak in abundance of a number of taxa including right-eyed flatfish (50%), dragonets (29%) and soles (Soleidae) (9%). Subsequent peaks were again dominated by blennies, though numbers of gobies were lower than in 2011.

The highest contributing families to total larval abundance over the 16-month survey period were flatfish (19%), dragonets (18%), gobies (16%) and blennies (15%). The highest abundances of gobies and blennies occurred in the summer months in both sampling years. In both 2011 and 2012, the peak abundances of flatfish occurred in mid-May.

In some cases, entrained fish larvae were damaged (perhaps by the passage through the CWS) and it was not possible to identify them with certainty. In these instances, individuals were labelled as 'indeterminate'; over the whole survey period this label was applied to 10% of fish larvae.

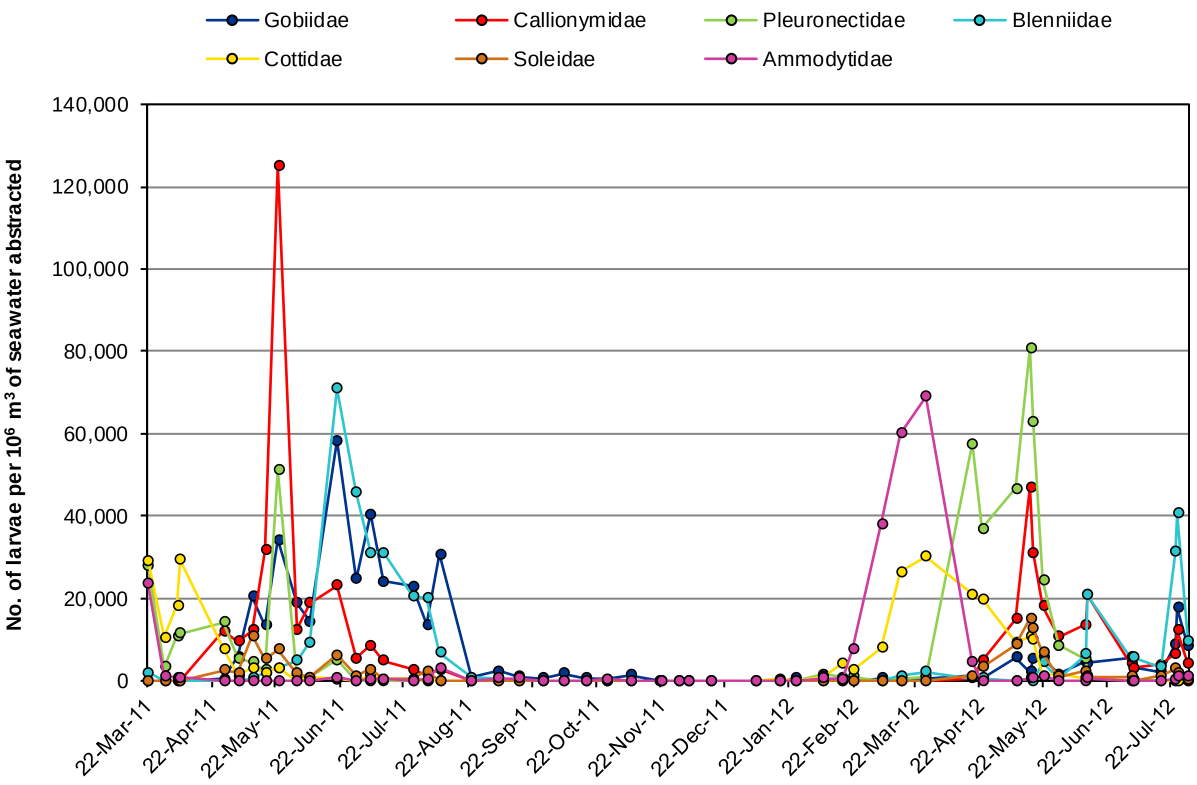


Figure 3.4 : Abundances of the dominating families of fish larvae per 10^6 m^3 entrained during 24-hour sampling periods at the Existing Power Station between March 2011 and July 2012 inclusive.

3.3.2 A comparison to coastal samples

The number of larvae entrained per 10^6 m^3 of seawater abstracted can be compared with the densities of larvae recorded from the ichthyoplankton tows along the north coast of Anglesey. These Gulf™ plankton sampler tows have been completed monthly at five sites since May 2010 increasing to six sites since July 2012. The locations of the sites are provided in Figure 3.5.

Ichthyoplankton samples were collected at these sites on a monthly basis with three replicate samples taken on a flood and ebb tide. From May 2012, samples were collected on a single random tidal state only owing to the lack of significant difference between previous samples from flood vs. ebb tides (see Jacobs, 2011). Sampling at Site 6 began approximately 16 months after the sampling programme began and samples were collected during both flood and ebb tides. Sampling at Site 7 was only carried out from March 2014 to September 2014 on a random tide. Figure 3.6 shows the mean number of larvae per 10^6 m^3 of seawater obtained from each site sampled each month since May 2010 and the mean number of larvae per 10^6 m^3 per month recorded in the entrainment samples from the Existing Power Station between March 2011 and July 2012

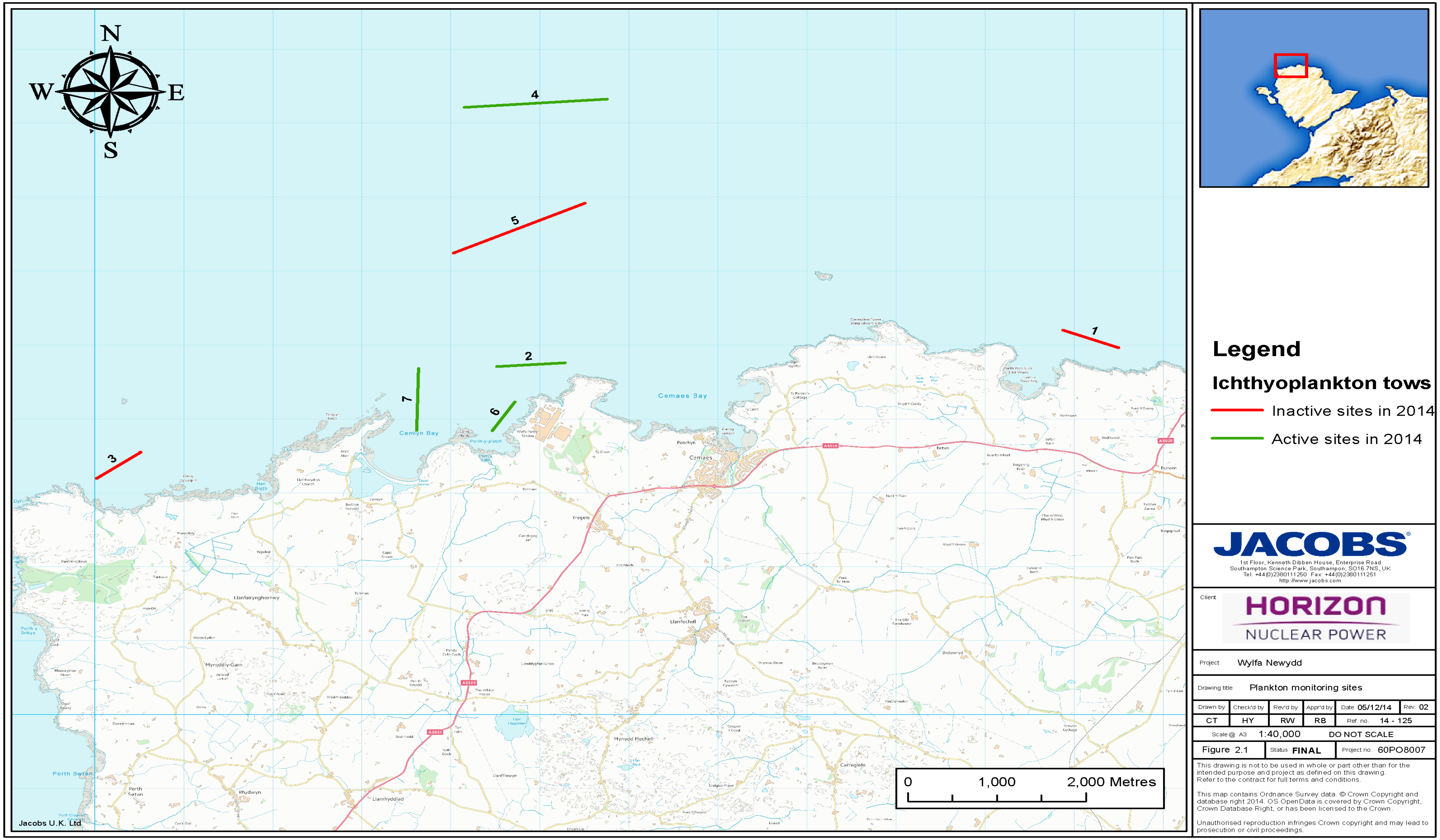


Figure 3.5 : Locations of seven ichthyoplankton sampling tows along the north Anglesey coast.

Figure 3.6 illustrates that larval densities were lower in the entrainment samples compared to the coastal sites sampled during the months of peak ichthyoplankton abundance (Feb to July) in both 2011 and 2012. The density of larvae in the entrainment samples was only 0.2% - 8.3% of that observed in the coastal plankton samples during the corresponding months. In both 2011 and 2012, the density of ichthyoplankton was greatest at Sites 1, 4 and 5. Ichthyoplankton density at Site 6 was most comparable to entrainment samples compared with the other coastal sites, in particular between August 2011 and November 2011 as well as January 2012 and June 2012.

Multivariate analyses were used to investigate any differences between the ichthyoplankton in the entrained samples compared with the Gulf tow samples from the coastal sites. An MDS (multidimensional scaling) plot of the data illustrated the monthly changes in ichthyoplankton composition as well as the clustering of the entrainment samples (Figure 3.7).

A one-way ANOSIM test demonstrated significant differences between the sites across all sampling months (Global R = 0.026, p = 0.001). Pairwise comparisons confirmed that significant differences occurred between the entrainment samples and coastal Sites 1, 3, 5 and 6 (R = 0.037 – 0.077, p < 0.017 in all cases). The only significant differences between samples from any of the coastal sites occurred between Site 6 and Sites 1, 2, 3, 4 and 5 (R = 0.047 – 0.112, p < 0.002 in all cases). The low (<0.2) R-values obtained in the pairwise comparisons suggests that there was considerable overlap in sample similarity and that the differences observed are mostly due to changes in species abundance rather than distinctly different communities.

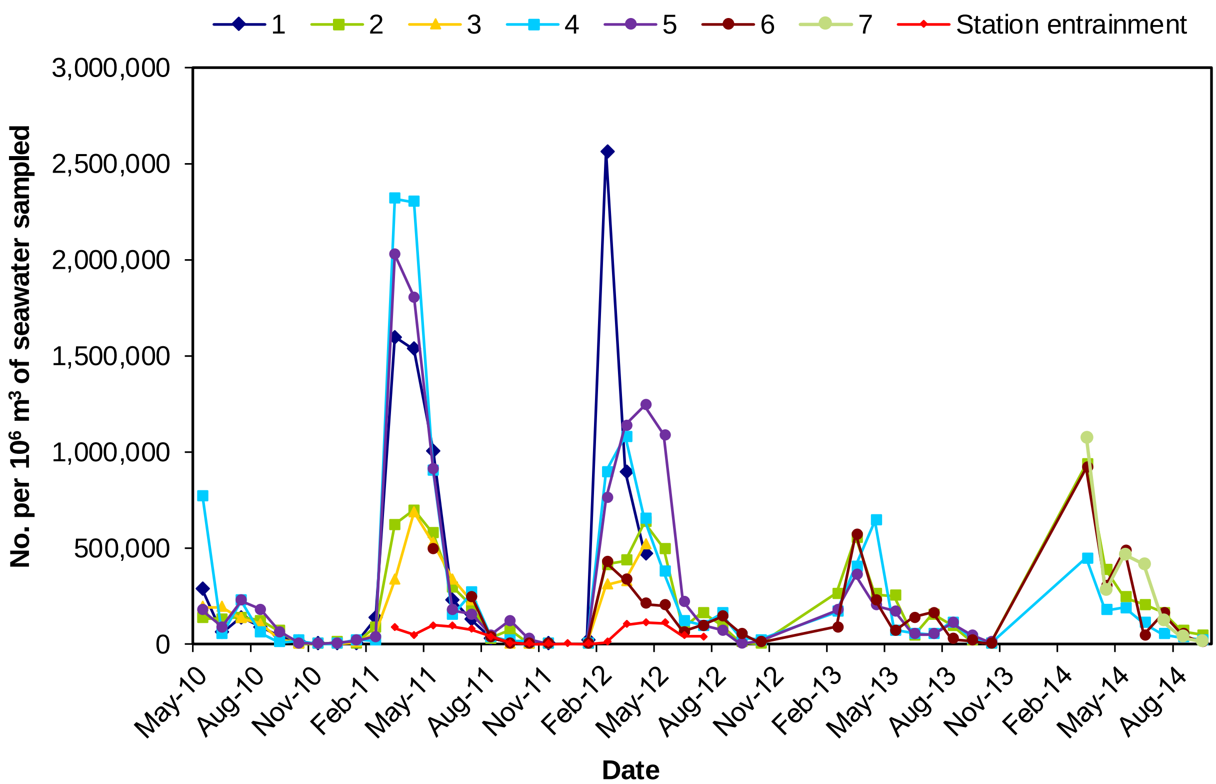
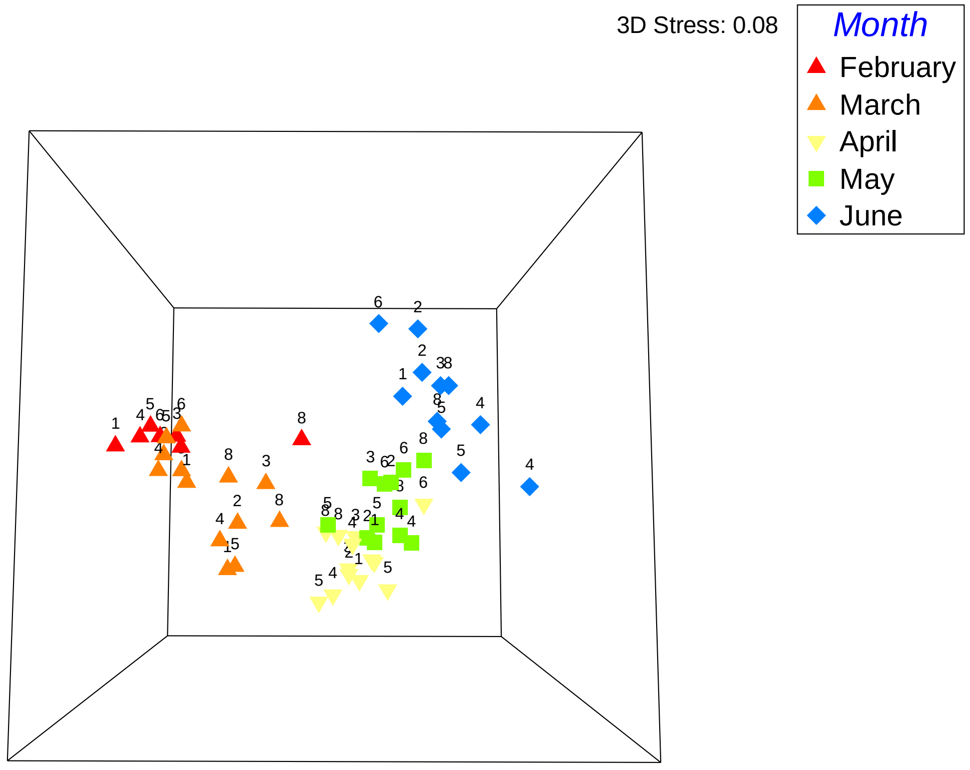


Figure 3.6 : Mean density of fish larvae (all species) per 10^6 m^3 seawater at seven sampling sites along the north coast of Anglesey between May 2010 and September 2014, and in the power station entrainment samples between March 2011 and July 2012.



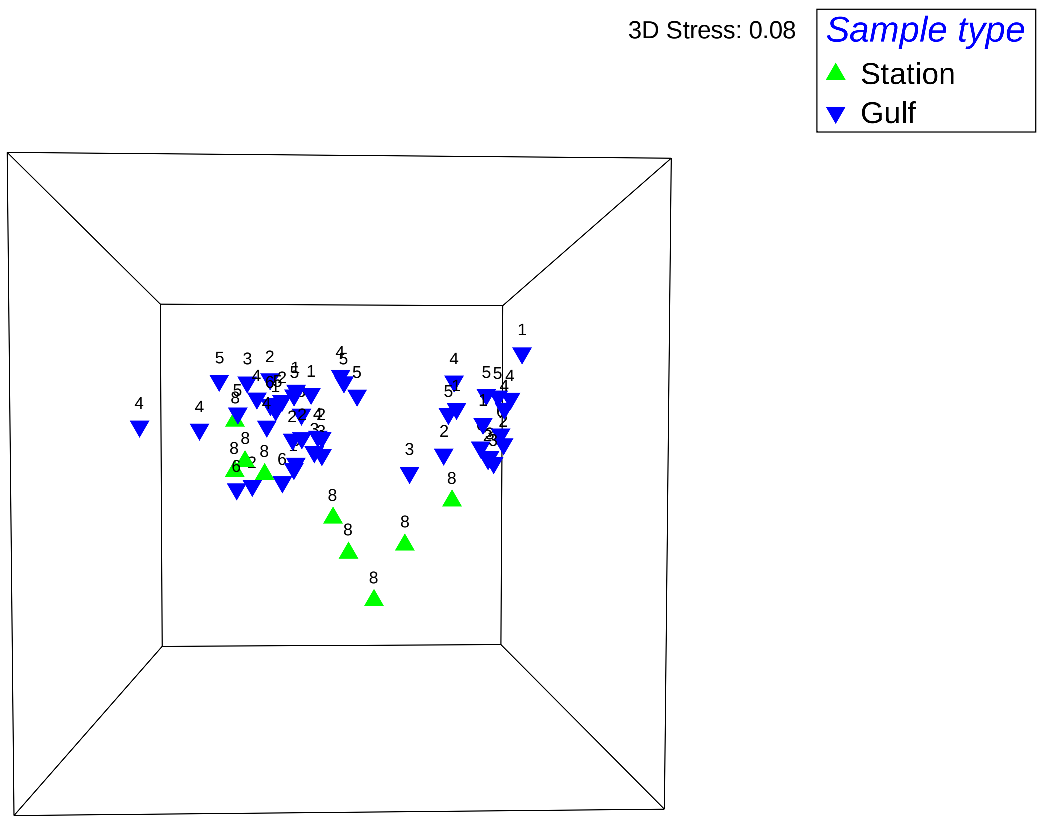


Figure 3.7 : 3D-MDS plots of the ichthyoplankton composition from entrainment samples from the Existing Power Station (Site 8) and from Gulf samples from the north Anglesey coastal areas (Sites 1-6) between February and June 2011 and 2012. The top plot shows the monthly patterns in composition and the bottom plot (rotated for clarity) shows the clustering of the entrainment samples away from the coastal samples.

Similarity Percentage (SIMPER) analysis compared the taxonomic composition between the entrainment samples and each coastal site. Overall, the coastal sites had much higher larval abundances of most taxa, in particular, sandeels, flatfish (Pleuronectidae and Soleidae), clupeids (sprat) and sea scorpions. The only group with higher abundances in the entrainment samples compared with all the coastal sites was the blennies. The results of the SIMPER analyses are provided in Appendix E.

3.4 Discussion

The entrainment surveys were conducted in parallel with the impingement surveys reported in the previous chapter and were undertaken during a period of typical power station operations in that no unexpected or long-term shutdowns occurred during the survey period that might have influenced the survey results.

The entrainment samples were dominated by inshore species adapted to a rocky, moderately exposed coastline subjected to strong tidal currents; predominately this included gobies, blennies, dragonets and sea scorpions (Table 3.1). Each of these families made significant contributions to the peaks observed in total larval numbers during each spring/summer season, though no single species dominated the fauna. Seasonal variation was clear with extremely low abundances or zero counts during the late autumn/winter seasons.

Abundances of gadoid and flatfish larvae were in general much lower, a result most likely owing to the lack of any recognised spawning grounds or suitable nursery areas in the immediate area around Wylfa Head (Coull *et al*., 1998; British Oceanographic Data Centre, 1998). Despite this, flatfish larvae did peak in numbers during May of both survey years, providing a strong contribution to the observed peaks. These peaks in flatfish larvae were mainly a result of increased numbers of dab. The Centre for Environment Fisheries and Aquaculture Science (Cefas) egg and plankton surveys show that dab spawn within Liverpool Bay to the east of Anglesey with tidal dispersion then distributing the eggs and larvae throughout the Irish Sea, reaching Anglesey from late April onward (Fox *et al*., 1997).

Entrainment studies were previously conducted at the Existing Power Station between October 1986 and September 1987 (Dempsey and Rogers, 1989). They recorded 27 larval species in the samples compared with the present study where 49 species were identified. The large disparity in species sampled might perhaps be in part owing to variation in the taxonomic resolution of identification or sampling methods. For example, in the present study, wherever possible, gobies were identified to species level resulting in a higher number of goby taxa than the 1986-7 study, where identification stopped at genus.

In the 1986-87 study, Dempsey and Rogers (1989) sampled the entrained plankton by lowering a Gulf™ V Plankton Sampler on a crane into the outfall channel. Each month, sampling was undertaken for periods of 55 minutes over an eight-hour period which included low water, dusk and two hours after dusk. On three occasions, a 25-hour sampling period was conducted to encompass two complete tides and a continuous day/night period. These three 25-hour surveys were used to produce correction factors for the remaining eight-hour surveys. Whilst there may be analytical issues in using one month’s data to correct for that of a different month, the lower number of dates sampled (12 vs. 55) could easily account for the different numbers of species recorded. Furthermore, by sampling at the point of outfall, the larvae would have passed through all stages of the station CWS. The various mechanical stresses involved at each stage of CWS passage and sampling could easily result in the physical degradation of larvae leading to difficulties with identification and therefore result in a lower number of taxa identified. Studies of larval survival following passage through CWSs are recognised as being hindered by damage caused even at the sampling stage (Dempsey, 1983).

Figure 3.8 demonstrates how, as with the impingement sampling, the number of species recorded greatly relies on the number of samples taken. This is likely to have played a major role in the disparity of the number of species identified between the two survey programmes. Both curves in Figure 3.8 begin to plateau out. This does not imply that Dempsey and Rogers (1989) had necessarily sampled all possible species; rather, the plateau is a result of the changing survey season and the lack of any larvae during the winter period. The secondary increase in new species from the present study after ~37 samples is likely due to the onset of the second spring survey season when a small number of additional species in low abundance was recorded.

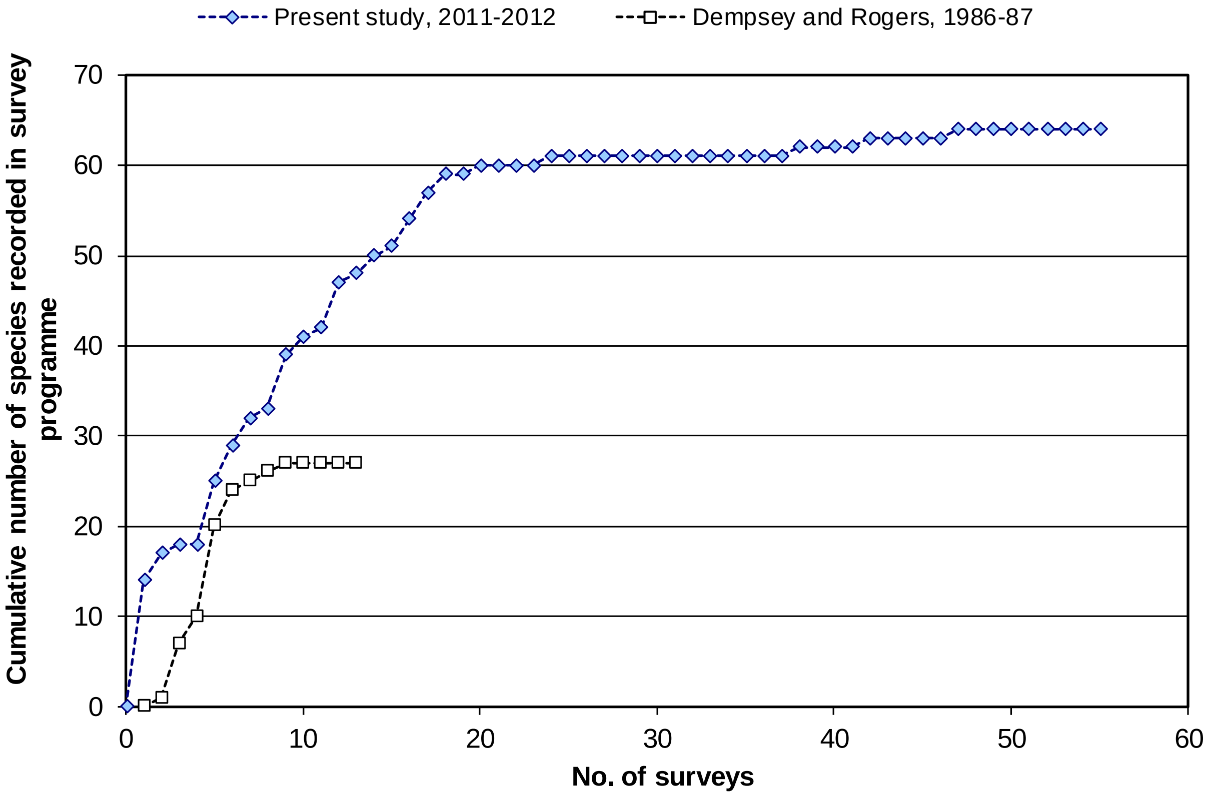


Figure 3.8 : A comparison between the cumulative number of larval fish species recorded on the CWS screens at the Existing Power Station with number of surveys conducted in the 1986-87 study (Dempsey and Rodger, 1989) and the present study (2011-2012).

Despite these methodological differences between the two surveys set some 25 years apart, there are similar patterns in the data. The May peaks in dab numbers observed in the present study also occurred during May 1987, and higher numbers of sea scorpion were recorded in April during both sets of surveys. In July and August 1987, goby numbers peaked as they did during the corresponding months of the present study. The only major difference between the two datasets is the peak in sandeel larvae in the present study (Figure 3.4) where this family group was not observed in the 1986-87 study.

The results of the present study suggest there are differences in the quantities and composition of the ichthyoplankton samples from the entrainment study on the Existing Power Station compared with the samples from the coastal sites. In general, the entrainment samples suggested a lower density was entrained compared with the coastal sites. In all comparisons (Appendix E), sandeels were the taxa most responsible for the sample differences, often followed by dragonets, flatfish (e.g. dab), gobies and clupeids (e.g. sprat). Sandeels and gobies are demersal spawners and therefore abundances of eggs and larvae in coastal waters within the vicinity of the intake would be expected to be reflected within entrainment samples. Other taxa such as flatfish, sprat and dragonets are pelagic spawners with buoyant eggs, likely to drift well away from the sheltered sea area where the intake is situated. This, coupled with the position and design of the present intake on the seabed, could be a major factor influencing the catch rates of species exhibiting these spawning characteristics and the overall abundance of fish larvae entrained.

The entrainment samples also contained a much greater density of blenny larvae and larvae from a number of species not identified in the samples obtained from the coastal waters; these included snake pipefish (*Entelurus aequoreus*), lumpsucker, goldsinny wrasse (*Ctenolabrus rupestris*) and Eckstrom's topknot (*Zeugopterus regius*). These additional species including the blennies are all reef-dwelling fish either spawning close inshore or attaching their eggs to the substrate; such behaviours are likely to be one the reasons for their absence in samples further from shore.

Dempsey and Rogers (1989) considered that the entrainment of juvenile fish at the Existing Power Station was not likely to have any significant adverse effect on the populations of those species entrained. The small percentage of the fish populations affected could be masked by year-on-year natural variations observed in fish population sizes. Section 4 of this report examines the EAVs of many of the species entrained in the present study to put them into the context of spawning populations.

4. Entrapment

4.1 Data analysis

Entrapment of larval (ichthyoplankton) and juvenile fish into power station CWSs is commonly assessed using the Equivalent Adult Value (EAV) concept (Horst, 1977; Dempsey, 1988; Dempsey and Rogers, 1989). The purpose of EAV analysis is to put entrapment catches into the context of commercial fishing which exploits adult fish above the Minimum Landing Size (MLS). An assessment of juvenile fish catches by power stations in terms of raw numbers assumes that all fish would have survived to adulthood and entered the commercial fishery had they not been entrapped. In reality, natural mortally among early life stages is extremely high and of the many eggs spawned, few will survive to adulthood and become available to the commercial fishery. Comparing raw numbers of entrapped juvenile fish directly to numbers removed by commercial fishing would therefore overestimate the impact of abstraction on commercial fish stocks.

Whilst the EAV methodology is most commonly used to quantify entrainment, several UK power plant studies have also applied EAVs to impinged fractions (Turnpenny, 1989; Turnpenny and Taylor, 2000). The EAV of entrained and impinged fractions combined allows entrapment impacts to be assessed in their entirety.

EAVs are calculated using lifetables which contain age and species-specific life history data such as fecundity and survivorship. These data are derived from published literature and therefore the applicability of the EAV methodology is limited to those species for which adequate life history data are available.

In 2013, Jacobs was commissioned by Horizon to develop lifetables for fish populations within the vicinity of the Existing Power Station. A preliminary assessment of available literature identified the possibility of developing three existing lifetables and creating a further seven (Table 4.1). The three existing lifetables for sandeel, dab and whiting were created in 2011 as part of an MSc project carried out in partnership with Kings College London. These were updated to reflect the most recent and geographically relevant data. The proposal to develop lifetables for seven new species was based on the availability of life history data as well as dominance of these species within entrapment catches (Sections 1 and 2) and also fish surveys conducted within the vicinity of the Existing Power Station as part of the ecological survey programme (Jacobs, 2013b). In 2015, a further review of these lifetables was undertaken with the purpose of ensuring EAV analysis was carried out using the best available data. Considering data published annually by the International Council for the Exploration of the Sea (ICES) for commercial fish stocks, the lifetables of sea bass, Dover sole and plaice were updated. No new published data were found to be available for the seven remaining lifetables.

In some cases, there was insufficient life history data to permit the development of species-specific lifetables but where the life histories of species within the same genus were sufficiently similar; a genus-level lifetable has been developed. These include dragonet and sandeel lifetables. Conversely, wrasse species (Labridae) demonstrate significant deviation in life histories; therefore, whilst Jacobs originally intended to develop a genus-level lifetable, species-specific lifetables for corkwing wrasse and goldsinny wrasse have been developed.

Details of the EAV methodology and the ten lifetables used within this report can be found in Jacobs (2015).

Table 4.1 : Lifetables created and updated within this report.

Taxa	Common name	Created	Updated
Dicentrarchus labrax	Sea bass	2013	2015
Merlangius merlangus	Whiting	2011	2013
Pleuronectes platessa	Plaice	2013	2015
Limanda limanda	Dab	2011	2013
Solea solea	Dover sole	2013	2015
Buglossidium luteum	Solenette	2013	-

Taxa	Common name	Created	Updated
Ctenolabrus rupestris	Goldsinny wrasse	2013	-
Symphodus melops	Corkwing wrasse	2013	-
Ammodytes spp.	Sandeel family	2011	2013
Callionymus spp.	Dragonet family	2013	-

To assess entrapment (entrainment plus impingement) catches, age-specific EAVs were calculated for the species outlined in Table 4.1. Age determination and EAV methodologies are outlined in detail in Jacobs (2015). EAVs were also calculated for herring and sprat, as lifetables for these species have recently become available (Jacobs, 2013c). EAVs for clupeids were presented as a range from both the herring and sprat lifetables. At present, no lifetable exists for pilchard.

Given the difficulties in speciating and ageing larval Gobiidae, Dempsey (1988) reported a generic EAV for entrained individuals. Gobiidae was the most abundant taxon entrained during the entrapment monitoring programme at the Existing Power Station, representing 15.9% of the total. This generic EAV has therefore been applied to Gobiidae abundances entrained per survey. It was not possible to apply a generic EAV to impinged individuals owing to their size and the variable life histories demonstrated by goby species. There were also insufficient data to create species-specific lifetables for all goby species. Gobiidae EAVs therefore represent the entrained fraction only.

Entrapment EAVs were extrapolated to the maximum abstraction rate of the Existing Power Station (70 m^3/s) to provide meaningful estimates scaled to CWS abstraction volumes. Where multiple surveys were carried out in a month, catches were summed and then divided by the volume of water abstracted during the corresponding period to yield estimates per m^3 of cooling water abstracted. These values were then multiplied by the volume of water abstracted (m^3) during each month to give extrapolated monthly impingement estimates. Summation of these values provides an annual EAV estimate.

To put entrapment catches into context, the EAV of commercial species including whiting, plaice, Dover sole, herring, sprat, clupeids (assuming unidentified individuals are either sprat or herring) and sea bass have been presented as a percentage of fishing statistics (ICES, 2014; 2015). For non-commercial species, such as dab, EAVs have been represented as a percentage of population estimates. It was not possible to assess the ecological significance of the remaining non-commercial species (solenette, goldsinny wrasse, corkwing wrasse and dragonet) EAVs due to the limited availability of relevant population data.

Fish entrapment can also be quantified in terms of the loss of food resources to key marine predators (e.g. seabirds and marine mammals). This is referred to as a dietary equivalence assessment and indicates the potential ecological significance of power station operations to higher trophic levels. Four marine predators have been examined: grey seal; Sandwich tern (*Sterna sandvicensis)*; Arctic tern (*Sterna paradisaea*); and common tern (*Sterna hirundo*). These species are common around the north coast of Anglesey and are of conservation importance, with grey seal being listed under the Habitats Directive and protected by the Conservation of Habitats and Species Regulations (as amended), and the three tern species being qualifying features of the Anglesey Terns/Morwenoliaid Ynys Môn SPA.

Fish entrapment estimates have been derived by summing the biomass of fish impinged and the biomass of EAVs entrained annually. The direct biomass of the impinged fraction has been used because the size of fish which are known to be vulnerable to impingement are approximately the same size as those known to be predated on by grey seal and terns (e.g. juveniles). Fish larvae do not represent a significant food resource to grey seal and terns and so the EAV of the entrained fraction has been used. The biomass of this fraction was calculated assuming a weight at 50% maturity as per the approach outlined by Turnpenny (1988). The sources for the allometric equations used to convert EAVs to biomass is summarised in Table 4.2. For all the species examined, length-weight relationships presented by Silva *et al*. (2013) were used.

Table 4.2: Source of allometric equations used to determine weight at 50% maturity to convert EAVs to a biomass.

Species	Taxonomic order	Weight at 50% maturity (g)	Method	Reference
Whiting	Gadiformes	88.9	Length at 50% maturity	Gerritsen *et al*. (2003)
Plaice	Pleuronectiformes	130.7	Length at 50% maturity	Doran (2011)
Dab	Pleuronectiformes	55.6	Length at 50% maturity	Langan (2012)
Dover sole	Pleuronectiformes	210.5	Age at 50% maturity; length-age relationship	Pawson and Harley (1997); Milner and Whiting (1996)
Solenette	Pleuronectiformes	7.6	Length at 50% maturity	Llkyaz *et al*. (2010)
Herring	Clupeiformes	109.0	Length at 50% maturity	Clarke *et al*. (2001)
Sprat	Clupeiformes	7.2	Length at 50% maturity	Mittermayer (2007)
Ammodytes spp.	Perciformes	7.6	Length at 50% maturity	Bergstad *et al*. (2001)
Corkwing wrasse	Perciformes	16.6	Age at 50% maturity; length-age relationship	Darwall *et al*. (1992); Dipper, (1976)
Goldsinny wrasse	Perciformes	14.1	Age at 50% maturity; length-age relationship	Darwall *et al*. (1992); Sayer *et al*., (1995)
Callionymus spp.	Perciformes	26.8	Length at 50% maturity	King *et al*. (1994)

4.2 Results

4.2.1 Equivalent Adult Values (EAVs)

The proportion of fish entrapped for which EAV analysis was possible represented 54% and 61% of the entrained and impinged fractions, respectively. These included some of the most abundant species entrapped, including whiting, dab, dragonet and sprat. Species-specific EAVs are presented in Table 4.3.

At the Existing Power Station, sprat was entrapped in the highest abundance and equated to 49,050 equivalent adults. Assuming all the clupeids sampled (including unidentified individuals) were sprat, a further 18,253 equivalent adults were also estimated to have been entrapped. The entrainment rate of larval sprat was much higher than impingement of juveniles; however, the abundance of these life stages within entrapment catches represented approximately the same number of equivalent adults. This outcome is driven by the assumption that a single juvenile is of greater value to a population than a single larva, being more likely to reach reproductive maturity to become an adult.

Equivalent adult herring were entrapped in fewer numbers (795 equivalent adults) compared to sprat and were predominately recorded within the impinged fraction. Assuming all the clupeids sampled (including unidentified individuals) were herring, these individuals only represented a further 34 equivalent adult herring.

Gobiidae demonstrated the second highest EAV despite representing the entrainment fraction only[6] and equated to between 13,143 equivalent adults. Dragonets and sandeels were entrapped in moderate numbers, collectively representing 6,684 equivalent adults. Both taxa were present within the entrained and impinged fractions in relatively equal numbers. All remaining species (solenette, Dover sole, sea bass, dab, goldsinny wrasse, corkwing wrasse, whiting and plaice) collectively represented 2,869 equivalent adults. The majority of entrapped plaice, solenette and Dover sole were entrained whilst dab were most common within the impinged fraction. Whiting and goldsinny wrasse were entrained and impinged in relatively equal proportions whilst sea bass were only recorded in the impinged fraction.

[6] EAVs for gobies were only applied to the entrained fraction owing to their size and the variable life histories demonstrated by goby species.

Table 4.3 : Number of equivalent adults estimated to have been entrained, impingement and entrapped (entrainment + impingement) annually scaled to an abstraction rate of 70 m³/s. * Goby EAVs represent the entrained fraction only.

Common name	Entrainment	Impingement	Entrapment
Sea bass	0	43	43
Sandeel	2,561	994	3,555
Solenette	148	19	167
Dover sole	118	7	124
Dragonet	2,048	1,081	3,129
Goldsinny wrasse	47	42	89
Corkwing wrasse	56	424	480
Dab	57	291	348
Whiting	384	342	726
Plaice	661	232	893
Goby*	13,143	-	13,143
Sprat	25,343	23,707	49,050
Herring	15	780	795
Clupeids as sprat	18,035	219	18,253
Clupeids as herring	20	14	34

4.3 Significance of entrapment

4.3.1 Comparisons to UK fishing statistics and population estimates

The ICES Working Group for the Celtic Sea Ecoregion (WGCSE) report (ICES, 2016a) provides information on commercial fishing efforts within the Irish Sea (ICES assessment division VIIa) in 2014[7]. International landings of whiting reported to ICES have declined since the 1990s from over 5,000 tonnes to 73 tonnes reported in 2014. Assuming a weight at 50% maturity of 86.7 g per individual (Gerritsen *et al*., 2003), the upper estimated number of equivalent adult whiting (tonnes) entrapped annually represented 0.09% of international landings reported in 2014.

In 2015, 1,005 tonnes of Irish Sea plaice were estimated to have been landed internationally (ICES, 2016a). Assuming a weight at 50% maturity of 130.7 g per individual (Doran, 2011), the estimated number of equivalent adult plaice entrapped annually represented 0.01% of landings.

The Dover sole fishery within the Irish Sea mainly takes place in the eastern Irish Sea (Liverpool Bay and Cardigan Bay). In 2015, 76 tonnes were estimated to have been landed (ICES, 2016a). Assuming a weight at 50% maturity of 210.5 g per individual (Langan, 2012), the estimated number of equivalent adult Dover sole entrapped annually represented 0.03% of landings.

ICES advice published in 2016 included a second preliminary assessment of sea bass stocks within the Irish Sea, Celtic Sea, English Channel and southern North Sea combined (ICES, 2016b). Landings (commercial and recreational) in 2014 were estimated to be 3,661 tonnes. Assuming a weight at 50% maturity of 519 g per individual (ICES, 2013), the estimated tonnage of equivalent adult sea bass entrapped annually represented 0.001% commercial landings and 0.002% of recreational fishing catches.

[7] 2015 estimate not considered reliable on publication of the 2016 WGCSE report (ICES, 2016).

ICES (2016c and 2016d) also provide landing statistics data for sprat and herring in the southern (ICES assessment division $VIIaS_{d-e}$) and northern Irish Sea (ICES assessment division $VIIaN_{g-h\,\&\,j-k}$), respectively. Assuming a weight at 50% maturity of 7.2 g per individual (Mittermayer, 2007), the estimated number of equivalent adult sprat (tonnes) entrapped annually represented 0.01% of commercial landings from the southern Irish Sea in 2015. Assuming all entrapped clupeids were sprat, these individuals represent a further 0.004%. In 2015, an estimated 17,578 tonnes of herring was landed from the northern Irish Sea. Assuming a weight at 50% maturity of 109 g per individual (Clarke *et al*., 2001), the estimated number of equivalent adult herring (tonnes) entrapped annually represented 0.0005% with clupeids (assuming all were herring) representing a further 0.00002%.

For non-commercial species, such as dab, other population metrics are available which contextualise entrapment catches. Selsay (2001) examined the population ecology of dab in the eastern Irish Sea off the coast of north Wales. The survey area included Red Wharf Bay, Conwy Bay and the offshore grounds on the north Wales coast. The total survey area was 656 km^2 and the population of dab within this area was estimated to be 2.34 x 10^6 individuals. The upper estimated number of equivalent adult dab entrapped annually at the Existing Power Station represented 0.01% of the local population.

With regards to commercial fish species, it is evident that the numbers of equivalent adults entrapped annually at the Existing Power Station represent a tiny fraction of those removed by the fisheries operating in the Irish Sea. A similar level of significance was observed when comparing the number of dab entrapped to local population estimates. This is due to not only to the relatively low abundance of fish entrapped but also the dominance of juvenile life stages within catches with 87% being equal to or below the smallest minimum landing size for a fish species (11 cm), as stipulated by the Council Regulation (EC) No. 850/98.

Whilst the impinged fraction (abundance and biomass) is lost from the local ecosystem, the entrained fraction is returned to the sea via the outfall. At present, no assessment of survivability of the entrained fraction has been made. However, Entrainment Mimic Unit studies indicate that mortality rates of some species are less than 100% and can vary between life stages. The EAVs presented within this report can therefore be regarded as precautionary estimates assuming 100% mortality of both entrained and impinged fractions.

4.3.2 Dietary equivalence assessment

The daily energy requirement of an adult tern is estimated to be 347 kJ (Wanless *et al*., 1998). Assuming the terns are present in the Anglesey Terns/Morwenoliaid Ynys Môn SPA from 1st April to 31st July (122 days), the total per capita energy demand of an adult during the breeding seasons would be 42,334 kJ.

Sandeel and clupeids have been found to be the dominant prey species collectively representing 83%, 78%, and 96% of the overall diet of Sandwich, common and Artic terns, respectively (Perrow *et al*., 2010; Newton and Crowe, 2000). The relative contribution of each prey species to the diet of Sandwich, common and Arctic terns is presented in Table 4.4.

Table 4.4: Proportion of Sandwich, common and Arctic tern diet made up of sandeel and clupeids ([1]Newton and Crowe, 2000; [2]Perrow *et al*., 2010).

	Sandwich tern[1]	Common tern[1]	Arctic tern[2]
Sandeel	0.52	0.10	0.85
Clupeids	0.31	0.68	0.11

The average length of fish eaten is 6 cm (Perrow *et al*., 2010). Using equations reported by Steinen (2006) and considering a digestive efficiency of 75%, the energetic value of each sandeel and clupeid consumed is 3.1 kJ and 7.7 kJ, respectively. The biomass of sandeel and clupeids that would need to be consumed by each species of tern to meet its per capita energy demand during the breeding season is presented in Table 4.5.

Table 4.5: Biomass (kg) of sandeel and clupeids that would need to be consumed per capita during the breeding season.

	Sandwich tern	Common tern	Arctic tern
Sandeel	9.47	1.11	5.80
Clupeids	1.19	7.33	3.34
Total	**10.66**	**8.45**	**5.80**

During the breeding season, a total of 161 - 288 kg of sandeel and clupeids is estimated to be entrapped at the Existing Power Station. This represents 0.4 - 0.7% of the biomass of these prey species which is required to sustain the tern populations of the Anglesey Terns/Morwenoliaid Ynys Môn SPA (calculations assume a five year mean population size: 1992 - 1996 for Arctic and common terns and 1993-1997 for Sandwich terns). Considering the tern species individually, the biomass of clupeids and sandeel entrapped at the Existing Power Station during the breeding season is equivalent to the diet of 15 – 27 Arctic terns, 19 – 34 common terns or 18 - 32 Sandwich terns during the corresponding period.

The weight of an adult grey seal varies between 105 kg to 310 kg, with 194 kg considered to be an appropriate average (Bonner, 1981; Jefferson *et al*., 2008). Using this biomass data and the equation presented by Innes *et al*. (1987) for Phocidae, the daily food consumption of an individual grey seal ranges from 2.7 kg to 6.8 kg, with an average of 4.6 kg. This equates to an annual food consumption of 996 kg to 2,472 kg (average of 1,667 kg).

Based on dietary composition data presented by Strong *et al*. (1996), grey seal is known to consume Rajiformes, Anguilliformes (e.g. conger eel), Cluepiformes (e.g. herring), Salmoniformes, Gadiformes (e.g. whiting), Pleuronectiformes (i.e. flatfish) and Perciformes (e.g. dragonets, wrasse and horse mackerel). Between 1,330 kg and 1,457 kg of fish predicted to be entrapped annually at the Existing Power Station belong to these taxonomic orders and represent a potential food resource to grey seal, equating to the annual diet of one average sized adult. adults. Whilst

5. Conclusions

- Impingement rates of fish at the Existing Power Station between March 2011 and July 2012 were lower in biomass but higher in number than those recorded previously in the late 1980s (Spencer, 1990).
- The smallest minimum landing size for a fish species, as stipulated by the Council Regulation (EC) No. 850/98, is 11 cm which is based on pilchard (*Sardina pilchardus*). Very few fish of any commercial value were impinged with 87% of all fish being 11cm or less and 95% being smaller than 18 cm standard length.
- Extrapolation of the data from the Existing Power Station estimated the annual catch at the Existing Power Station to be approximately 79,450 with a biomass of approximately 1.8 tonnes.
- Impingement of fish at the Existing Power Station is very low. It remains lower than at other UK power stations and does not pose any threat to the integrity of commercial stocks.
- Impingement of fish at the Existing Power Station peaks in the winter when higher numbers of clupeids, dragonets, sea scorpion and lesser-spotted dogfish are impinged. Increased numbers of juvenile gadoids (particularly whiting) are impinged between May and July.
- Impingement of lobsters is low at the Existing Power Station with an estimate of approximately 65 per year. Impacts on the local lobster fishery are considered to be negligible.
- The main bulk of all impinged material was composed of macroalgae and invertebrates. Increased impingement of material was found to be approximately correlated to periods of strong north-westerly winds.
- The peak season for jellyfish impingement is between early May and late July. The dominant species of jellyfish encountered were moon and lion's mane jellyfish.
- The peak season for larval entrainment was between early February and late August in both years when sampling was completed. This peak season coincided with peak abundances recorded from coastal ichthyoplankton surveys.
- The density of larvae in the entrainment samples was only 0.2% - 8.3% of that observed in the coastal plankton samples during the corresponding months.
- Annual entrapment catches of sea bass, whiting, plaice, Dover sole, solenette, dab, corkwing wrasse, goldsinny wrasse, sandeel, dragonet, goby and clupeids (assuming these are either all sprat or all herring) extrapolated to 70 m^3/s of seawater represent between 72,550 and 90,800 equivalent adults.
- Equivalent adult catches of sea bass, whiting, plaice, herring, sprat and Dover sole represent a tiny fraction of commercial fishing statistics with each species representing between 0.0005% and 0.09%.
- Equivalent adult catches of dab represented a tiny fraction of the local population (0.02%).
- Entrapment of sandeel and clupeids at the Existing Power Station represented a loss of food resources equivalent to 0.4% – 0.7% of that which is required to sustain the tern population in the Anglesey Terns / Morwenoliaid Ynys Môn SPA during the breeding season. Entrapment of fish species known to be prey of grey seal equated to the annual diet of one average sized adult.
- The significance of equivalent adult catches of solenette, corkwing wrasse, goldsinny wrasse and dragonet could not be assessed due to the absence of commercial and ecological metrics for these species.

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Appendix A. Impingement and Entrainment Survey Dates

2011

Mar

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	**22**	**23**	24	25	26	27
28	**29**	**30**	31			

Apr

M	T	W	T	F	S	S
				1	2	3
4	**5**	**6**	**7**	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	**27**	**28**	29	30	

May

M	T	W	T	F	S	S
						1
2	3	**4**	**5**	6	7	8
9	10	**11**	**12**	13	14	15
16	**17**	**18**	19	20	21	22
23	**24**	25	26	27	28	29
30	31					

Jun

M	T	W	T	F	S	S
		1	**2**	3	4	5
6	**7**	8	9	10	11	12
13	14	15	16	17	18	19
20	**21**	22	23	24	25	26
27	28	**29**	**30**			

Jul

M	T	W	T	F	S	S
				1	2	3
4	5	**6**	**7**	8	9	10
11	**12**	**13**	14	15	16	17
18	19	20	21	22	23	24
25	**26**	**27**	28	29	30	31

Aug

M	T	W	T	F	S	S
1	**2**	**3**	4	5	6	7
8	**9**	10	11	12	13	14
15	16	17	18	19	20	21
22	**23**	**24**	25	26	27	28
29	30	31				

Sep

M	T	W	T	F	S	S
			1	2	3	4
5	**6**	7	8	9	10	11
12	13	14	**15**	**16**	17	18
19	20	21	22	23	24	25
26	**27**	28	29	30		

Oct

M	T	W	T	F	S	S
					1	2
3	4	5	**6**	**7**	8	9
10	11	12	13	14	15	16
17	**18**	19	20	21	22	23
24	25	26	**27**	**28**	29	30
31						

Nov

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	**8**	9	10	11	12	13
14	15	16	17	18	19	20
21	**22**	**23**	24	25	26	27
28	29	**30**				

Dec

M	T	W	T	F	S	S
			1	2	3	4
5	**6**	7	8	9	10	11
12	13	14	**15**	**16**	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

2012

Jan

M	T	W	T	F	S	S
						1
2	3	4	5	**6**	**7**	8
9	10	11	12	13	14	15
16	**17**	**18**	19	20	21	22
23	24	**25**	**26**	27	28	29
30	31					

Feb

M	T	W	T	F	S	S
		1	2	3	4	5
6	**7**	**8**	9	10	11	12
13	14	15	**16**	**17**	18	19
20	**21**	**22**	23	24	25	26
27	28	29				

Mar

M	T	W	T	F	S	S
			1	2	3	4
5	**6**	**7**	8	9	10	11
12	13	**14**	**15**	16	17	18
19	20	21	22	23	24	25
26	**27**	**28**	29	30	31	

Apr

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	**18**	**19**	20	21	22
23	**24**	25	26	27	28	29
30						

May

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	**9**	**10**	11	12	13
14	15	**16**	**17**	**18**	19	20
21	**22**	**23**	24	25	26	27
28	**29**	**30**	31			

Jun

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	**12**	**13**	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Jul

M	T	W	T	F	S	S
						1
2	**3**	**4**	**5**	6	7	8
9	10	11	12	13	14	15
16	**17**	**18**	19	20	21	22
23	**24**	**25**	**26**	27	28	29
30	**31**					

Figure A.1: Dates of 24-hour entrapment surveys conducted at the Existing Power Station between March 2011 and July 2012.

Appendix B. Seawater Abstraction Volumes

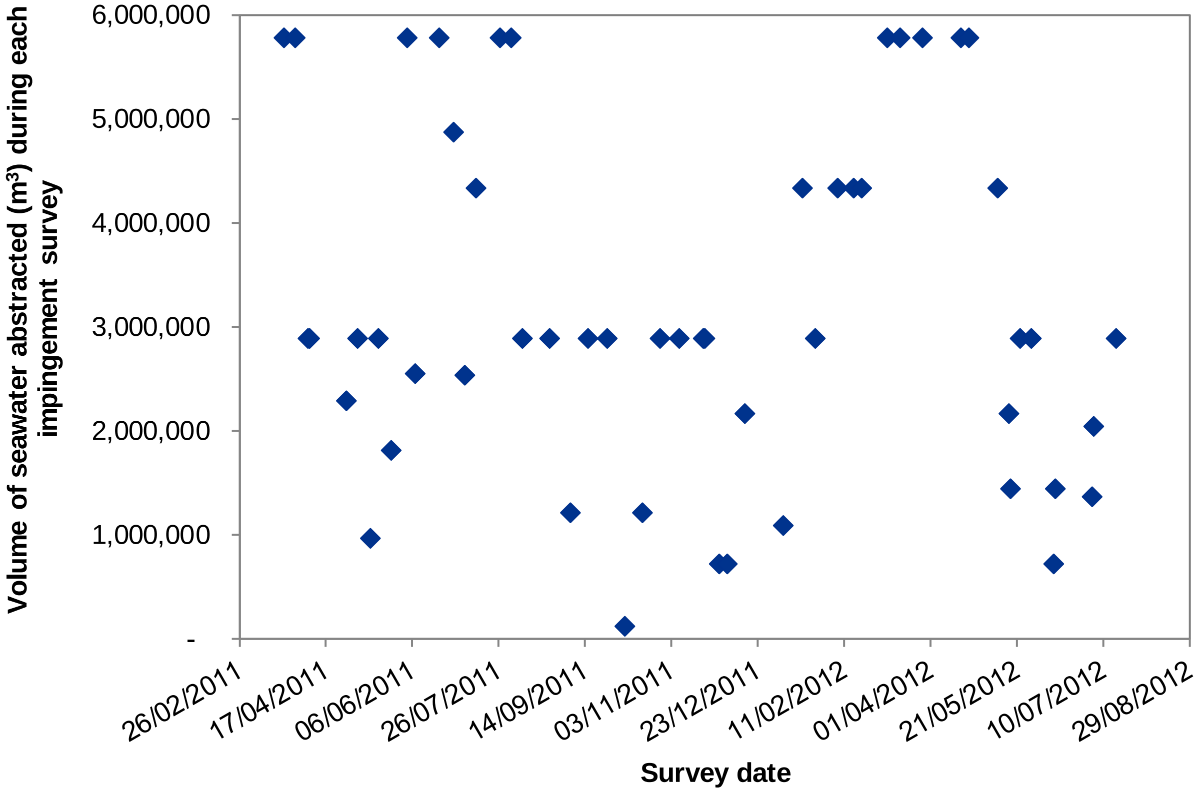

Figure B.1: Volume of seawater (m^3) sampled during each impingement survey carried out between March 2011 and July 2012.

Appendix C. Impinged Invertebrate Taxa

Table C. 1: Invertebrate taxa impinged on the CWS screens at the Existing Power Station between March 2011 and July 2012 during 24-hour entrapment surveys.

Taxa	Common Name	Taxa	Common Name
Sponges			
Amphilectus fucorum	Orange sponge	*Leucosolenia* sp.	Sponge
Dysidea fragilis	Goose bump sponge	*Sycon ciliatum*	Sponge
Grantia compressa	Sponge	*Stelligera stuposa*	Sponge
Haliclona oculata	Sponge	*Stelligera rigida*	Sponge
Halichondria panicea	Breadcrumb sponge	Porifera sp.	Orange sponge
Halichondria bowerbanki	Sponge	Porifera sp.	Yellow sponge
Cnidarians			
Abietinaria abietina	A hydroid	*Hydrallmania falcata*	A hydroid
Actinia equina	Beadlet anemone	*Metridium senile*	Plumose anemone
Sagartia sp.	An anemone	*Nemertesia antennina*	Antenna hydroid
Actinothoe sphyrodeta	Sandalled anemone	*Nemertesia ramosa*	A hydroid
Aglaophenia sp.	A hydroid	*Obelia* sp.	A hydroid
Aurelia aurita	Moon jellyfish	*Tubularia indivisa*	Oaten pipe hydroid
Alcyonium digitatum	Dead men's fingers	*Tubularia larynx*	A hydroid
Amphisbetia operculata	A hydroid	*Urticina eques*	An anemone
Chrysaora hysoscella	Compass jellyfish	*Urticina felina*	Dahlia anemone
Clava multicornis	Club-headed hydroid	*Rhizostoma pulmo*	Barrel jellyfish
Ctenophora	Comb jelly	*Sarsia eximia*	A hydroid
Cyanea capillata	Lions mane jellyfish	*Sertularia argentea*	A hydroid
Cyanea lamarckii	Blue jellyfish	*Sertularia cupressina*	A hydroid
Dynamena sp.	A hydroid	*Sertularella gayi*	A hydroid
Halecium sp.	A hydroid	*Eudendrium* sp.	An athecate hydroid
Flatworms			
Platyhelminthe	Flatworm		
Molluscs			
Aeolidia papillosa	Nudibranch	*Loligo* sp.	A squid
Aequipecten opercularis	Queen scallop	*Musculus* sp.	Mussels
Anomiidae sp.	Saddle oyster	*Mytilus edulis*	Common mussel
Aplysia punctata	A sea hare	*Nucella lapillus*	Dog whelk

Taxa	Common Name	Taxa	Common Name
Archidoris pseudoargus	Sea lemon	*Onchidoris bilamellata*	Nudibranch
Buccinum undatum	Common whelk	*Patella vulgata*	Common limpet
Coryphella sp.	A sea slug	*Pecten maximus* (juv.)	King scallop
Dendronotus frondosus	Nudibranch	*Philine aperta*	Lobe shell
Eledone cirrhosa	Curled octopus	*Polycera quadrilineata*	A sea slug
Facelina sp.	Nudibranch	Polyplacophora sp.	Chiton
Flabellina sp.	Nudibranch	*Sepiola atlantica*	Little cuttlefish
Gibbula sp.	A top shell	Tellinoidea	A bivalve
Helcion pellucidum	Blue-rayed limpet	*Trivia arctica*	Arctic cowrie
Janolus cristatus	Nudibranch	*Trivia monacha*	Spotted cowrie
Nassarius reticulatus	Netted dog whelk	*Velutina velutina*	Sea snail
Littorina littorea	Periwinkle		
Annelid Worms			
Aphrodita aculeata	Sea mouse	*Pherusa plumosa*	Bristle worm
Arenicola marina	Lugworm	Phyllodocidae	Paddle worm
Lepidonotus squamatus	Scaleworm	*Spirobranchus* sp.	Polychaete worm
Polynoidae sp.	Scaleworm	Sabellidae sp.	Polychaete worm
Eunicidae sp.	Polychaete worm	*Spirorbis* sp.	Polychaete worm
Nereididae sp.	Polychaete worm	Terebellidae sp.	Polychaete worm
Nephtys sp.	Catworm		
Nemertean Worms			
Nemertea sp.	Nemertean worm	*Lineus longissimus*	The bootlace worm
Crustaceans			
Amphipoda	Shrimp	*Liocarcinus holsatus*	Flying crab
Balanus balanus	Barnacle	*Macropodia* sp.	A spider crab
Cancer pagurus	Edible crab	*Maja squinado*	European spider crab
Caprella linearis	Shrimp	Mysidae	Shrimp
Carcinus maenas	Shore crab	*Necora puber*	Velvet swimming crab
Corophiidae	Shrimp	*Pagurus bernhardus*	Hermit crab
Crangon allmanni	Shrimp	*Palaemon elegans*	Shrimp
Crangon crangon	Brown shrimp	*Palaemon serratus*	Common prawn

Taxa	Common Name	Taxa	Common Name
Eualus occultus	Hippolyte shrimp	*Pandalina brevirostris*	Shrimp
Galathea strigosa	Squat lobster	*Pandalus montagui*	Pink shrimp
Galathea squamifera	Squat lobster	*Pasiphaea sivado*	Shrimp
Gammarellus angulosus	Shrimp	*Pilumnus hirtellus*	Hairy crab
Hippolyte varians	Shrimp	Pinnotheridae	Pea crab
Homarus gammarus	Common lobster	*Pirimela denticulata*	Toothed crab
Hyas araneus	Crab	*Pisidia longicornis*	Long-clawed porcelain crab
Hyas coarctatus	Crab	Pisinae sp.	A spider crab
Hyperia galba	Shrimp	*Porcellana platycheles*	Broad-clawed porcelain crab
Inachus sp.	Crab	*Processa edulis edulis*	Shrimp
Isopoda	Isopod	*Eualus cranchii*	Shrimp
Liocarcinus depurator	Harbour crab		
Sea spiders			
Pycnogonida	Sea spider		
Bryozoans			
Alcyonidium diaphanum	Sea fingers	*Crisia* sp.	A bryozoan
Bowerbankia sp.	Creeping bryozoan	*Flustra foliacea*	A bryozoan
Bugula flabellata	A bryozoan	*Flustrellidra hispida*	A bryozoan
Bugula plumosa	A bryozoan	*Membranipora membranacea*	A sea mat
Bryozoa	A bryozoan	*Scrupocellaria* sp.	A bryozoan
Cellaria sinuosa	A bryozoan	*Vesicularia spinosa*	A bryozoan
Chartella sp.	A bryozoan	Indet.	Encrusting bryozoa
Echinoderms			
Antedon bifida	Feather star	*Ophiothrix fragilis*	Brittle star
Asterias rubens	Common starfish	*Ophiura ophiura*	Brittle star
Henricia sp.	Starfish	*Psammechinus miliaris*	Green Sea Urchin
Ophiocomnia nigra	Brittlestar		
Sea squirts			
Ascidiella aspersa	Sea squirt	*Botryllus schlosseri*	Star ascidian
Ascidia conchilega	Sea squirt	*Ciona intestinalis*	Vase tunicate
Ascidia mentula	Sea squirt	*Corella eumyota*	Invasive species

Taxa	Common Name	Taxa	Common Name
Ascidia virginea	Sea squirt	*Molgula* sp.	Sea squirt
Ascidiella scabra	Sea squirt	*Morchellium argus*	Sea squirt
Aplidium punctum	Sea squirt	*Leucosolenia* sp.	Sea squirt
Botrylloides leachii	Sea squirt	*Didemnum* sp.	Sea squirt

Appendix D. Impinged marine macroalgae species

Table D. 1: Algal species recorded from the CWS screens at Wylfa Power Station between March 2011 and July 2012.

Red algae	Brown algae	Green algae
Acrosorium ciliolatum	*Alaria esculenta*	*Cladophora* sp.
Acrosorium venulosum	*Ascophyllum nodosum*	*Codium* sp.
Chondrus crispus	*Brongniartella byssoides*	*Enteromorpha intestinalis*
Chylocladia verticillata	*Bryopsis plumosa*	*Ulva intestinalis*
Corallina officinalis	*Calliblepharis ciliata*	*Ulva lactuca*
Cryptopleura ramosa	*Calliblepharis jubata*	*Ulva* sp.
Cystoclonium purpureum	*Callithamnion* sp.	
Cystoseira sp.	*Callophyllis laciniata*	
Delesseria sanguinea	*Ceramium* spp.	**Seagrass**
Dilsea carnosa	*Chorda filum*	*Zostera marina*
Drachiella spectabilis	*Cladostephus* sp.	
Dumontia contorta	*Cutleria multifida*	
Erythroglossum laciniatum	*Desmarestia aculeata*	
Furcellaria sp.	*Desmarestia ligulata*	
Gastroclonium sp.	*Desmarestia viridis*	
Gelidium sp.	*Dictyopteris polypodioides*	
Grateloupia sp.	*Dictyota* sp.	
Griffithsia corallinoides	*Dictyota dichotoma*	
Halarachnion ligulatum	*Dictyota spiralis*	
Halurus flosculosus	*Fucus ceranoides*	
Heterosiphonia plumosa	*Fucus serratus*	
Heterosiphonia japonica	*Fucus* sp.	
Lomentaria clavellosa	*Fucus spiralis*	
Lomentaria orcadensis	*Fucus vesiculosus*	
Lomentaria articulata	*Halidrys siliquosa*	
Mastocarpus stellatus	*Halopteris filicina*	
Membranoptera alata	*Himanthalia elongata*	
Nitophyllum punctatum	*Hypoglossum hypoglossoides*	
Osmundea sp.	*Laminaria* sp.	
Palmaria palmata	*Laminaria digitata*	
Phycodrys rubens	*Laminaria hyperborea*	
Phyllophora crispa	*Pelvetia canaliculata*	
Phyllophora pseudoceranoides	*Spongonema tomentosum*	
Plocamium cartilagineum	*Saccharina latissima*	

Red algae	Brown algae	Green algae
Plumaria plumosa	*Petalonia* sp.	
Polyides sp.	Brown filamentous macroalgae	
Polyides rotundus		
Polysiphonia elongata		
Polysiphonia lanosa		
Polysiphonia spp.		
Porphyra sp.		
Pterothamnion sp.		
Ptilota gunneri		
Rhodophyllis divaricata		
Rhodymenia holmesii		
Rhodymenia pseudopalmata		
Rhodymenia sp.		
Schottera nicaeensis		
Sphacelaria sp.		
Sphaerococcus sp.		
Sphaerococcus coronopifolius		

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Red algae	**Red algae continued**	**Brown algae continued**
Acrosorium ciliolatum	*Phyllophora pseudoceranoides*	*Desmarestia aculeata*
Acrosorium venulosum	*Plocamium cartilagineum*	*Desmarestia ligulata*
Chondrus crispus	*Plumaria plumosa*	*Desmarestia viridis*
Chylocladia verticillata	*Polyides* sp.	*Dictyopteris polypodioides*
Corallina officinalis	*Polyides rotundus*	*Dictyota* sp.
Cryptopleura ramosa	*Polysiphonia elongata*	*Dictyota dichotoma*
Cystoclonium purpureum	*Polysiphonia lanosa*	*Dictyota spiralis*
Cystoseira sp.	*Polysiphonia* spp.	*Fucus ceranoides*
Delesseria sanguinea	*Porphyra* sp.	*Fucus serratus*
Dilsea carnosa	*Pterothamnion* sp.	*Fucus* sp.
Drachiella spectabilis	*Ptilota gunneri*	*Fucus spiralis*
Dumontia contorta	*Rhodophyllis divaricata*	*Fucus vesiculosus*
Erythroglossum laciniatum	*Rhodymenia holmesii*	*Halidrys siliquosa*
Furcellaria sp.	*Rhodymenia pseudopalmata*	*Halopteris filicina*
Gastroclonium sp.	*Rhodymenia* sp.	*Himanthalia elongata*
Gelidium sp.	*Schottera nicaeensis*	*Hypoglossum hypoglossoides*
Grateloupia sp.	*Sphacelaria* sp.	*Laminaria* sp.
Griffithsia corallinoides	*Sphaerococcus* sp.	*Laminaria digitata*
Halarachnion ligulatum	*Sphaerococcus coronopifolius*	*Laminaria hyperborea*
Halurus flosculosus	**Brown algae**	*Pelvetia canaliculata*
Heterosiphonia plumosa	*Alaria esculenta*	*Spongonema tomentosum*
Heterosiphonia japonica	*Ascophyllum nodosum*	*Saccharina latissima*
Lomentaria clavellosa	*Brongniartella byssoides*	*Petalonia* sp.
Lomentaria orcadensis	*Bryopsis plumosa*	**Green algae**
Lomentaria articulata	*Calliblepharis ciliata*	*Cladophora* sp.
Mastocarpus stellatus	*Calliblepharis jubata*	*Codium* sp.
Membranoptera alata	*Callithamnion* sp.	*Enteromorpha intestinalis*
Nitophyllum punctatum	*Callophyllis laciniata*	*Ulva intestinalis*
Osmundea sp.	*Ceramium* spp.	*Ulva lactuca*
Palmaria palmata	*Chorda filum*	*Ulva* sp.
Phycodrys rubens	*Cladostephus* sp.	**Seagrass**
Phyllophora crispa	*Cutleria multifida*	*Zostera marina*

Appendix E. SIMPER Analysis Results

The output below show the results of the SIMPER analysis (top ten taxa contributing to between group dissimilarity) between ichthyoplankton samples from the entrainment study at the Existing Power station (Site 8) and the Gulf samples from the six coastal sites (Sites 1 - 6).

Groups 8 & 1
Average dissimilarity = 89.41

	Group 8	Group 1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ammodytidae	35.43	307.15	17.12	0.70	19.15	19.15
Pleuronectidae	76.56	189.64	10.72	0.93	11.99	31.14
Gobiidae	79.95	69.48	10.27	0.70	11.48	42.62
Callionymidae	90.07	78.06	8.19	0.87	9.16	51.78
Cottidae	57.20	91.72	7.17	0.73	8.02	59.80
Blenniidae	66.69	12.62	5.64	0.65	6.31	66.11
Clupeidae	8.11	132.45	5.57	0.69	6.23	72.35
Soleidae	37.46	76.74	5.48	0.69	6.13	78.47
Syngnathidae	11.84	16.32	4.62	0.32	5.16	83.64
Labridae	22.28	25.14	3.06	0.46	3.42	87.05
Liparidae	11.60	58.29	2.84	0.64	3.17	90.23

Groups 8 & 2
Average dissimilarity = 86.63

	Group 8	Group 2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ammodytidae	35.43	173.26	15.25	0.73	17.60	17.60
Gobiidae	79.95	89.35	11.65	0.78	13.44	31.04
Pleuronectidae	76.56	98.78	8.87	0.88	10.24	41.29
Callionymidae	90.07	64.73	8.62	0.91	9.95	51.24
Blenniidae	66.69	45.53	7.91	0.68	9.13	60.37
Cottidae	57.20	66.11	7.27	0.72	8.39	68.76
Labridae	22.28	60.00	5.83	0.58	6.73	75.49
Clupeidae	8.11	89.80	5.18	0.50	5.98	81.47
Soleidae	37.46	65.56	5.15	0.88	5.95	87.41
Agonidae	11.37	18.68	1.93	0.46	2.23	89.64
Gadidae	7.26	26.02	1.70	0.46	1.97	91.61

Groups 8 & 3
Average dissimilarity = 87.14

	Group 8	Group 3				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ammodytidae	35.43	158.35	14.89	0.72	17.09	17.09
Gobiidae	79.95	107.25	12.94	0.81	14.85	31.94
Callionymidae	90.07	87.03	9.43	0.98	10.82	42.76
Pleuronectidae	76.56	83.94	8.72	0.82	10.01	52.77
Cottidae	57.20	94.50	8.71	0.78	9.99	62.76
Blenniidae	66.69	46.79	7.68	0.75	8.81	71.57
Clupeidae	8.11	100.47	5.54	0.70	6.36	77.93
Soleidae	37.46	36.37	4.11	0.73	4.71	82.64
Labridae	22.28	20.38	2.82	0.54	3.24	85.88

Liparidae	11.60	32.35	2.67	0.53	3.07	88.94
Agonidae	11.37	23.51	2.14	0.50	2.46	91.40

Groups 8 & 4
Average dissimilarity = 87.56

	Group 8	Group 4				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ammodytidae	35.43	284.69	17.43	0.70	19.90	19.90
Gobiidae	79.95	77.83	11.18	0.71	12.77	32.67
Callionymidae	90.07	121.12	10.43	0.89	11.91	44.58
Pleuronectidae	76.56	166.64	9.66	0.93	11.03	55.61
Clupeidae	8.11	152.17	6.88	0.68	7.86	63.47
Cottidae	57.20	73.46	6.86	0.70	7.83	71.30
Blenniidae	66.69	25.16	6.36	0.68	7.26	78.56
Soleidae	37.46	64.22	4.70	0.82	5.37	83.93
Labridae	22.28	11.62	2.46	0.46	2.81	86.75
Syngnathidae	11.84	3.82	2.27	0.28	2.59	89.34
Liparidae	11.60	38.77	2.05	0.55	2.34	91.68

Groups 8 & 5
Average dissimilarity = 87.23

	Group 8	Group 5				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ammodytidae	35.43	272.23	19.00	0.76	21.78	21.78
Callionymidae	90.07	111.51	9.75	0.88	11.18	32.96
Pleuronectidae	76.56	184.83	9.45	0.93	10.83	43.79
Gobiidae	79.95	69.78	8.91	0.74	10.21	54.00
Blenniidae	66.69	36.39	7.29	0.61	8.36	62.36
Clupeidae	8.11	173.90	6.80	0.71	7.79	70.15
Cottidae	57.20	92.88	6.60	0.74	7.57	77.72
Soleidae	37.46	79.01	4.66	0.92	5.35	83.07
Gadidae	7.26	54.76	2.55	0.54	2.92	85.99
Labridae	22.28	11.75	2.27	0.43	2.61	88.60
Liparidae	11.60	51.12	2.24	0.56	2.57	91.17

Groups 8 & 6
Average dissimilarity = 90.69

	Group 8	Group 6				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Gobiidae	79.95	70.93	14.46	0.83	15.94	15.94
Ammodytidae	35.43	111.59	14.33	0.64	15.80	31.75
Callionymidae	90.07	40.95	9.73	0.95	10.73	42.48
Blenniidae	66.69	35.17	9.17	0.70	10.11	52.59
Pleuronectidae	76.56	25.43	8.21	0.76	9.05	61.64
Cottidae	57.20	22.58	8.07	0.62	8.89	70.54
Labridae	22.28	50.65	6.27	0.52	6.92	77.46
Soleidae	37.46	42.45	6.26	0.62	6.90	84.36
Clupeidae	8.11	41.60	3.79	0.50	4.18	88.54
Syngnathidae	11.84	4.58	2.91	0.33	3.21	91.74