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Diet of demersal fish species in relation to aquaculture development in Scottish sea lochs

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Abstract

The diets of demersal fish, principally haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and several flatfish species, sampled from four Scottish sea lochs (Hourn, Kishorn, Duich and Nevis) which support aquaculture sites, were examined in order to determine whether the impact of aquaculture on benthic biodiversity would affect the diets of demersal fish. Loch Kishorn had the highest maximum planned aquaculture production, loch Nevis follows and lochs Hourn and Duich have the lowest planned production. Samples were collected from locations less than and more than 2000 m from fish farm cages. Fish close to the fish farm cages were on average of greater individual weight than those further away from fish farms. Haddock ate predominantly Malacostracan crustacea, Ophiurid echinoderms and Polychaete annelids; whiting ate predominantly Malacostracan crustacea and teleost fish and flatfish ate Malacostracan crustacea, Polychaete annelids and Ophiurid echinoderms. A small number of saithe sampled had eaten mainly fish farm pellets. Dietary variation in each species was analysed in relation to loch, proximity to aquaculture facilities and fish size. Diet of whiting varied with body size. Dietary differences were observed between the lochs and between sites close to and far from farms in two lochs although these differences cannot be specifically attributed to aquaculture development. Controlling for differences between individual lochs, proximity to aquaculture facilities did not consistently affect diet composition.

Keywords: Aquaculture; Diets; Sea lochs; Demersal fish

1. Introduction

During the last 20 years, aquaculture has assumed an important role in the Scottish economy as well as for the generation of jobs and development of many rural areas (Scottish Executive, 2000). The salmon farming industry is now a major source of employment, particularly in many of the more remote areas in Scotland (Scottish Executive, 2000, 2006).

The Scottish salmon aquaculture industry began in 1968 by domestication of the natural river stock (Heen et al., 1993). Commercial production started in the mid-1970s and 500 tonnes of salmon where produced from 14 different sites in 1979 (Shearer, 1992). Since the early 1980s, the total annual production of Atlantic salmon increased steadily from 600 tonnes in 1980 to 126,686 tonnes in 1999 (Scottish Executive, 2000).

The West Coast of Scotland, along with the Western Isles, Orkney and the Shetland Isle are the principal locations for the Scottish salmon industry. Indeed, the West Coast has become the most productive salmon region in the UK, with an estimated 42,634 tonnes of farmed salmon produced in 2000. This reflects the requirement for relatively clean and sheltered areas in which to locate marine fish farms.

Multi-nationals, two-thirds of which are owned by foreign companies and around 50% by Norwegians, currently dominate the salmon industry in Scotland (ICES, 2002; Scottish Executive, 2006). In contrast shellfish farms are usually run by small local companies (Scottish Executive, 2000, 2006).

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Production has declined since 2004, with the total farmed Atlantic salmon production during 2005 (129,588 tonnes) being 18% lower than production in 2004. This downward trend continued in 2006 (Scottish Executive, 2006).

Scottish salmon aquaculture suffers similar problems to those seen in other countries (Williamson and Beveridge, 1994; Karakassis et al., 2000, 2002, 2006; Naylor et al., 2000; Pearson and Black, 2001; Machias et al., 2005). Among these problems, the most important are diseases, escapes of farmed fish, local and wider scale effects of eutrophication, and cumulative changes to benthic biodiversity beneath cage complexes and the environmental impact arising from waste release (Beveridge, 1996; Costa-Pierce, 2002; Gillibrand, et al., 2002; Mente et al., 2006).

The Scottish fishing fleet has an interest in stocks of approximately 80 fish and shellfish species and accounts for 70% of all UK landings. Demersal landings formed 21% of the total weight landed but formed 35% of the total value landed (Scottish Sea Fisheries Statistics, 2005). Despite having declined sharply in total value (real terms) since 1998, the demersal sector remained the most valuable to the Scottish based fleet in 2005. The literature highlights the importance of local environmental variability for fisheries landings (Erzini, 2005).The main species fished for off the West Coast of Scotland include cod, haddock, whiting, megrim, saithe, anglerfish, Norway lobster and scallops (Scottish Sea Fisheries Statistics, 2005). Many of these species are also found in the sea lochs where aquaculture facilities are located.

The coastline of western Scotland is characterised by the presence of a series of sea lochs, glacial formations analogous to Nordic fjords. Road access is often restricted and there is little agricultural development in the surrounding land. The inaccessibility of these lochs may explain why few previous studies have been conducted in the area. The potential future expansion of aquaculture in these lochs and the lack of biological information pertaining to them, underlines the need for further research on biodiversity and habitats, so as to efficiently assess the biological sustainability of aquaculture. The increased organic loading due to presence of aquaculture is known to result in local reduction in species diversity and increase in biomass of opportunistic species (Brown et al., 1987). The potential effect of the impact of changes in benthic biodiversity on other marine species and at larger spatial scales requires further investigation.

The present study examined the diet composition of several species of commercially valuable demersal fish species within four Scottish sea lochs and aimed to compare fish diets in sea lochs with different degrees of aquaculture development and to determine whether diet differed according to proximity to fish farms. Sites less than and more than 2 km from active fish farms are compared. As noted above, local-scale effects (e.g. within 50 m, Mente et al., 2006) of fish farms on benthic communities are well-documented. However, even if 50 m represents the limit for direct effects on benthic community composition, indirect effects would be expected at a larger scale, e.g. due to trophic interactions. Thus, if there is a difference in food available to demersal fish near to and far from fish farms one might expect to see this reflected in stomach contents, provided that the sampled fish have not travelled far from their feeding areas. The choice of scale selected for this investigation was ultimately largely pragmatic. First, a very fine scale of sampling is precluded because a trawl haul covers a large area and fish move around. Second, trawling was impossible in some parts of the sampled lochs due to presence of creels.

2. Materials and methods

2.1. The study area

The study was based in four sea lochs (Kishorn, Duich, Nevis and Hourn) located on the West Coast of Scotland (Fig. 1). They are among the most inaccessible lochs on the West Coast, with only restricted road access. They have relatively similar physical and hydrographic characteristics, being long, narrow and containing deep basins separated by relatively shallow sills. Average water depths at fish farm sites in lochs Kishorn, Duich, Nevis and Hourn are 82 m, 87 m, 122 m and 94 m respectively. In restricted exchange environments (e.g. Scottish lochs) estimates of the flushing time (the time taken to exchange all or some part of the local water volume with new coastal water; Gillibrand, 2001) are used to evaluate the significant increase of nutrient concentrations inside the environment (loch). There are differences in flushing time: 3 days for loch Kishorn, 7 days for loch Duich, 9 days for loch Nevis and 11 days for loch Hourn. The study area is not affected by agricultural pollution (SEPA, 1999).

There are, in total, 8 Atlantic salmon fish farms, one of which also grows rainbow trout along with the Atlantic salmon, and six shellfish farms in the study area (Figs. 1 and 2) (Scottish Executive, 2000). The shellfish that are farmed include oysters (*Ostrea edulis*), mussels (*Mytilus edulis*) and scallops (*Pecten maximus*). All lochs host more than one aquaculture site. Data on actual fish production for individual farms were unavailable. Within the study site, loch Kishorn holds the highest maximum planned production (around 4000 t/year). Loch Nevis follows with a total of 3800 t/year and loch Hourn and loch Duich have the least planned production (2075 t/year and 1250 t/year, respectively). The relatively high annual maximum planned production implies a healthy local aquaculture production level.[1] Scotland, like most European countries, regulates marine fish farming and has Environmental quality standards (EQS) mainly in relation to water quality and nutrient output. To achieve sustainable fish farming in Scotland Scottish Environment Protection Agency (SEPA) sets a maximum tonnage of product (Henderson and Davies, 2000) since there is no EQS for the "carrying capacity" of marine aquaculture. The regulations to maintain the environmental standards rely on measures of hydrological and biological features and sediment and water quality. Consequently it is expected that the "maximum planned production" does not substantially deviate from the amount of aquaculture production.

Under the Control of Pollution Act (1974) (COPA 74) it is an offence to cause or knowingly permit discharge of poisonous, noxious or polluting substances to controlled waters in Scotland. The Act also requires the relevant parties to follow the principles of Best Available Technology Not Entailing Excessive Cost (BATNEEC) to minimize the polluting effect of the discharge. However discharges of sewage and trade effluent into controlled waters, including all coastal and inland waters may be made under a Discharge Consent authorized by the SEPA. This Consent is required for new sites or if the owner of an existing site wishes to increase the product biomass or use chemical therapeutics. Monitoring by SEPA is routinely carried out at cage fish farms to ensure compliance with "consent to discharge", ensure EQS and other standards are being met, measure effects on the environment, determine any action to be taken and audit the results of self monitoring (which include paper or electronic records of biomass and medicine and chemical usage). SEPA also specifies which medicines may be used and the amounts and the rates that may be discharged at each farm to ensure that there is no damage to the environment.

[1] Scottish Environmental Protection Agency (SEPA) public register.