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# Size variation of 0-group plaice: Are earlier influences on growth potential a contributing factor?☆

Clive J. Fox [a,*], Timothy E. Targett [b], Benjamin J. Ciotti [b,1], Kasper de Kroon [c], Lena Hortsmeyer [d], Michael T. Burrows [a]

[a] Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, United Kingdom
[b] School of Marine Science and Policy, University of Delaware, Lewes, DE 19958, USA
[c] Van Hall Larenstein, University of Applied Sciences, The Netherlands
[d] Universität Konstanz, 78457 Konstanz, Germany

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A B S T R A C T

Over a decade of sampling has shown that there are consistent differences in the sizes of 0-group plaice by late summer comparing 21 nursery sites on the Scottish west coast. However, when young fish were collected from two sites which produce particularly small and large fish and reared using a common garden design, growth rates between fish from the two sites were indistinguishable. Either there is little selection for fast or slow growth up to a few weeks post-settlement, or such effects do not persist sufficiently strongly to influence later growth. There were also no significant correlations between the time-series of fish size comparing sites, although within some sites there was evidence of inter-annual density-dependent effects. Any influences of offshore regional-scale factors, such as sea temperature or pelagic primary productivity on growth thus appear to be heavily modified by local conditions on the nursery grounds. The field observations combined with the experimental results lead us to conclude that the size 0-group plaice attain in late summer is mainly controlled by post-settlement habitat quality.



## 1. Introduction

European plaice (*Pleuronectes platessa* L.) is a commercially important flatfish which has been a focus for fishery research for over a century. Plaice spawning generally commences early in the year and, following a period of planktonic drift, metamorphosing larvae settle into shallow, sandy habitats which are often accessible to researchers (Gibson, 1999). The commercial importance of plaice and the ready accessibility of the nursery grounds explains why so many studies have been undertaken on the post-settlement ecology of plaice, studies which have significantly contributed to our understanding of recruitment dynamics in marine fish (Ciotti, 2012; Nash and Geffen, 2012). An important conclusion from these studies is that fish size and mortality rates are inversely related and that this is generated by predator–prey interactions (Beverton and Iles, 1992a; Ellis and Gibson, 1995; Gibson et al., 1995). Larval and juvenile flatfish growth rates should thus be of key importance in determining overall survival (Ciotti, 2012; Freitas et al., 2012; Teal et al., 2008; van der Veer et al., 2010). Except for the period immediately after settlement (Ciotti et al., 2010, 2013a; Freitas et al., 2012), growth of 0-group plaice appears to be lower than predicted from laboratory experiments (Freitas et al., 2012; van der Veer et al., 2010). The commonest explanation for this is that some form of food limitation is occurring on the nursery grounds. This could result directly from reductions in the abundance or production of prey (Ciotti et al., 2013a), increasing inter-specific competition or declines in food quality (Ciotti, 2012; Freitas et al., 2012; van der Veer et al., 2010). However, there is little clear empirical support for any of these hypotheses. The lack of predictive power of current growth models in relation to field-data (van der Veer et al., 2010) suggests that either some fundamental processes are missing, or that we are not measuring the right factors at appropriate spatial and temporal scales (Ciotti et al., 2013b, 2013c).

The numbers of plaice larvae reaching individual nurseries depends on oceanographic connectivity with the spawning grounds (Bolle et al., 2009; Cushing, 1990; Fox et al., 2006). Plaice spawning on the Scottish west coast has been confirmed in the Clyde Sea by means of plankton surveys (Poxton, 1986) whilst Ellis et al. (2010) and Coull et al. (1998) indicated further spawning grounds to the west of Islay, to the south of Tiree and Coll and to the eastern side of the Isle of Lewis (Fig. 1). Steele and Edwards (1970) also reported a small area of localised spawning between Gairloch and Loch Ewe. Since the prevailing Scottish Coastal Current runs in a northerly direction (Inall et al., 2009), the more



* Corresponding author.
*E-mail address:* Clive.fox@sams.ac.uk (C.J. Fox).
[1] Present address: National Oceanography Centre Southampton, University of Southampton Waterfront Campus, Southampton SO14 3ZH, UK.

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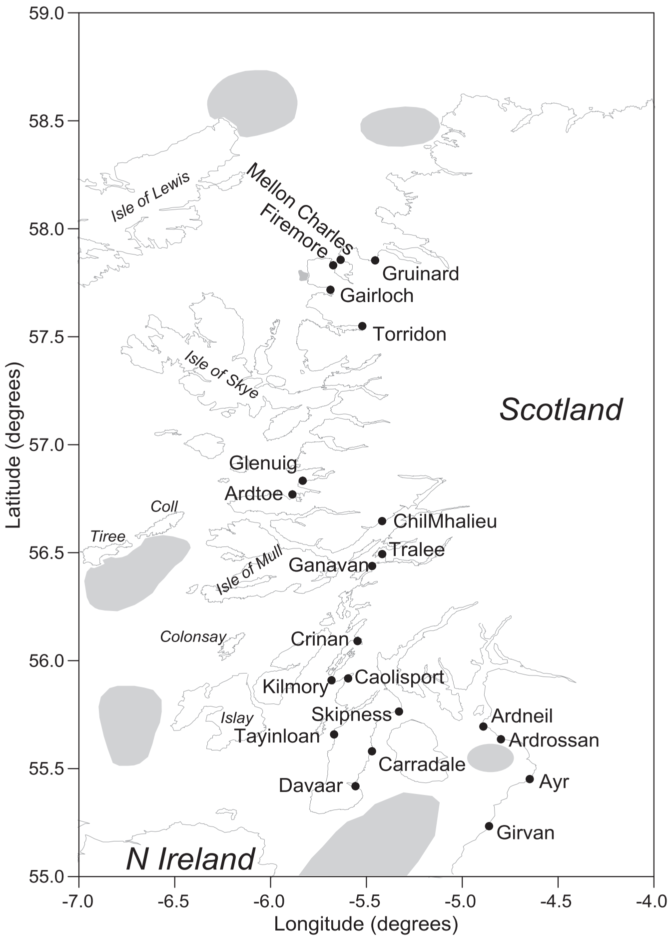


**Fig. 1.** Locations of the 21 nursery grounds sampled between 2001 and 2011. Shaded areas indicate the locations of plaice spawning grounds reported in the literature.

southern spawning sites may be the source of metamorphosing plaice settling onto beaches along most of the Scottish west coast. Thus, given the variable drift distances of different nurseries from these spawning grounds, there could be potential for growth-rate dependent selection to occur during the planktonic phase. The onset of metamorphosis in flatfish larvae is thought to be related more to size than age (Chambers and Leggett, 1987; Geffen et al., 2007) and, in addition, plaice do not appear to be able to delay settlement while searching for suitable substrates (Gibson and Batty, 1990). Sites further from the spawning grounds might therefore favour settlement of slower growing larvae whilst sites closer to spawning grounds might favour faster growing larvae. If selection for fast- or slow-growing larvae does occur during the planktonic stages, and these differences persist beyond settlement, this could provide an explanation for why faster or slower growing fish tend to be found at certain sites. Growth-dependent selection during the planktonic phase has been demonstrated in anchovy (Takasuka et al., 2004) and mackerel (Dominique et al., 2007) and has been shown to persist beyond larval life in tropical damselfish (Vigliola et al., 2007).

We firstly examined data from surveys conducted each August between 2001 and 2011 at the same twenty-one beaches where 0-group plaice growth has also been estimated using an RNA-based method by Ciotti et al. (2013b). We then tested whether selection for fast or slow-growing fish during earlier life could provide an explanation for the differences in sizes reached in late summer by rearing young post-settlement plaice collected from contrasting sites in a common-garden experiment.

## 2. Materials and methods

### *2.1. Beach sampling for size in August, 2001–2011*

Juvenile flatfish were sampled at the sites shown in Fig. 1. Four additional locations (Dunstaffnage, Kentra, Shallachen and Loch Sween) were also sampled but were excluded from the data because very low numbers of plaice (<20) were caught at each of these sites in most years. Fish were sampled using 1.5 m beam-trawls towed manually at walking pace for 5 min in water between 0.5 and 1.5 m deep. Three to five replicate tows were completed at each site within 1 h either side of low water. The distance covered by each tow was recorded using hand-held Garmin GPS units. Each trawl had a single spiked tickler chain and 10 mm mesh net and the same trawls were used throughout. Fish were sorted from the catches and anaesthetized using benzocaine or clove oil and then either fixed in 4% formalin or, for years where juvenile plaice were also analysed for molecular condition (2005–2007 only), photographed against a calibration rule before being frozen (Ciotti et al., 2013b). On return to the laboratory, plaice were sorted from the catches and their total lengths (TL) recorded. For fish which had been photographed, lengths were calculated from the calibration rule. Lengths were not adjusted for preservation method as Lockwood (1973) showed that 0-group plaice only shrink by 2.5% when fixed in formalin. For a 50 mm fish this would only make a difference of 1 mm. The density of fish at each site by year was estimated as the total number of fish caught divided by the total swept area. Abundance data were not corrected for net avoidance or gear efficiency (see Discussion). Any plaice caught which were >120 mm TL were assumed to be 1-group survivors from the previous year and were not included in the data analysis.

### *2.2. Common garden rearing experiments, 2011–2012*

To investigate whether 0-group plaice from different sites have inherent growth differences we compared the growth of fish which originated from two sites which have consistently yielded the greatest differences in late-summer size, namely Tralee (56.493°N 005.418°W) which tends to produce larger fish and Caolisport (55.918°N 005.595°W), which tends to produce smaller fish (Fig. 1). In 2011, juvenile plaice (30–60 mm total length) were collected from Caolisport on 27 June and from Tralee on 29 June using the trawl described above (rearing Trial I). Sufficient fish were collected for stocking the experiment plus holding a reserve to replace any mortalities. Fish were transported from the two collection sites to the laboratory in insulated, aerated containers. After 48 h acclimation, fish >35 mm TL were subdermally tagged (ventral surface) using visible-implant-elastomer (VIE, Northwest Marine Technology, Washington, USA) with different colours identifying their site of origin. Using existing data on the typical standard-deviations in size in mid-August, power analysis was used (Faul et al., 2007) to estimate that a total sample size of at least 36 would be needed to detect a difference of 10 mm in final sizes between groups ($\alpha$ probability at 0.95 and $\beta$ probability at 0.2). Twenty-five fish from each site were therefore assigned to each of three rearing tanks on 1 July ensuring that the initial length distributions of fish from each site within each tank were as equal as possible. The initial size distributions were compared with ANOVA to check that there were no significant differences. Rearing was conducted in 120 l fibreglass tanks with continuous aeration and flow-through seawater. The bottom of each tank was covered with aquarium sand to allow the plaice to undertake their normal burying behaviour. Tanks were cleaned daily and the fish fed *ad libitum* with finely chopped fresh mussel (*Mytilus edulis*). The quantities of mussel offered were increased as the fish grew so that a small amount of uneaten food remained the following morning. Uneaten food was removed using a small hand-net before re-feeding. Water temperature in the tanks was recorded daily. Room lighting was set on a time-cycle of 16:8 h (light:dark) approximating natural conditions at this time of