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Spatial management measures for disease mitigation as practiced in Scottish aquaculture

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ABSTRACT

Aquaculture is an increasingly important economic activity in coastal waters. The fluid environment means spatial management is an important tool for protecting fish health. Scottish aquaculture (largely Atlantic salmon) uses a range of different types of area to group farms for different management or reporting purposes related to fish health. Farm Management Areas are defined by local knowledge and used by industry for co-operation among groups of farms, including in the management of sea lice. Disease Management Areas, defined using a simple but robust model, are used by the Scottish Government for control of notifiable diseases. Particle dispersal models are used to assess areas affected by treatment residue around farms, and to manage maximum allowable area biomass for environmental protection. Sophisticated models of sea lice transport have been developed to help inform management of this key parasite. Large regional areas are used for a variety of purposes, such as a policy presumption against new farms covering the entire east and north coasts of Scotland, and five reporting areas for official production statistics. Scottish aquatic environments are shared by many interest groups and spatial management is proving essential for sustainable development by aquaculture and other users.

1. Introduction

Aquaculture is an increasingly important commercial activity in Scottish waters and is a particularly important employer in remoter areas of Scotland. The largest component of Scottish aquaculture is Atlantic salmon, with 179,022 t produced in 2014, together with 5822 t of trout [1], 7683 t of mussel [2] and smaller quantities of other species. Salmon constitutes Scotland's largest single food export. However, Salmon production has been impacted by a range of diseases and parasites, such as furunculosis [3], ISA [4] and sea lice [5]. The different pathogens have led to the development of a range of different control measures.

Epidemiology theory tells us that to control infection either pathogen removal must be increased or rate of new infection reduced so that the basic reproduction number $R0 < 1$ [6,7]; disease impacts may also be controlled even when infection is present. A variety of disease control methods are available, such as vaccination [8], selective breeding [9], treating with medicines [10] or culling [4].

Pathogens can also be controlled by using physical separation to reduce or prevent transmission between populations. Separation allows the exclusion of pathogens from naïve populations and for pathogens to be managed more effectively within infected populations. Separation of populations by means of farming in tanks or ponds with biosecure sources of water is possible, and may occur in some circumstances (e.g. to protect broodstock). However, given the widespread use of open net pens in marine aquaculture, physical separation requires that farms, or groups of farms, be strategically located at epidemiologically significant distances from other farms; these distances depend on environment, size of farms and the nature of the pathogen [11]. Achieving adequate separation requires a system of spatial planning that takes into account these epidemiological/environmental factors.

Spatial control of disease in salmon aquaculture has been applied in major producing countries such as Norway, Chile [12], Canada [13] and Scotland. In Scotland area-based control systems have been developed in response to specific challenges, such as a major Infectious Salmon Anaemia epidemic [14], or shared management concerns [15]. Tools developed in Scotland to control salmon diseases can be informative for the management of disease in other sectors and countries. The following text reviews the spatial tools that have been developed in Scotland to help with different aspects of the control of disease impacts. The review identifies the different tools used, the purpose(s) for which they

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are applied and limitations and benefits in their application.

2. Review of tools used for spatial management of Scottish aquaculture

2.1. Local areas

A Management Area is a local area within which farms are managed in a co-ordinated way. Two such structures are used in Scotland Farm Management Areas and Disease Management Areas (Fig. 1). (Sea lochs are also assessed to limit local biomass to sustainable levels, but this is described later in Section 2.1.2.) Boundaries are defined without any explicit modelling of pathogen biology but are based on assumptions or simple models of local dispersal distance over a short period. These areas define local groups of farms that are potentially in contact with each other and may therefore share pathogens.

2.1.1. Local knowledge: farm management areas

Farm management areas (FMAs) have been derived by the aquaculture industry to help with day-to-day management of aquaculture (Fig. 1(a)), in particular health issues. Farms in a FMA are farms that collaborate on issues of relevance to the management of aquaculture among groups of farms that experience shows interact with their neighbours. Historically, furunculosis management was a driver for local collaboration, but more recently they have become of particular relevance to the management of sea lice where co-ordination of treatments and of fallowing are effective, often essential, tools for the management of lice infestation.

Area boundaries are defined on the basis of experience and practical management issues, such as shared ownership, in order to form meaningful and practical epidemiological units. Currently there are 89 FMAs containing 1–27 sites, with maps published [15]. Scottish Ministers have powers to modify boundaries under the Aquaculture and Fisheries Act (Scotland) 2013, but generally the boundaries are those agreed by industry. Experience can lead to boundaries being modified, for example in south-east Shetland several small FMAs were amalgamated after an outbreak of infectious salmon anaemia that spread among the smaller FMA [4] indicating boundaries were unsatisfactory.

Under the Aquaculture and Fisheries Act (Scotland) 2013, farms within a FMA must have a farm management agreement (FMAg) with other farms in the area, or a farm management statement (FMS). This agreement, or statement, describes activities concerning fish health and parasite management, fallowing, movements of fish on and off, and harvesting operations. More detailed suggestions for the contents and operations of FMAg and FMS are defined in the code of good practice [15].

Even if FMA boundaries are epidemiologically imperfect they may be quite effective at controlling disease emergence provided the farms in the area collaborate [16] and this may be easier to achieve with smaller groups of farms with shared ownership [17]. Therefore, both epidemiological and social factors need to be considered for effective management of infection. The FMA boundaries, being industry agreed, are likely to be effective at social cohesion in management.

FMAs are working areas, defined by experience and practicality. They lack a simple objective description, which means boundaries are defined subjectively. This gives the flexibility to adapt boundaries to incorporate new knowledge, but makes it difficult to deal with disagreements on where boundaries should be. In particular the effect on FMA boundaries of new farms, or closure of existing farms, are not objectively defined, and this makes planning difficult.

2.1.2. Simple circles: disease management areas

Disease management areas are areas used for the control of serious notifiable diseases (Fig. 1(b)), and were defined as part of the effort to control an outbreak of ISA in 1998/9, and were successfully applied to control of a second outbreak in 2008/9. The boundaries are used to impose controls in the case of ISA outbreaks, and potentially IHN. Area management is also used to control mollusc disease with two areas of Scotland currently under official controls for Bonamia [2]. There are 54 finfish disease management areas [18] that contain between 1 and 27 sites (the largest being in southeast Shetland and covers the same area as the largest FMA).

The boundaries are defined by circles that reflect hydrodynamic processes with a circle of radius:

$$X_t = UT/\pi$$

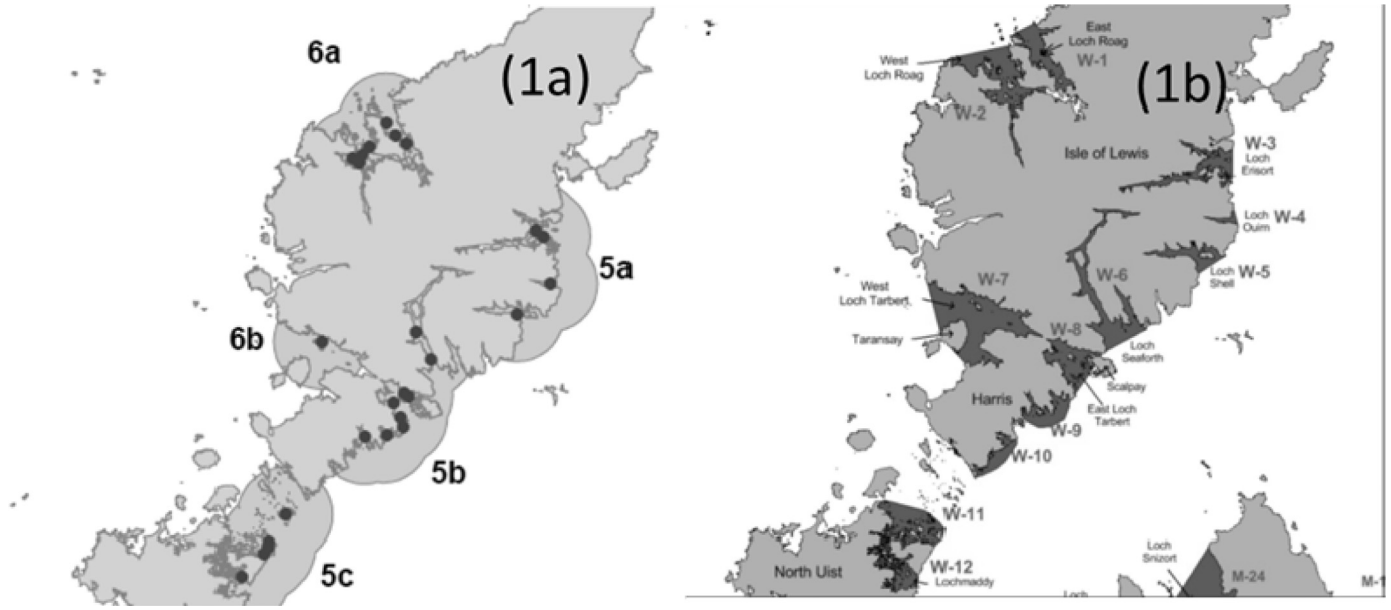

Fig. 1. (a) Farm Management Areas (GoGP 2015) and (b) Disease Management Areas (Anon 2015a) maps for Lewis, Western Isles of Scotland. DMAs may incorporate one FMA (e.g. DMA 6b and FMA W-7) or multiple FMAs (e.g. DMA 5a).