Assessing the impact of climate change on infectious diseases of freshwater fish in England & Wales

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1. Introduction

Temperature across England & Wales may rise between 0.5 and 1.5°C by 2020 and between 2 and 3.5°C by 2080, winters are likely to become wetter and summers drier. Extreme weather events – droughts, heat waves, flooding – are likely to become more frequent. Fish are heterothermic; their physiology is directly affected by the temperature of the environment, therefore, climate change may affect fish more severely and earlier than other animals. The fish immune system responds optimally at normal summer temperatures for each species. Gradual increases in water temperature increase the speed at which the fish immune system responds up to a species dependent temperature threshold. Sudden temperature increases (heat waves) adversely affect the ability of the fish immune system to respond. Similarly pathogens and parasites also have optimal temperature ranges for survival and replication. This work examines the likely impact of climate change on infectious diseases of freshwater fish in the UK through causal webs and risk assessment approaches.

2. Assessing potential impact of climate change on fish diseases

Causal webs

The impact of extreme weather events is likely to increase disease prevalence and distribution but the impacts are likely to be localised (Figure 1). Droughts combined with heat waves are likely to result in poor water quality, increased pathogen replication and increased fish density and stress. These will combine to result in disease outbreaks in wild fish populations during summer months.

A risk framework

The effect of gradual changes in water temperature will be species and pathogen specific. Pathogens with thresholds below which infection or clinical disease does not occur are likely to become increasing threats with climate change (Table 1). The risk assessment framework developed by Gale et al (2009) (Table 2) allows other factors (routes of introduction and spread, intermediate hosts etc) to also be considered. The framework was developed as a screening tool for terrestrial livestock pathogens and has been adapted here for fish diseases.

The main results from applying the risk framework to diseases listed in Table 1 is that climate change will increase the risk of introduction of exotic pathogens (module 1). Pathogen replication will increase (module 2). As water temperatures remain above disease thresholds for longer, duration and frequency of outbreaks will increase (module 3). Higher water temperatures and decreased water quality will increase stress in salmonid hosts resulting in more disease, but cyprinids (e.g. carp) will not be affected (module 3). The byrozoan intermediate host of *T. byrosalmonae* will increase in range and abundance, increasing the prevalence and geographic distribution of proliferative kidney disease (module 4). The effect of low river flows in summer will increase pathogen transmission (module 5). Flooding may result in the spread of pathogen between rivers (module 6).

3. Conclusions

- Both causal webs and risk assessment methods are useful approaches to assessing the likely impact of climate change on infectious disease in freshwater fish.
- *L. garvieae* is the exotic disease whose risk of introduction and establishment is most increased with increasing water temperature.
- A number of important diseases of farmed trout (eg PKD, white spot) will become increasingly difficult to control as water temperatures rise.
- Disease outbreaks in wild fish are likely to increase, especially during periods of low water flow.
- Risk mapping using geo-referenced environmental data is needed to identify fish populations at greatest threat from climate change.
- Mathematical models are needed to explore how climate change, including changes in disease epidemiology, may influence the structure and abundance of wild fish populations.

Figure 1. Potential impacts of increased frequency of extreme weather events on aquatic animal disease epidemiology

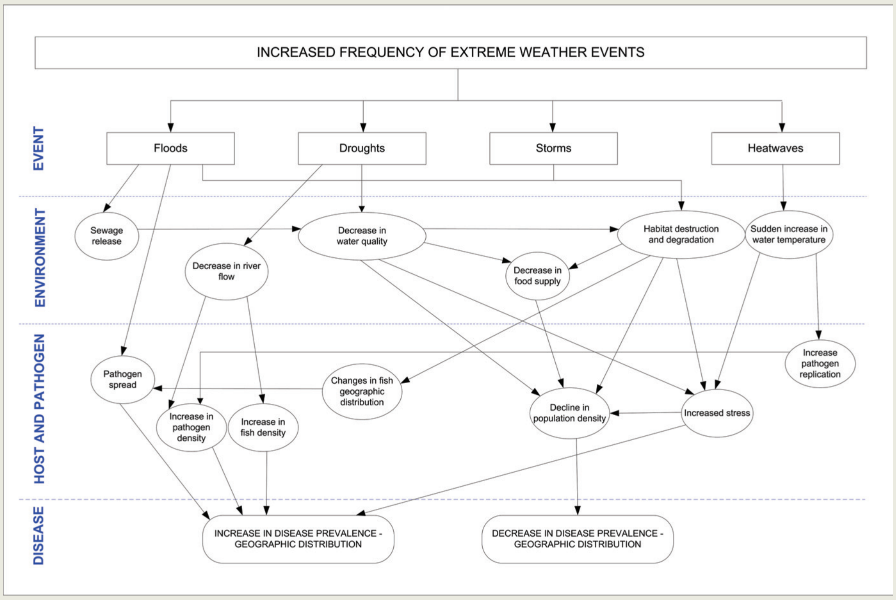

Table 1. The effect of climate change on selected aquatic animal pathogens with optimal temperature ranges

Pathogen (disease name)	Optimal temperature (°C)	Host	Status in the UK	Observations	Impact of increasing water temperature in England and Wales
Viruses					
Koi herpesvirus	16-28	Carp	Endemic, notifiable	No morbidity observed below 13°C and over 30°C.	Increased frequency of outbreaks in managed fisheries and garden ponds.
Epizootic haematopoietic necrosis virus	>12	Perch and rainbow trout	Exotic, notifiable	Infection does not establish when water temperatures are below 12°C.	Increased risk of establishment, increased size of outbreak.
Bacteria					
Renibacterium salmoninarium (bacterial kidney disease)	>13	Salmonids	Endemic, notifiable	Most severe outbreaks at temperatures between 15-18°C.	Increased frequency of outbreaks, greater level of mortality. Impact mainly in farmed salmon
Lactococcus garvieae (lactococcosis)	>14	Rainbow trout	Exotic	Most severe outbreaks occur when water temperature > 18°C.	Increased risk of establishment, increased size of outbreak.
Warm water strawberry disease	>10	Rainbow trout	Endemic	Unknown aetiology. Not observed in the winter in the UK.	Increased frequency, duration and impact of outbreaks.
Parasites					
Tetracapsuloides. Byrosalmonae (proliferative kidney disease)	>15	Salmonids	Endemic	At lower temperatures fish infected but no clinically disease. Increasing water temperature increases abundance of the alternative, byrozoan host.	Management of disease in farmed trout increasingly problematic. Increased likelihood of negative impact in wild salmonid populations.
Ichthyophthirius multifiliis (white spot)	>15	Rainbow trout	Endemic	Salmonids may be affected at water temperatures as low as 4°C, but most outbreaks occur at >15°C (higher temperatures lead to shorter life-cycle).	Management of disease in farmed trout increasingly problematic
Oomycete					
Anaphamyces invadans (epizootic ulcerative syndrome)	>18-30	Wide host range	Exotic, notifiable	Outbreaks occur when water temperature is >18°C	Increased risk of establishment, increased size of outbreak.

Table 2. Risk framework for assessing potential impact of climate change on fish diseases (after Gale et al, 2009)

Module Description	Aim
1: Routes of pathogen introduction into England and Wales	Identify routes of introduction, assess whether climate change may promote new routes or increase risk of release in existing routes
2: Mutation, replication and virulence of the pathogen	Potential of pathogen to evolve to exploit new opportunities created by climate change; impact of temperature on rate of replication and virulence.
3: Host reservoirs and host-pathogen interaction	Identify existing host reservoirs and assess effect of climate change on the range, abundance and diversity of potential vertebrate hosts, and impact on host-pathogen interaction.
4: Vectors, intermediate and alternative hosts	Assess effect of climate change on vectors, intermediate and alternative hosts
5: Fish-to-fish contact and movement	Assess effect of climate change on transmission through animal to animal contact (due to changes in movement and mixing of animals)
6: Environmental routes	Assess effect of climate change on transmission from environmental routes (eg fomites, sediment, water)

Reference: Gale P, Drew T, Phipps LP, David G & Wooldridge M (2009). The effect of climate change on the occurrence and prevalence of livestock disease in Great Britain: a review. *Journal of Applied Microbiology,* doi:10.1111/j.1365-2672.2008.04036.x.

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