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Adaptation to extreme weather events in complex health and social care systems: the example of older people's services in England

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Abstract: Our findings contribute to a growing international literature on how conceptual models from complexity theory may be relevant to inform planning in health and social care systems, helping to adapt and improve preparedness and resilience to extreme weather events. We focus on findings from two case studies in England and their relationship to national policy for adaptation. Complexity theory helped to frame strategies for planning for events that are emergent and unpredictable. We find from our case studies that, in spite of the uncertainty involved, some 'principles' derived from parts of the literature on complexity theory may provide a helpful framework for the development of more robust preparedness strategies in the health and social care sector. By viewing health and social care as a 'system of systems', adaptation planning recognises the interrelationships of built, institutional and social infrastructures. The idea of local systems, with variable, path dependent attributes, which are partially closed, but permeable to other parts of the wider network, leads to an actionable model of adaptation which emphasises the potential value of local self-organization, but also underlines the importance of co-evolution across the wider system and the vital role for national initiatives and support for adaptation strategies. The value of sharing experience from local case studies across the national system, as well as among local partners, is very apparent in the experience reported here.

1. Introduction

This paper contributes to the literature concerning complexity and co-evolution, especially as these influence adaptation and resilience planning for extreme weather events impacting on health and social care systems. Despite recognition 'in principle' of the importance of adaptation, it is less certain what this means in practice (Bulkeley and Betsill, 2005). Drawing upon the literature on resilience, adaptation, governance and environmental planning, we argue that, despite the uncertainties implied by complexity theory, it can provide a useful framework for preparedness planning in systems such as health and social care, with practical implications for adaptation. We discuss findings from a project addressing the effects of extreme weather on health and social care delivery for older people. This provided narratives of the impact of disruptive events and adaptive responses, showing how local adaptation may co-evolve in relation to the wider system in ways that may help to build future resilience. We conclude by considering the implications for local and national governance of risks associated with extreme weather.

2. Theoretical framework: Complexity and adaptation in health and social care systems

Although complex systems cannot be understood in terms of 'linear' relationships, they are characterised by certain 'typical' features which help us to envisage system behaviour. For example, from a geographical perspective, Phillips (1999) contrasted the 'traditional reductionist' view (that systems can be understood by enhanced measurement and modelling of a 'reduced' set of known environmental controls operating within 'finite' systems) with arguments from chaos theory (that variability and change are due to complex, organic, non-linear workings of open systems, impossible to reduce to a limited set of key components or to predict using conventional scientific models). Phillips proposed an intermediate view of 'deterministic uncertainty', recognising arguments from chaos theory that unstable, and uncertain change in complex, dynamic and open systems may be provoked by initially small changes in certain parts of the system, but also arguing that it may be possible to understand the system better by studying a reduced number of crucial components. Similarly, Stacey (1996) argued that while it may not be possible for organisations to predict and precisely control the long term outcomes of processes operating together in complex systems, they may be able to identify underlying mechanisms contributing to instability. Like Tierney et al. (2001), we believe that this type of knowledge has the potential to assist actors in the system to adapt and prepare, making the system more resilient.

2.1 'Typical' behaviours in complex systems producing 'unpredictable' changes and outcomes

While we recognise that we cannot fully comprehend and predict the outcomes of dynamic complex systems, we can recognise certain 'typical' characteristics of the elements of these systems, which are important for the development of operational adaptation strategies. Literature summarising these attributes (Suteaunu, 2005; Capra, 2005; O'Sullivan, 2004) shows how they might be relevant for different types of systems, including health and social care. Viewed geographically (Gatrell, 2005; Curtis and Riva; 2010) and from other disciplines (Lanham, 2013; Lega and Calciolari, 2012; Eppel, 2012; Gerrits, 2010), these 'typical' attributes include:

- *non-linear dynamics and emergent properties*, meaning that change cannot be predicted simply on the basis of constant relationships among the components of the system;
- capacity for *self-organisation,* associated with *'organic'* and *evolutionary* adaptive behaviour, allowing the system to be transformed in response to changing conditions,

and giving rise to the *emergence* of new forms and characteristics;

- *path dependency,* whereby 'critical junctures' in the 'life-history' of a system will affect the way it develops in future (we argue below that key steps in the establishment of past practice by actors in the system, which influence subsequent responses to change, are consistent with the idea of 'critical junctures' that help to determine path dependency);
- *diverse agents* (or *actors) linked* through networks, but *with imperfect knowledge* of each other, so behaviour of one part of the system may affect other parts in unintended or unpredictable ways;
- *openness* and *connectedness* across geographical scales, combined with *'organisational closure'* in that local systems are partially isolated by a permeable and flexible boundary or 'membrane' that makes them distinct but also connects them to the wider world;
- *co-evolution*, in which local systems (or groups of agents/actors) and their wider environment interact, co-evolve and adapt together. Therefore, changes in one part of the environment may stimulate wider system change.

Such ideas from complexity theory emphasise that the scale of analysis and action (e.g. Kluvankova-Oravska & Chobotova, 2013; Boyd and Folke, 2012) has implications for the governance of these types of systems (Buijs,et al., 2009; Klijn, 2008; and Klijn and Snellen, 2010) especially during extreme events (Noordegraaf and Newman, 2011; and Wistow et al., 2015). There is no 'right' scale at which to analyse complex systems (Adger et al., 2003), and it is important to generate '*insights about the way in which the different parts of the system relate to each other at different scales'* (Suteaunu, 2005:117). By understanding how systems operate at and between different scales, Klijn (2008) argues that we can generate insights into how complex integrated service delivery can be governed. For health and social care systems this includes the poly-scalar networks of interactions between agents including (but not limited to): service users; carers (both formal and informal); public, private, and voluntary service providers; advocacy groups; and commissioners and managers of services.

Furthermore, complex systems often have *'intricate non-contiguous spatial structures'* with hierarchies that are not necessarily *'neatly nested into progressively larger entities'* (O'Sullivan, 2004:285). Co-evolution underlines '*the existence of causal relations operating bi-directionally between different scales of organisation',* creating *'poly-scalar'* systems (Chapura 2009:466) which are more than the sum of their constituent parts (O'Sullivan, 2004: 471). Gerrits (2008) emphasises that agents in the system may or may not have complete knowledge of the system as a whole but do have agency and reflexive capacity, linked to significant self-organising tendencies. Thus models of governance help us understand and respond to the complex interactions between different social and political actors (Kooiman, 2003). By promoting openness and co-evolution we may enhance governance solutions that bring together agents, with their dynamic and self-organising characteristics.

In contrast, some more recent literature on fragility of human and natural ecosystems, for example Haldane and May (2011) and Scheffer et al (2012), emphasises modularity and heterogeneity of systems as crucial for their stability. They argue that human as well as natural systems have greater adaptive capacity when they comprise locally differentiated, subsystems with a degree of closure, only partially connected to other parts of the wider system. This means that under stress induced by changing conditions, localised parts of the system may suffer losses but other parts will be less affected and will survive in changed conditions.

These perspectives from complexity theory can contribute to conceptualisations of

adaptation in uncertain conditions (Pelling, 2011). We adopt here a perspective which focuses particularly on *preparedness* (Tierney et al., 2001) in conditions of uncertainty (rather than relying on prediction) and on 'post-traumatic growth' after disruptive events, building on past experience to enhance future resilience. Like Adger (2006: 268-9), we frame resilience as 'the magnitude of disturbance that can be absorbed before a system changes to a radically different state ….[and the]… capacity to self-organise …for adaptation to emerging circumstances'. Berkes (2007:283) suggests that conditions helping to build resilience include: *'(1) learning to live with change and uncertainty, (2) nurturing various types of…diversity for increasing options and reducing risks, (3) increasing the range of knowledge …, and (4) creating opportunities for self-organisation, including strengthening of local institutions and building cross-scale linkages and problem-solving networks'*. O'Sullivan et al. (2013), and Cutter et al. (2008) also argue that in addition to developing resilience in 'hard capital', such as built facilities and supplies, attention should be paid to 'soft capital' in the form of social infrastructure. These perspectives are encouraging a reframing of the resilience paradigm (e.g. by Linkov et al, 2014) making it more relevant to large, integrated systems faced with uncertain future challenges.

2.2 Local case studies of complex systems as 'geographical narratives' can inform social action

The conceptual framework from complexity theory outlined above suggests that attributes of a local system can be relevant to practice and future adaptation across the system as a whole. Byrne (2005:101) argued that *'the essential character of complexity based knowledge is local'* and that it can be built by comparing locally based case studies of historical trajectories of systems in different contexts. Similarly, O'Sullivan (2004) commented that *'it may be useful to think in terms of 'geographical narratives'* in order to understand how theory relates to complex real world systems. Martin and Sunley (2007:595) also discussed to what extent complexity theory can be meaningfully applied' to improve our understanding of uneven development in a 'landscape' of interest.

Knowledge from interdisciplinary research may seed diverse, locally relevant adaptation across a complex system, provoking '*constructive engagement between different perspectives'* (O'Sullivan, 2004:282). We extend this argument beyond the academic debate, emphasising the potential for change through engagement of diverse stakeholders, variably positioned in complex systems. Related arguments have been put forward in relation to flood risk management by Lane et al. (2011), Landstroem et al. (2011) and Pattison et al. (2012). Also Zaidi and Pelling (2013) and Wolf et al. (2010a) emphasise the need for institutional as well as individual adaptation in order to tackle the challenges of extreme weather, although Pelling (2011: 112 *et seq*.) also discusses institutional constraints limiting such adaptation. Similarly, Boin and Van Eeten (2013) emphasise how organizational processes that are important for adaptation and resilience often involve seemingly chaotic emergence of strategies through improvisation and spontaneous sense-making. Local case studies viewed through the framework of complexity theory can support co-evolution and adaptation across the wider system.

A growing literature interprets health and social care and its supporting infrastructure as a complex system (e.g. Wilson & Holt, 2001; Curtis & Riva, 2010; Klijn & Snellen, 2010; O'Sullivan et al. 2013, Boyd & Folke, 2012; Lega & Calciolari , 2012) comprising 'agents' that are variably configured in different settings. These services and supporting infrastructures are impacted by 'extreme weather events' including heatwaves, floods and cold weather, (Oven et al 2012 ; DEFRA, 2012; Hames et al., 2012; IPCC, 2014;Plsek & Greenhalgh, 2001; Department of Health, 2011; Hames et al., 2012), in ways that depend upon their complex characteristics (Lanham et al, 2013; Joseph et al. 2013), and vary due to local diversity in physical, social and institutional conditions (Dominelli, 2012; Carr-West et al. 2011). When extreme events occur, responses may be emergent, while also partly pre-

determined by existing governance systems (Kapacu and Garayev, 2011; Noordergraaf and Newman, 2011; Wistow et al., 2015). The research reported below contributes to this literature on complexity in health and social care. We discuss (in Sections 4 and 5) the complex attributes of the health and social care system in England and the relevance of knowledge generated at local level.

3. An empirical approach based on complexity theory

Drawing on the arguments above, we conducted a project in England aiming to explore how to adapt the built infrastructure supporting health and social care for older people to extreme weather events. This research focus reflects a growing older population (aged 65 years and older) in the UK, which has significant health and social care needs, is projected to increase significantly (ONS 2012), and is one of the groups most likely to be vulnerable to extreme weather (Department of Health, 2011; Hames et al., 2012, Age UK, 2012)).

Our approach involved case studies in two localities, that explored the diverse knowledge, priorities and understanding of participants within each local system, and how these influenced their various responses to extreme weather events.

3.1 Selection of case study areas and their relevance for extreme weather planning across England

We conducted a national hazard mapping exercise **(reference withheld for review)**, for Local Authorities (LAs), the local government administrative divisions where coordination of health and social care for older people and strategic emergency planning is organised. Two case study areas were purposively selected from a larger group of 13 Local Authority (LA) areas in England, where the growing risk of significant impact on health and social care for older people is likely to be greatest. These were areas projected to experience an increased risk of significant disruption due to extreme weather events in future and high concentrations of older people (especially in the oldest age groups) [1 **insert link to footnote 1**.].

Drawing on published data and intelligence from key informants relating to local areas within the two selected LAs, we examined particular districts and communities with high numbers of older people and past experience of hydro-meteorological hazards e.g. floods and cold waves. We attribute pseudonyms to all localities and people involved in our research.

LA North is a large, predominantly rural local authority in the north of England with a population of over 300,000 people, over half of whom live in dispersed rural communities and isolated coastal settlements. There are also a number of market towns and small urban centres. The LA area is generally affluent, with pockets of deprivation in both rural and urban settlements. The population is predominantly 'white-British' with some ethnic diversity in the urban centres (although the proportion from minority groups is below the national average). The older population is growing, in part due to the inward migration of retired people, especially to areas such as 'Coastal Town' and the surrounding 'Rural Coastal Area'.

LA South covers a smaller geographical area and a population of approximately 100,000 people, which on average is relatively affluent and predominantly 'white-British'. The main urban centre is 'Southern Town', and local services are located in smaller centres such as 'Village Hub', surrounded by hamlets in 'Rural Inland Area'.

3.2 Methodological approach

Participants were selected purposively from theoretically relevant categories of actors at the LA area level and within the selected communities, in order to understand the knowledge and behaviours of actors positioned in different parts of the system, and how their interactions may influence local response to extreme weather events. We were also in dialogue with actors at the national scale to consider aspects of the national health and social care systems in which local examples were framed.

The research was approved by a National Health Service (NHS) ethics review board, local research governance agencies and relevant University Research Ethics committees.

At the LA area level we convened consultative groups of representatives from different parts of the local health and social care systems. Key 'strategic level' stakeholders, with local knowledge about the actual configurations of different agents in the locality, took part in discussion groups facilitated by members of the research team, using participatory mapping techniques (Dunn, 2007; Pain and Kindon, 2007). Base maps for these mapping exercises drew on secondary data including Environment Agency flood maps, and maps showing the location of National Health Service (NHS) facilities, compiled with assistance from NHS SHAPE (Strategic Health Asset Planning and Evaluation). This research was innovative in being the first to apply SHAPE maps to extreme weather planning. The mapping identified health and social care facilities (e.g. hospitals, residential care homes, GP surgeries); health and social care services (e.g. domiciliary care, meals-on-wheels and community nurses); and infrastructure systems supporting the facilities and services identified (e.g. transport, electricity, gas, water and telecommunication networks). Participants were asked to consider how extreme weather might impact on these components, and where the impacts would be most disruptive. Based on these discussions, we selected localities for more in-depth research, referred to as '*Coastal Town'* and *'Rural Coastal area'* in LA North and *'Village Hub'*; and *'Rural Inland Area'* in LA South.

We used local reports and directories and discussions with key informants to identify local level stakeholders to participate in the study, including frontline service providers from local government, the NHS, the independent care sector, and community and voluntary groups. Group discussions and participatory mapping exercises were undertaken with local service providers, as well as in-depth, semi-structured interviews and group discussions with older residents with different health and social care needs. These included participatory mapping exercises to facilitate the exchange of key information between participants and to visualise the essential parts of the complex systems being referred to. Thus we gathered rich information on how systems were affected by extreme weather events. Most interviews and discussions were digitally recorded, with permission, and transcribed. Tables 1 and 2 **[insert links to electronic tables 1&2**] summarise the discussion groups and interviews on which we are drawing in the following account of our findings, and the codes included alongside the quotes below relate to the information in these tables. Through a thematic analysis of transcripts, three of the authors first independently identified themes relevant to our understanding of the complexity of the system, then triangulated their findings to agree on the interpretation below.

The project then proceeded through knowledge exchange with partners across the system and inputs to national strategic planning, resulting in adoption of similar procedures in other localities.

4. The 'everyday' complexity of health and social care systems

Crucial to the impact of perturbations caused by extreme weather events is the complexity of health and social care systems under normally prevailing, 'everyday' conditions. In

conversation with research participants we developed 'organograms' (Table 3 and Figure 1) **[insert link to electronic table 3 and Figure 1]** representing the diverse groups of agents in the system, including formal service agencies responsible for provision of health and social care for older people's health and wellbeing, and groups of informal carers in local communities. Participatory mapping also helped us to share partial information on non-human 'actors' comprising networks of critical built infrastructures. It was challenging and sometimes not possible for the groups to construct a complete vision of the local built and institutional system (e.g., data on power utility systems were often treated as sensitive information, not to be shared). This highlighted the partial closure of different parts of the risk governance network.

4.1 Formal care services interpreted as complex organizational systems

Many frail older people need continuous health and social care support, involving diverse agents with self-organising characteristics. Informal carers, often family members, deliver much of this care. They operate independently of, but also interactively with, formal services that are also essential for care. Formal services operate within spatially defined administrative catchments that are not all geographically coterminous, being variously defined by the boundaries of local authority social care agencies, general practice areas, or zones of responsibility for NHS Trusts or independent and voluntary agencies providing hospital treatment and domiciliary nursing (some of which are commissioned to supply state funded care).

Table 3 and Figure 1 show how local primary and community care provision and governance varied among Local Authorities. In LA North, responsibility for local authority services had been combined under a single 'Unitary Council'. In contrast, LA South was a 'two tier' authority with functions divided between a 'County Council' providing strategic planning, social, education and transport services, and seven 'District Councils' providing local planning and maintenance services. Both District and County Councils had sustainability teams, with responsibilities including extreme weather resilience planning within the health and social care sectors. The organisational system was further complicated given a competitive, market model for service provision. Carr-West et al (2011) highlight that LAs are increasingly commissioning, rather than directly providing, services through an array of public, private and voluntary organisations. This produces a 'fragmented' system and local collaborative arrangements are 'path dependent' upon earlier 'critical junctures' in central and local level organisational development, reflecting national and local policy decisions. (Examples include contracts drawn up to select local service suppliers and decisions on location and development of infrastructure facilities.) The systems are also partially closed because accumulated organizational memories and system knowledge are not shared by all partners.

Care infrastructure is organized via networks of nodes (Holden et al, 2012), including older people's own homes, primary and community care facilities including GP surgeries, pharmacies, and community centres, and secondary care facilities in hospitals. These nodes co-evolve together and are connected by crucial infrastructure including public and private transport that was recognised as "*an underpinning issue"* (LA staff member, Adult Social Care, Village Hub, SFM1)**.** Also utility infrastructure systems (such as power supplies) are essential for everyday operation of the system. Thus care for older people is a networked system (Klijn & Snellen, 2010) comprising interdependent built, institutional and social infrastructures, with partial *closure* into heterogeneous local sub-systems.

4.2 Longer term change in poly-scalar health and social care systems

What may seem to be sudden disruptions in complex systems may be better understood as outcomes of processes operating over longer time scales (Hughes et al, 2013). Local health

and social care systems are evolving in response to changes in policy and practice that may contribute to 'fragility' during extreme weather events.

One such trend is reduction in human resource capacity in health and social care systems as central government policy aims to make services 'leaner' in ways which may particularly impact on populations where needs for services are greatest (see: Pearce et al, 2013; Public Accounts Select Committee, 2013). The health and social care system is 'open' to prevailing economic conditions, including a long term drive to make 'efficiency savings' in adult health and social care, reinforced by emergence of a governmental austerity programme introduced in response to the 'critical juncture' of the economic crisis arising in 2007, and impacting health and social care as we carried out our research [3 **insert link to footnote 3**]. Associated with this, participants perceived a reduction in the social interaction associated with physical care delivery, since professional carers *"…don't seem to have the time to spend* [interacting with the client]*....They seem to be instructed to come in, do it, and go."* (Town Councillor, Coastal Town, NFM). More stringent eligibility criteria for the receipt of state funding were leading to closure of some publicly funded day centres for older people, requiring longer distances to travel to the remaining facilities. Reductions in the provision of statutory services place more demand on informal care and support for older people.

Policies for 'personalisation' of adult social care, whereby older people can choose to manage their own care directly (e.g. by employing personal assistants to provide services (Department of Health, 2008)), were seen to present emerging challenges and opportunities for adaptation planning. Older people have more freedom as self-organising components of the health and social care system with more autonomy to arrange care to meet their specific needs. However, participants in discussion groups across both LA areas, commented that because of personalisation, LA officers have less direct control and knowledge of the health and social care workforce as a whole. It had become more difficult to share information about clients and to prepare for extreme weather events with reference to the needs of potentially vulnerable older people.

Simultaneously, social and demographic changes in household composition, roles of family members, and retirement migration, were reducing availability and proximity of informal care from younger family members. Older people explained that friends and neighbours (who were often older people themselves) played an important role. Some older people moving to 'Coastal Town' and 'Village Hub' on retirement were demonstrating adaptive, self-organising behaviour in setting up older people's support groups, and social networks. However, this approach was seen as socially selective and potentially unsustainable; "...*a middle class voluntary organisation… runs most of these things … but… they are now getting very old themselves... they are trying to hand the things on … and they can't."* (Parish Councillor, Village Hub, SFM1). These findings resonate with arguments by Wolf et al. (2010b: 45) that bonding social capital 'may exacerbate rather than reduce vulnerability' in conditions of extreme weather'.

Other significant aspects of long term system change included a growing older population (aged over 65 years) in the UK (ONS, 2012), with expanding care needs; of those using community based health and social care in 2009-2010, 65% were in this age group (NHS Information Centre, 2011). Formal and informal health and social care is increasingly delivered in diverse settings, including individual patient's homes (Milligan, 2009).

Overall, then, the care system displayed chronic stress due to changes in the wider economic, social and political environment (see also O'Brien and Leichenko, 2000). Local actors in the system were continuously adapting to changing conditions, drawing partly on their capacity for self-organisation and organic change, and some comments reported above reflected a growing sense that system-wide, coordinated risk governance measures for emergency response to extreme events was becoming more challenging.

5. Exploring the impact of extreme weather events on health and social care systems

Extreme weather events create additional, sudden perturbations within these already complex and dynamic systems. Participants described their experiences of such events and impacts on their access to health and social care, especially during extended periods of extremely cold weather with snow and ice, during the winters of 2009/10 and 2010/11. Participants also recalled the impact of severe flood events. Heatwaves had not occurred in the study areas around the time when the empirical research was conducted and featured much less prominently in discussions. This demonstrates how local intelligence and 'co-evolution' relies most strongly on short term collective memory associated with recent critical events.

Participants reported diverse manifestations of 'typical' attributes of complex systems affecting adaptation planning in the context of the hazards faced, including:

- interdependency between built, institutional and social infrastructures that might make health and social care systems fragile;
- self-organization and path dependency underpinning local behaviours;
- imperfect and varying knowledge of different actors;
- co-evolution through organizational learning across the system.

Figures 2a, 2b 3a, 3b provide diagrammatic representations of the infrastructures on which older people in the study areas were depending, as identified in participative mapping exercises. These illustrate how theoretical dimensions of a complex system, discussed in section 2 are realised in the study settings [2].

5.1 Interdependency and fragility

Since much of older people's care involves multiple participants and must be provided 'in person', there is interdependency between care systems and physical infrastructure such as transport systems. In both study areas, road network closure, due to snow or flooding, disrupted patient transport to service facilities and prevented domiciliary care workers from completing their everyday rounds to help clients at home.

At local level, response to such disruption included greater reliance on virtual communication networks and temporary reorganisation of the local delivery of care, as explained by a LA (Adult Social Care) representative in Southern Town (SFM2): *"...in Adult Services... we've been encouraging* [staff]... *for example in times of heavy snow fall... if they … can't get to the place where they normally work, that they should report to somewhere that's nearer [to their home]... assuming their computers will work and everything... and actually work from that base... providing some kind of community response to vulnerable adults in the local community..."*

In both areas the full range of health and social care provision was unsustainable during such extreme weather events, as services moved to an emergency footing, concentrating mainly on delivery of the most 'essential' care for their clients. One participant explained, "*It's about the basics: ... heating ... food and ... medication, and... we do an awful lot more check calls on people in bad weather simply to make sure they're okay... a lot of the other things that they would normally access which may be outside of their own home... 'shut down'"* (Independent Care Provider, Southern Town, LA South, SFM2). On occasions when villages

were snow bound for longer periods, even essential provision was reduced, or maintained with difficulty, as reported by an older female resident in Coastal Town (N4):

resident: *"...Prescriptions kept on coming in very difficult situations."*
Interviewer: "*...And if you had an appointment at the doctor's or at the hospital?"*
resident: "*It was terrible to get there…."*
Interviewer: "*…But you still made appointments, did you?"*
resident: "*Yes, we did, but under very difficult circumstances."*

Participants underlined the increased fragility of provision during prolonged periods of extreme weather. In the short term, local adaptive mechanisms might alleviate the lack of access to everyday care, especially in settlements like Coastal Town which *"...is a good place really because we have shops and two chemists"* (Older resident, N4). However, during longer periods of disruption this was not seen as an effective substitute for normal service provision, especially in more isolated communities with fewer facilities.

Domiciliary services delivered across relatively large catchment areas are especially likely to be interrupted during extreme weather, placing additional stress on the service users and their informal carers, who are often elderly. One older carer in LA North relied on domiciliary mental health nursing for her son which was reduced during a prolonged disruption due to snow, when nurses were "*not….able to come ... when they should…because they were slowed down even if they could get through"* (Older person, Rural Coastal Area, N1). Although she was given support and advice by telephone, she felt her son's condition required face-to-face care. During a flood event, another older female carer living in a village within Rural Coastal Area was evacuated from her home with her husband who was recovering from a stroke. They lived in a mobile home for five months while their bungalow was made habitable.

For some very frail older people, often reliant on an array of services, protracted disruption to the physical infrastructure of the system resulted in even more serious impacts and undermined the possibility of independent living at home in the community, as illustrated by an older person in Rural Coastal Area (N7)*: "… I had two lovely neighbours who were quite elderly… and it really, really affected them. …they didn't come back here…they ended up, both of them, in a residential home…they've died since…they were in their 80s but, oh, they were so traumatised…."*

Thus the case studies illustrated varying local responses to fragility in systems featuring complex interdependencies, ranging from successful adjustment to changing circumstances to catastrophic breakdown. The intensity and duration of disruptive change, as well as the adaptive capacity of the agents in the system contributed to the diversity of outcomes.

5.2 Self-organisation as an adaptive strategy

Effective local adaptation was often attributed by research participants to self-organisation at the community level, facilitating information flows and action during emergencies. In a village near Coastal Town in LA North a local resident is employed by the Parish Council as a village caretaker. His extensive knowledge of the locality and the vulnerability of the population played an important bridging role between older residents and wider health and social care systems. Similarly, in LA South, a warden in a social housing scheme in Village Hub (SFM1) described actions to communicate with potentially vulnerable tenants to help them take pre-emptive action:

> *"I warn my tenants about October time … start stocking up on bits and pieces, fill your freezers up so that if you do get bad weather you haven't got to go out…'cause you've only got to break a hip…"*

Older people likely to be vulnerable during severe weather and volunteers willing to help them also self-organised for better local intelligence sharing and networking. In Village Hub (SFM1) a Parish Councillor said:

> *"…nobody was doing anything…there were no voluntary charities...and* [the County Council] *weren't interested...so we thought we ought to set something up, because there are quite a few vulnerable people around here…But the interesting thing was trying to find out who those vulnerable people were!...We do a quarterly newsletter and we did a letter within that...it's delivered to everybody within the* [Village Hub] *area, and the letter...asked for two things: for you to fill it in and return it if you're feeling in any way, under extreme weather, you would be vulnerable; or, conversely, if in severe weather you have a four-wheel drive that you would be willing to assist us with…to help vulnerable people. So then we got these two batches of papers returned…and then we dotted them all on maps and tried to match them up and then got the people together..."*

Examples of more spontaneous self-organisation included neighbours reporting that they *"… took…* [older people living in the neighbourhood] *meals and things...Got the post for them"* (Older person, Rural Coastal Area, N6) and in some cases provided more personal care to *"... help them get out of bed and get dressed..."* (Older person, Village Hub, S5). This was motivated by a sense of traditional social solidarity that "…*goes back to the community spirit"* (Older resident, Rural Coastal Area, N2) and of self-sufficiency, reflected in a comment that "*I think you have to help yourself as well"* (Older female 2, Group interview, Rural Coastal Area, N2).

Path dependency of local experiential knowledge and practice was often apparent in these self-organising strategies. Participants in our research drew on previous experience of local self-organising action to imagine how they might develop preparedness in the future, recognizing the need for constant effort to maintain this aspect of resilience, as illustrated in the case of local sharing of vehicles in Coastal Town (NFM):

CVS representative: *"…we have to be self-sufficient because of the nature of the place...all the farmers have got tractors which are 4-wheel drives...and...a lot of them have got bulldozers on them...you know, if it snowed...the farmers would say 'yes'.... they'd probably come out and* [assist]*…"*

Police Inspector: *"The* ['Farm-Alert' support scheme run by Farmers]*...has sort of died in* [participants' community]*...to reinvigorate it, we need to get a new Chairman, I think, to get them up and running again...this is one of the things I can bring to* ['Farm-Alert']*to say well 'In severe weather would you do this?' and I'm fairly sure that they will say yes."*

A further recurrent theme from interviews with older people was their own high level of preparedness for extreme weather events. They often attributed this to experiences in the past that shape how they now prepare for, and respond to, extreme weather events. One older woman explained: *"…*[younger] *people today they have been cosseted with all the central heating and everything…they're not built…for this cold weather or, you know, not used to it or can't cope with it. But…we had the war you see, we are strong people"* (Older person, Village Hub, S5).

Contemporary technology was combined with traditional adaptive practices in commonly reported preparations such as stockpiling food and bottled water, having torches and candles to hand. *"*[I]*f I got stuck… we have two freezers, so I have always got food"* (Older person, Rural Coastal Area, N5). *"... in future times, if we're looking at sustainability, one of the things … that will help isolated people, is the fact they can use a computer"* (Parish Councillor, Village Hub, SFM1). Thus technological progress across the system was also resulting in emergence of new strategies for adaptation.

However, it was also acknowledged that such strategies may not be feasible for all older people especially for those living on a fixed income or relying on daily services such as meals-on-wheels provision, or for people with dementia. Also, some older people may be reluctant to ask for help. As one older man and community organiser commented: *"...there are problems…the old people, they are too proud to ask but they just need somebody to knock on their door"* (Older person, Coastal Town, N3).

Thus the case studies offered participants an opportunity to share ideas about how, while self-organization based on local intelligence and past experience contributes to adaptive strategies, it does so variably and unequally, according to personal history and individual and social assets.

5.3 Imperfect knowledge and vulnerability

Self-organizing local adaptation was also liable to fail due to the imperfect knowledge exchange between human actors in the wider system. Even when physical infrastructures and systems of communication for emergency response measures were in place they were not always consistently coordinated across the system. A solution similar to the voluntary scheme described above was deployed by Adult Social Care administrators in both study areas, pooling access to four-wheel drive vehicles for access over snow-bound or flooded roads. However, in Village Hub (SFM1) it seemed that this solution was not consistently and effectively coordinated at the local level:

LA (Adult Social Care): *"… in the most recent snow and ice problems…staff that have 4-wheel drive vehicles...were invited to act as volunteers to provide some essential services for people in social care terms... I'm wondering whether* [the district council] *covering* [Village Hub in LA South] *do likewise..?"*

Parish Councillor: *"Well they've certainly have never made any offer at all to come and give us* [this kind of help...]."

Similarly, in LA North, participants in a discussion group in Coastal Town (NFM) found that emergency plans for extreme weather were inadequate during a severe flooding incident.

Town Councillor 1: *"... there was an emergency plan but it was totally overrun…and you just couldn't get* [immediate help]*…in the end I rang…*[the responsible officer in the Local Authority]*…and…finally got through to him and he helped a bit…"*

Town Councillor 2: *"They didn't realise that there was no communication coming through at all…"*

LA (Adult Social Care): *"...it can be a great plan on paper, can't it, but* [until] *it actually happens you don't realise how…potentially badly it works"*

CVS representative, *"...people had got away* [evacuated from their homes to an emergency shelter –see Figure 1b] *without their medication…there was no way of getting medication…the* [nursing staff at the local community' hospital] *said...they couldn't give it without a doctor...it turned out that there were two doctors stranded in* [a nearby] surgery…but *they didn't know they were there! ...the medical services for older people, they've got to be coordinated."*

Also, the formal care sectors in Rural Coastal Area had prepared a rest centre with medical provision to assist local people during a severe flooding incident. However, the residents affected by the flood were unaware of this and had instead retreated to the local public house, which served as an informal focal point in the community but had no specialist health care provision to offer.

Thus through the case studies, participants exchanged accounts of experiences showing how in a care system with high levels of interdependency across networks, apparently rational adaptive strategies on the part of different actors were undermined due to imperfect knowledge.

5.4 Co-evolution through organizational learning across the wider network

We noted instances where processes of co-evolution of knowledge and infrastructures, across different levels of the complex care system, seemed to offer better opportunities for successful adaptation to the challenges of extreme weather.

A focus group participant in LA South described an upward information 'cascade': *"…as a Parish Council we are part of a cascade system within the* [District Council] *area for any severe weather...the people who are the contacts, obviously we're all volunteers as there's only two...paid people, and they're the clerks, and so the clerks have to be...the daytime contacts, and then we have out of hours contacts as well."* (Parish Councillor, Village Hub, SFM1).

Conversely, knowledge derived from more centralised expertise was passed down to local level, as reflected in the following account from Coastal Town, where local residents needed technical information provided by the Local Authority: *"...I know somebody who worked at* [LA North]*...he rang home and they said 'It's flooded'...he said 'Aren't the pumps working?' She said 'Nobody knows how to work them.' So he went to his boss; he says 'I know how to work them, can I go?'...and he went down and started them up"* (Older person, Coastal Town, N3). This account draws attention to the importance of specialist knowledge sharing in complex systems and we see how messages back and forth across the system allowed a co-evolving adaptive process of knowledge sharing.

At the national scale we can also interpret our research as part of a co-evolution process in adaptation to climate change. The research activity (prompted by a nationally funded research programme) was used by participants in our local case study areas as the pretext to create *ad hoc* fora in which to pursue their own emergency planning objectives by gathering the collective learning from previous experience in their locality and planning for future extreme weather events. Subsequently this experiential learning was shared across the wider health and social care system, as the research team supported participants to prepare local 'case studies' illustrating their experience and good practice in adaptation planning [reference (2012) to online toolkit withheld] . Key points from these were disseminated nationally by government agencies responsible for the government's National Adaptation Plan (DEFRA, 2013, NHS SDU 2014) and Climate Change Risk Assessment (CCC, 2016). It was notable that central planners charged with the production of these plans were seeking the kind of local knowledge that this research produced, to support communication across the national health and social care network, using demonstration studies from local areas to share what is considered to be good practice. Subsequently, other local actors have used the case studies reported from this study, modified them to suit their own situation for extreme weather resilience planning, and then broadcast these in public meetings with partners from other areas. Thus we observed an important, repeating cycle of experiential knowledge permeating upwards through the system and then cascading down throughout the country.

6. Conclusions: The potential for strategic adaptation using principles of complexity

Our findings contribute empirically and theoretically to the international literature concerning whether and how concepts framing 'typical' attributes of complex systems can be applied in practice to inform organizational efforts in health and social care systems. Responding to the call for improved risk governance put forward by Bulkeley and Mol (2003:144) we have demonstrated that ideas from complexity thinking can inform planning to mitigate the impacts of extreme weather on health and social care systems. These are recognized to be of international significance (WHO, 2009) and the general approach to planning for extreme events demonstrated in this research, built on co-production of knowledge, guided by principles of complexity theory, is likely to be helpful in other parts of the world.

We demonstrated how, in complex multi-scalar health and social care systems, successful adaptation strategies cannot be developed solely through homogeneous, 'top down', system-wide policies or by means of specialised emergency response services controlled at national, regional or local authority levels. There is strong potential in capacity for self-organization by 'first responders' who are likely to be local, non-specialised actors, and we observe that this is path dependent, affected by past experience and events. However, locally self-organising solutions have limitations, in terms of the assets available (built, institutional and social infrastructures) and specialised knowledge and skills. System-wide strategic co-evolution, involving national guidance informed by local case studies, is necessary for innovative preparedness planning and risk governance.

Also, in practice, development of innovative local solutions may challenge governmental actors, partly due to budgetary reductions and conflicting priorities, but also because acceptable action has conventionally been based on precedent and positively mandated in a legal or administrative sense by a higher authority (i.e. action should not be *ultra vires*). Recent legislation under the Localism Act 2011 has introduced a new 'General Power of Competence' giving more freedom for innovation in this respect. In contrast, independent sector actors may be more accustomed to undertaking innovative work without central government direction. This may help to explain why local informal, voluntary or commercial sector actors often seemed more proactive and innovative in their action to cope with extreme weather. However, their efforts were often undermined by lack of coordination and cooperative action, so that they too may benefit from a strategy that encourages principles of co-evolution. We concur with Folke et al (2005, p449) who advocated 'adaptive co-management', tailored to specific local conditions and involving collaboration and support at different organizational levels.

The case studies reported here also illustrate the conceptual and practical challenges of preparing for sudden, emergent system failure when a system is 'routinely' under stress from evolution and change, underlining arguments concerning the importance of envisaging complex systems in 'timespace' (May & Thrift, 2001). Chronic pressures are arising from the continuous, dynamic processes of social and demographic change, service reorganization and fragmentation of responsibility among many different agencies, and the impact of austerity measures. Policy makers and service providers and users need to be aware that local adaptive capacity to address hazardous events such as extreme weather are in danger of being sacrificed in the course of efforts to deal with these other aspects of large scale system change.

This paper contributes to a growing body of work (e.g. Bentley et al, 2014) exploring the complex, emergent relationships between natural environmental and human systems. Our discussion calls into question whether it is really the case, as some have argued, that the chaotic, emergent nature of human-environmental systems makes it impossible to anticipate

which behaviours seem likely to favour more successful adaptation. It is important to pay attention to messages from the earlier literature (eg. Adger et al., 2005: 77) that adaptation can be both reactive to unfolding events and also 'anticipatory in the sense that it is based on some assessment of conditions in the future'. Useful frameworks to guide constructive action for adaptation can be based on contemporary, anticipatory knowledge of 'typical' features of complex systems.

Footnotes

[1] The two case study areas were selected from a 'priority' group of 13 from a total of 354 English local authority areas. In this 'priority group' the risk of significant impact on health and social care for older people is likely to be most significant, due to a combination of environmental and socio-demographic factors. The 13 areas in our 'priority' category (with a total population aged over 65 of 407800 in 2006) ranked most highly across the country in terms of the relative size and projected growth rate of the population over 65 and the relative level of socio-economic deprivation in the general population, which is judged to be an additional factor in vulnerability to extreme weather effects. Our 2 case study local authorities had a combined population of 86,300 people over 65 in 2006. These areas were also especially relevant for our research, given the local environmental risks of extreme weather, including flooding and rapid change in relative risk of extreme temperatures. Furthermore they were among the more rural areas of the country, where issues of access to health and social care were most likely to arise when systems are disrupted. We do not argue that the two case study areas are completely representative of wider national conditions in all respects, but they were carefully selected as areas which were likely to provide nationally relevant evidence of local processes affecting growing risks of extreme weather for health and social care for vulnerable older people.

[2]

The key elements represented in Figure 2a and Figure 3a are examples of local settlements with very local primary care facilities and other local infrastructure, linked by road networks to other secondary healthcare facilities located some distance away. We see in both diagrams that the settlements where the participative mapping was carried out are illustrative of places which are prone to flooding that may affect parts of the settlement, and also may cut off the only road access to the more distant facilities that older people need to use regularly for care of chronic health conditions. During flood events, critical infrastructure also included pumps to clear floodwater, as discussed in Section 5 of the paper.

Figures 2b and 3b represent in more detail the local infrastructure within the settlements studied. Figure 2b shows a settlement with a relatively comprehensive range of local infrastructure, and it can be seen that older people were using facilities run by a range of providers operating in different sectors: NHS primary care, independent residential care, community centres operating with local government support, commercial facilities including retail, and police, fire and ambulance service stations. While these were located in close

proximity, the discussion in 'Coastal Town' reported in section 5 demonstrated that the providers and users at each facility were not always communicating effectively with each other during the extreme weather events, or as part of preparatory planning, so that local flood resilience was impaired. In Figure 3b, we see that 'Village Hub' has a primary care facility and facilities in the (separate) residential care sector providing for older people in the local area. However, for smaller rural settlements in a flood prone area within the catchment, these could become inaccessible during a flood event, as would the secondary care facilities further away in Southern Town (Figure 3a). Village Hub in Figure 2b has a more limited range of local facilities than we see in Coastal Town (Figure 2b), which underlines our arguments regarding local diversity in the specific nature of the complex care system, and illustrates the importance of informal networks to complement the formal sector services. The participants in a mapping exercise undertaken in Village Hub discussed the routine challenge of ensuring informal outreach to individuals living in smaller rural settlements surrounding Village Hub (Section 5) and they emphasised how these informal networks became especially significant for care of frail elderly people during flood events.

[3] For example, local authority spending on adult social care in England as a whole is reported to have been reduced by approximately 8% in real terms between 2010-11 and 2012-13, https://www.nao.org.uk/report/adult-social-care-england-overview-2/ . This is in context of an expanding need for care as life expectancy is increasing (with a national increase in England of 63% in the numbers of people aged over 65 years forecast between 2006 and 2031) support for chronic conditions, according to the Office for National Statistics. A study was published in the press (Sunday Times 2016a&b) by a consortium of charitable agencies involved in social care (Continuing Healthcare Alliance, 2016) reporting that in 2015 the Inpatient healthcare system bore the cost of 650,000 hospital bed days taken up unnecessarily due to lack of community based social care resulting in longer hospital stays for people with complex care needs and arguing that procedures for determining eligibility for continuing healthcare were excessively selective, excluding patients in genuine need.

References

Adger, W. N., Arnell, N.W. and Tompkins, E.L. (2005) Successful adaptation to climate change across scales. *Global Environmental Change*, 15: 77-86.

Adger, W. (2006) Vulnerability. *Global Environmental Change*, 16(3): 268-281.

Age UK (2012) *Age UK warns of dangers of cold weather* http://www.ageuk.org.uk/latest-news/archive/age-uk-warns-of-dangers-of-cold-weather/ (accessed December 2016)

Bentley, R.A., Maddison, E., Ranner, P.H., Bissell, J., Caiado, C., Bhatanacharoen, P., Clark, T., Botha, M., Akinbami, F., Hollow, M., Michie, R., Huntley, B., Curtis, S., Garnett, P. (2014) Social tipping points and earth systems dynamics, Frontiers in Environmental Science doi:10.3389/fenvs.2014.00035.

Berkes, F. (2007) Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards,* 41**,** 283-295.

Boin, A. & van Eeten, M.J.G. (2013) The Resilient Organisation. *Public Management Review*, 15, 429-445.

Boyd, E. & C. Folke. 2012. *Adapting institutions: governance, complexity and socio-ecological resilience.* Cambridge: Cambridge University Press.

Bulkeley, H. and Mol, A. (2003) Participation and environmental governance; consensus, ambivalence and debate. *Environmental Values*, 12,2, 143-154.

Byrne, D. (2005) Complexity, configurations and cases. *Theory Culture & Society,* 22, 5, 95-111

Capra, F. (2005) Complexity and Life, *Theory Culture and Society*, 22,5, 33-44

CCC (2016) UK Climate Change Risk Assessment Evidence Report, Committee on Climate Change https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/climate-change-risk-assessment-2017/ Accessded December 2016.

Carr-West, J., Lucas, L., Thraves, L. . (2011) *Risk and Reward: Local Government and Risk in the New Public Realm* London, Local Government Information Unit, http://www.lgiu.org.uk/risk-and-reward/ .

Chapura, M. (2009) Scale, causality, complexity and emergence: rethinking scale's ontological significance. *Transactions of the Institute of British Geographers,* 34**,** 462-474.

Curtis, S. & M. Riva (2010) Health geographies I: complexity theory and human health. *Progress in Human Geography,* 34**,** 215-223.

Cutter, S., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J. (2008) A place-based model for understanding community residence to natural disasters, *Global Environmental Change*, 18, 598-606.

DEFRA (Department for Environment Food & Rural Affairs) 2012. *UK Climate Change Risk Assessment: Government Report.* DEFRA, London.

DEFRA https://documents.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Appendix.pdf

DEFRA (2013) National Adaptation Plan: Making the Country Resilient to a Changing Climate. London, Department for Environment Food & Rural Affairs. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209866/pb13942-nap-20130701.pdf

Department of Health. 2008. *Commissioning for Personalisation.* DoH, London

Department of Health, 2011. *Cold Weather Plan for England: Protecting Health and Reducing Harm from Severe Cold Weather.* DoH, London.

Dominelli, L (2012) *Green Social Work*. Cambridge: Polity Press.

Dunn, C. E. (2007) Participatory GIS - a people's GIS? *Progress in Human Geography,* 31**,** 616-637.

Eppel, E. (2012) What does it take to make surprises less surpising? The contribution of complexity theory to anticipation in public management. *Public Management Review*, 7, 881 – 902.

Folke, C., Hahn, T., Olsson, P., Norberg, J. (2005) Adaptive governance of social-ecological

systems, *Annual Review of Environmental Resources*, 30, 441-473.
Gatrell, A. C. (2005) Complexity theory and geographies of health: a critical assessment. *Social Science & Medicine,* 60**,** 2661-2671.
Gerrits, L. (2010) Public decision-making as coevolution. *E:CO* 12,1, 19-28.
GB Parliament, 2011 Local Authorities; the General Power of Competence, SN/PC/05687.
Holden, R., Val, D.V., Burkhard, R. & Nodwell, S. (2013) A network flow model for interdependent infrastructures at the local scale. *Safety Science*, 53, 51-60.
Haldane A. and May, R. (2011) Systemic Risk in Banking Ecosystems, *Nature* 469, 351-355.
Hames, D., Vardoulakis, S. (2012) *Climate Change Risk Assessment for the Health Sector*. Department for Environment Food & Rural Affairs, London.
Hughes, T. P., S. Carpenter, et al. (2013). Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution* 28(7): 389-395.
IPCC. 2014. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf.
Joseph, G. M., M. W. Skinner & N. M. Yantzi (2013) The weather-stains of care: Interpreting the meaning of bad weather for front-line health care workers in rural long-term care. *Social Science & Medicine (1982),* 91**,** 194-201.
Kluvankova-Oravska, T. & V. Chobotova (2013) The challenges of policy convergence: the Europeanization of biodiversity governance in an enlarging EU. *Environment and Planning C,* 31**,** 401-413.
Klijn, E., and Snellen, I. (2010) Complexity theory and public administration, in Teisman, G, Gerrits, L and van Buren, A. (Eds) *Managing complex governance systems: Dynamics, self-organization and coevolution in public investments*, New York/London: Routledge 17-36.
Landstroem, C., S. J. Whatmore, S. N. Lane, N. A. Odoni, N. Ward & S. Bradley (2011) Coproducing flood risk knowledge: redistributing expertise in critical 'participatory modelling'. *Environment and Planning A,* 43**,** 1617-1633.
Lane, S. N., N. Odoni, C. Landstroem, S. J. Whatmore, N. Ward & S. Bradley (2011) Doing flood risk science differently: an experiment in radical scientific method. *Transactions of the Institute of British Geographers,* 36**,** 15-36.
Lanham, H., Leykum, L, Taylor, B., McCannon, C., Lindberg, C., Lester, R. (2013) How complexity science can inform scale-up and spread in health care: Understanding the role of self-organization in variation across local contexts. . *Social Science & Medicine,* in press.
Lega, F. & S. Calciolari (2012) Coevolution of Patients and Hospitals: How Changing Epidemiology and Technological Advances Create Challenges and Drive Organizational Innovation. *Journal of Healthcare Management,* 57**,** 17-33.
Linkov, I, Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kroger, W., Lambert, J., Levermann, A., Montreuil, B., Nathwani, J., Nyer, R., Renn, O., Scharte, B., Scheffler, A., Schreurs, M., Thiel-Clemen, T. (2014) Changing the Resilience Paradigm. *Nature Climate Change,* 4, 407-409.
Martin, R. & P. Sunley (2007) Complexity thinking and evolutionary economic geography. *Journal of Economic Geography,* 7**,** 573-601.
May, J. and Thrift, N. (editors) (2001) *Timespace: Geographies of Temporality.* Abingdon, Routledge.
Milligan. 2009. *There's No Place Like Home: Place and Care in an Ageing Society*. Farnham
NHS SDU (2014) *Sustainable Development Strategy for the Health and Care System 2014 – 2020; Supporting modules: Healthy, Sustainable and Resilient Communities,* http://www.sduhealth.org.uk/policy-strategy/engagement-resources.aspx. NHS Sustainable Development Unit, London.
Noordegraaf, M. and Newman, J. (2011) Managing in disorderly times; how cities deal with disaster and restore social order. *Public Management Review*, 13, 3, 4, 513-538.
ONS (2012) 2008-based Sub-national Population Projections. Office of National Statistics,

London.
O'Brien, K.L. and Leichenko, R.M. (2000) Double exposure: assessing the impacts of climate change within the context of economic globalization. *Global Environmental Change*, 10(3): 221-232.
O'Sullivan, D. (2004) Complexity science and human geography. *Transactions of the Institute of British Geographers,* 29**,** 282-295.
O'Sullivan, T., Kuziemsky, C., Toal-Sullivan, D., Corneil, W. (2013) Unravelling the complexities of disaster management: a framework for critical social infrastructue to promote population health and resilience. *Social Science & Medicine,* in press.
Oven, K. J., S. E. Curtis, S. Reaney, M. Riva, M. G. Stewart, R. Ohlemueller, C. E. Dunn, S. Nodwell, L. Dominelli & R. Holden (2012) Climate change and health and social care: Defining future hazard, vulnerability and risk for infrastructure systems supporting older people's health care in England. *Applied Geography,* 33**,** 16-24.
Pain, R. & S. Kindon (2007) Participatory geographies. *Environment and Planning A,* 39**,** 2807-2812.
Pattison, I. & S. N. Lane (2012) The link between land-use management and fluvial flood risk: A chaotic conception? *Progress in Physical Geography,* 36**,** 72-92.
Pearce, J. (2013) 'Financial crisis, austerity policies and geographical inequalities in health,' *Environment and Planning A* 45, 2030–2045.
Pelling, M. (2011). Adaptation to Climate Change: from Resilience to Transformation. .
Abingdon, Oxon, UK, Routledge.
Phillips, J. D. (1999) Spatial analysis in physical geography and the challenge of deterministic uncertainty. *Geographical Analysis,* 31**,** 359-372.
Plsek, P. E. & T. Greenhalgh (2001) Complexity science - The challenge of complexity in health care. *British Medical Journal,* 323**,** 625-628
Public Accounts Select Committee (2013) *Department for Communities and Local Government: Financial sustainability of local authorities,* London: The Stationery Office Limited.
Sheffer, M., Carpenter, S., Lenton, T., Bacompte, J., Brock, W., Dakos, V., van de Koppel, J., van de Leemput, I., Levin, S., van Nes, E., Pascual, M., Vandermeer, J. (2012) Anticipating Critical Transitions, *Science*, 338, 344 – 348.
Stacey, R. (1996) Emerging strategies for a chaotic environment. *Long Range Planning,* 29**,** 182-189.
Sunday Times (2016a) Letters to the Editor 'Government's Duty of Social Care' *Sunday Times* 13.11.2016 p20.
Sunday Times (2016b) Slow, patchy, cruel: care funding damned as 'not fit for purpose' *Sunday Times Money* 13.11.2016 p4-5.
Suteanu, C. (2005) Complexity, science and the public - The geography of a new interpretation. *Theory Culture & Society,* 22**,** 113 - 140

Tierney, K., Lindell, M., Perry, R. (2001) *Facing the unexpected.* Joseph Henry Press, Washington, DC. USA.
Wistow, J., Dominelli, L., Oven, K., Dunn, C., and Curtis, S. (2015) The role of formal and informal networks in supporting older people's care during extreme weather events. *Policy and Politics,* 43(1): 119-135.
Wilson, T. & Holt, T (2001) Complexity science and clinical care. *British Medical Journal*, 323: 685-688, 22 September.
Wolf, J., Adger, W.N. and Lorenzoni, I. (2010a) Heat waves and cold spells: an analysis of policy response and perceptions of vulnerable populations in the UK. *Environment and Planning A*, 42: 2721-2734.
Wolf, J., Adger, W. N., Lorenzoni, I., Abrahamson, V., and Raine, R. (2010b) Social capital, individual responses to heat waves and climate change adaptation: An empirical case study of two UK cities. *Global Environmental Change*, 20(1): 44-52.
WHO (2009) Protecting Health from Climate Change; Connecting Science, Policy and People, World Health Organization, Geneva

http://www.who.int/globalchange/publications/reports/9789241598880/en/

Zaidi, R. Z. and M. Pelling (2013). "Institutionally configured risk: Assessing urban resilience and disaster risk reduction to heat wave risk in London." *Urban Studies*, 0(0): 1-16. DOI: 10.1177/0042098013510957.

Table 1: Group discussions and interviews with older people: Number of participants, their age and health status

Local Authority	*Locality*	*Code used in text*	*No. of Partici-pants*	*Age*	*Characteristics of resear*
LA North	Rural Coastal Area	N1	1	Early 70s	Active female, carer for her son who has a
	Rural Coastal Area	N2	2	Mid 60s	Active female, carer for her husband who Active older female and former carer for h ago
	Coastal Town	N3	1	70s	Active male, community organiser
	Coastal Town	N4	1	60s	Female with bowel disease, carer for her h from a stroke and her son who has a ment
	Rural Coastal Area	N5	1	Early 60s	Active female with leukaemia, carer for he
	Rural Coastal Area	N6	2	Late 60s	Female, carer and husband who has suffe
	Rural Coastal Area	N7	1	Early 70s	Female, cancer survivor, carer for her hus community
	Coastal Town	NG1	8	Late 60s to late 70s	Active older people in reasonably good he
	Coastal Town	NG2	8	Mid 60s to mid 80s	Active older people in reasonably good he
LA South	Village Hub	S1	1	80s	Female with high blood pressure and arthr
	Village Hub	S2	1	Late 60s	Female, former carer, with bowl disease a
	Village Hub	S3	1	80s	Active male, good health
	Village Hub	S4	2	70s	Active female, carer for her husband who
	Village Hub	S5	1	Late 60s	Reasonably active female with severe arth mother with dementia
	Village Hub	S6	4	70s	Two active females, including one carer ar stroke; and one older male with mobility is

Note: Interviews were conducted between January and March 2012

Table 2: Focus group discussions with stakeholders at the strategic (local authority) level and frontline service providers

Local Authority	*Focus group*	*Year/month*	*Code used in text*	*No. of partici-ants*	*Sectors represented*
LA North	Strategic level	2011 June	NSM	17	LA (Adult Social Care, Sustainability, Continuity Planning, Neighbourhood Management, Housing) NHS (Public Health, Emergency Planning, Joint Commissioning) CVS (Health and Social Care Network, Rural Community Council) Independent sector (bus company)
	Frontline (Coastal Town)	2012 July	NFM	7	LA (Adult Social Care and Carers' Network) Town Council CVS (Stroke Club) Statutory Services (Police)
LA South	Strategic level	2011 June	SSM	19	County Council (Adult Social Care, Adaptation and Climate Change, Emergency Management, Highways) District Council (Adaption and Climate Change, Continuity Planning, Older Persons' Officer, Community Planning) NHS (PCT and Community Trust) CVS (Age UK, Council for Voluntary Services, Senior Persons' Council, Community Transport provider)
	Frontline (Village Hub)	2012 July	SFM1	6	LA (Adult Social Care) Parish Council Housing Association Older person
	Frontline (Southern Town)	2012 July	SFM2	6	LA (Adult Social Care) CVS (Cognitive Help and Therapy) Assistive Technology Manager Independent Care provider Statutory services (Police and Community Support)

Table 3: Organogram summarising the diverse types of agencies involved in systems of health and social care for older people's health and wellbeing in the areas studied (See also Figure 3).

Local Government	National Health Services
Council • Adult Social Care • Emergency planning • Spatial planning • Infrastructure planning • Climate change adaptation • Neighbourhood management • Community services ***Coordinating bodies*** • Local Strategic Partnership • Local Resilience Forum • Health and Wellbeing Boards • Sustainability Forums	***Primary Care Trust*** • Public Health Intelligence • Joint Planning and Commissioning • Provider services • GP representative ***Acute (hospital care) Trust(s)*** • General Acute Inpatient Services • Geriatric Inpatient Care • Inpatient Dementia and Mental Health Care • Accident and Emergency • NHS Estates ***Community (healthcare) Trust*** ***Mental Health Trust***
Utilities Providers	**Emergency Services**
• Water company • Electricity company • Gas company • Telecommunications	• Fire and Rescue Service • Police Force • Ambulance Service
Independent Sector Care Services	**Other Agencies**
Informal, Voluntary Sector (not for profit) Organizations • Age UK • Older People's Forum • Carers' advisory groups • Alzheimer's Society • 'Other' local user-led groups • Older people's charter groups ***Independent (for profit) Care Providers*** • Private care companies • Care homes • Care in the community schemes ***Social Housing Corporation/Major Housing Associations***	***Inspection and Regulation Agencies*** • Environment Agency • Care Quality Commission ***Transport providers*** • Rail service providers • Network Rail • Local bus companies • Dial-a-ride schemes • ***Advocacy and Brokerage Groups*** • Health-Watch

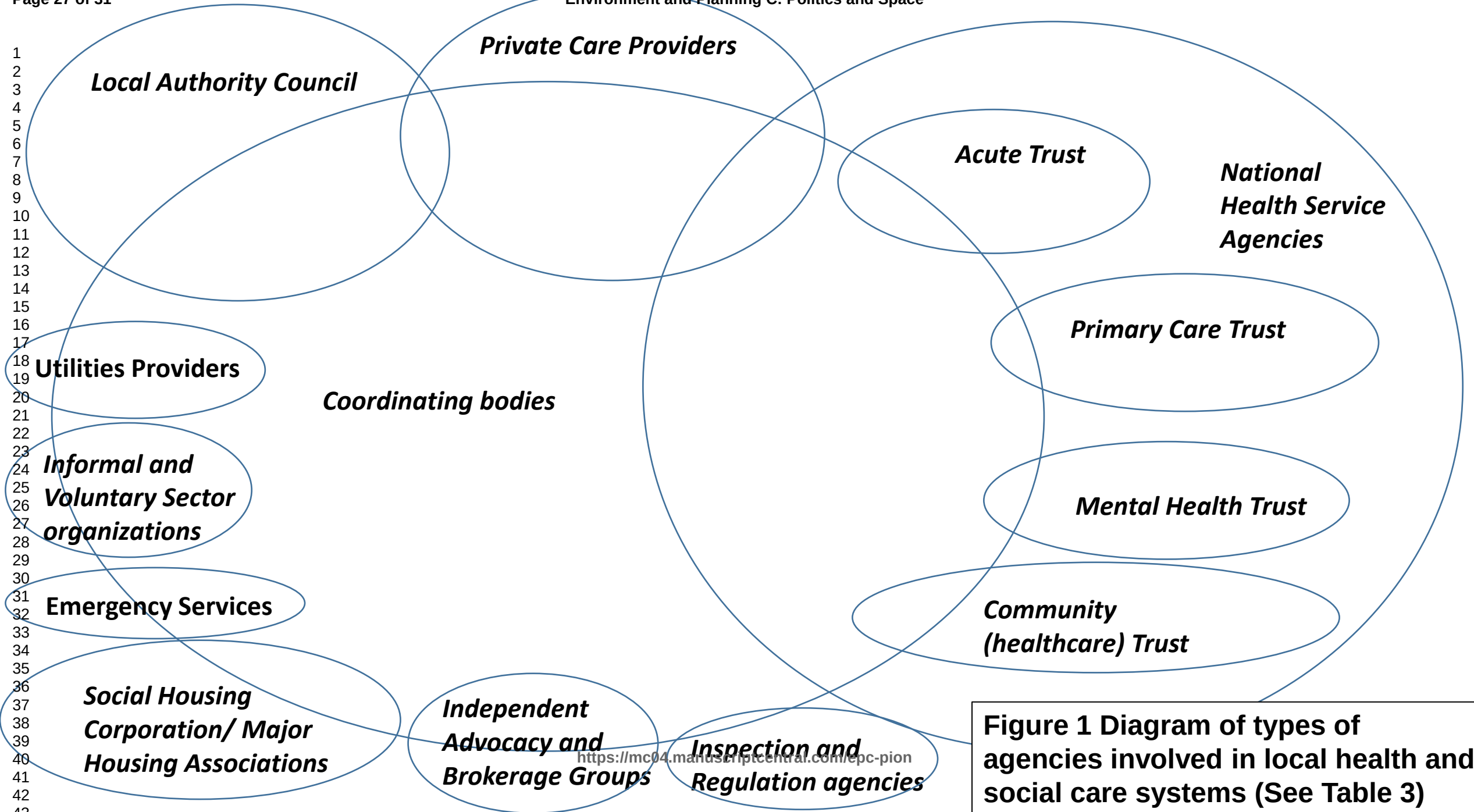

Figure 1 Diagram of types of agencies involved in local health and social care systems (See Table 3)

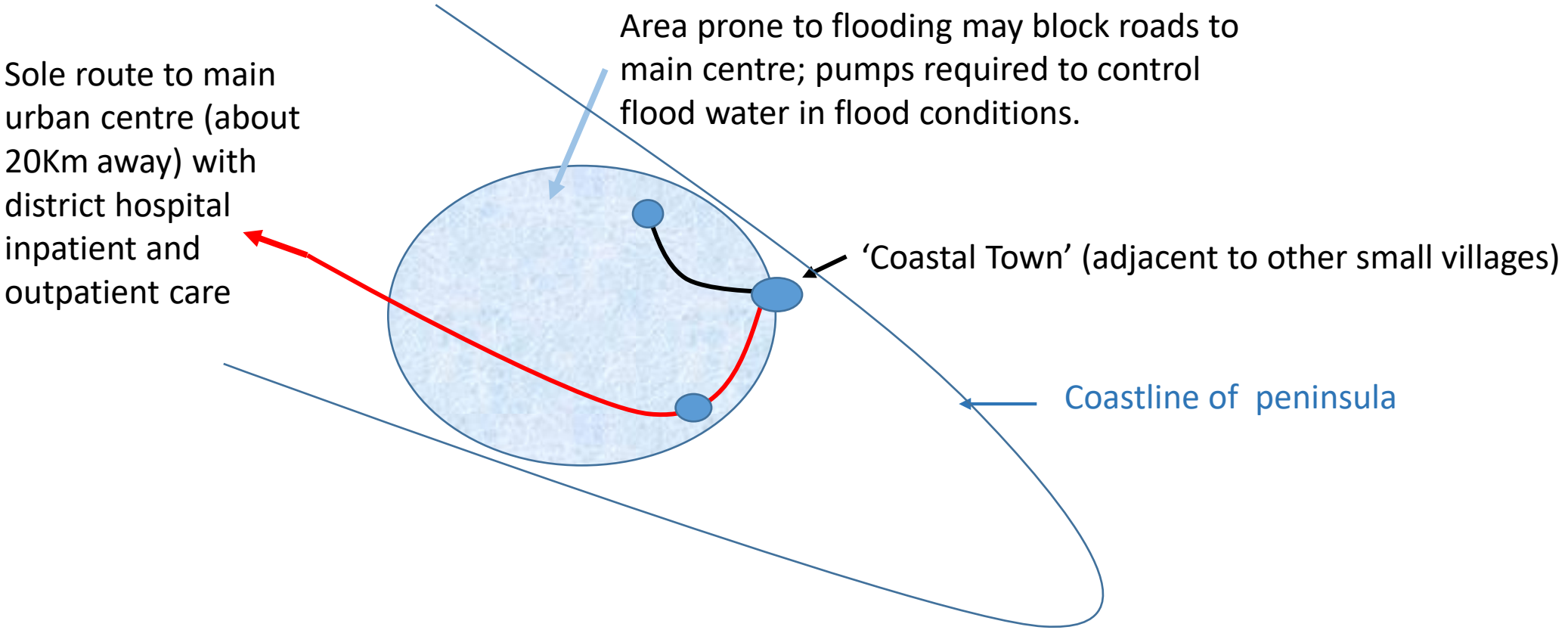

Figure 2a Schematic map of 'rural coastal area' in LA North, showing position of 'Coastal Town' and nearby settlements, illustrating potential to loose access to secondary care by road during flood events.

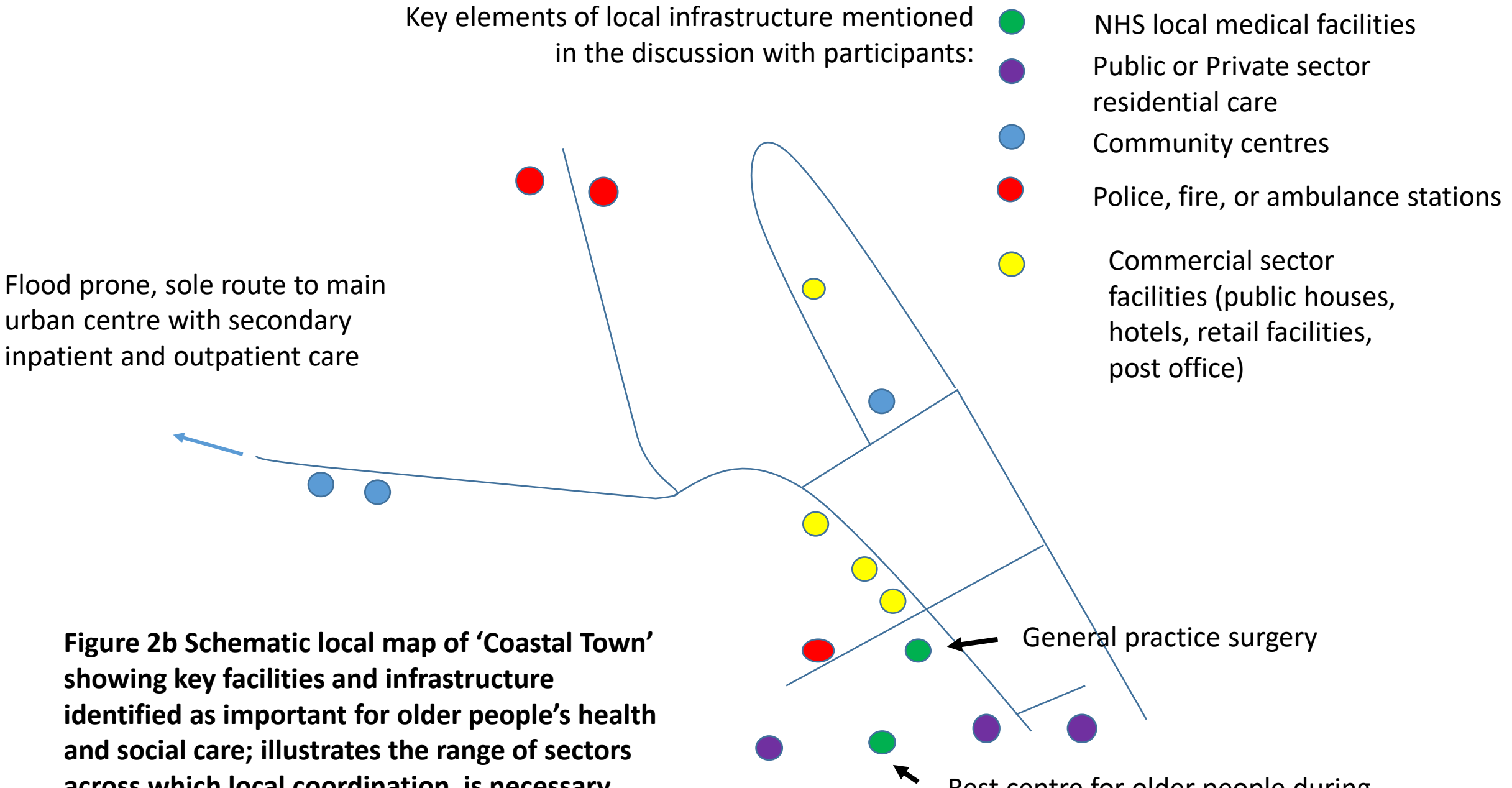

Figure 2b Schematic local map of 'Coastal Town' showing key facilities and infrastructure identified as important for older people's health and social care; illustrates the range of sectors across which local coordination is necessary during an extreme weather event

Figure 3a schematic map of Southern Town and surrounding area

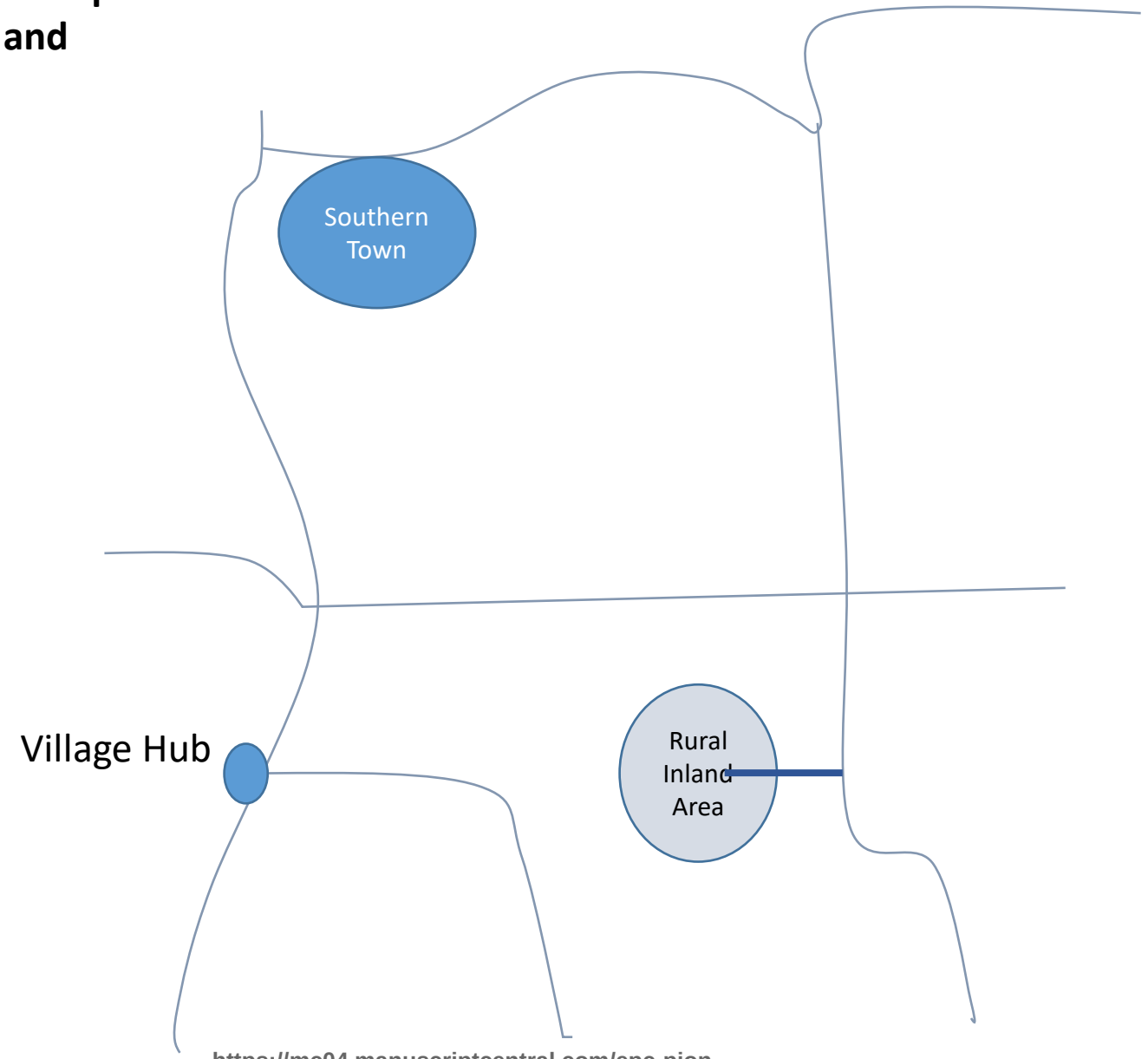

Figure 3b Local Map of 'Village Hub' in 'Rural Inland Area'