

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Are we adapting to climate change?

Lea Berrang-Ford^{*}, James D. Ford¹, Jaclyn Paterson

Dept. Of Geography, McGill University, Montreal H3A2K6, Canada

ARTICLE INFO

Article history:

Received 24 June 2010

Received in revised form 22 September 2010

Accepted 23 September 2010

Available online 23 October 2010

Keywords:

Climate change

Global adaptation

Systematic review

Indicators

Intergovernmental Panel on Climate

Change IPCC

ABSTRACT

Human systems will have to adapt to climate change. Understanding of the magnitude of the adaptation challenge at a global scale, however, is incomplete, constrained by a limited understanding of if and how adaptation is taking place. Here we develop and apply a methodology to track and characterize adaptation action; we apply these methods to the peer-reviewed, English-language literature. Our results challenge a number of common assumptions about adaptation while supporting others: (1) Considerable research on adaptation has been conducted yet the majority of studies report on vulnerability assessments and natural systems (or *intentions* to act), not adaptation actions. (2) Climate change is rarely the sole or primary motivator for adaptation action. (3) Extreme events are important adaptation stimuli across regions. (4) Proactive adaptation is the most commonly reported adaptive response, particularly in developed nations. (5) Adaptation action is more frequently reported in developed nations, with middle income countries underrepresented and low-income regions dominated by reports from a small number of countries. (6) There is limited reporting on adaptations being developed to take advantage of climate change or focusing on women, elderly, or children.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Evidence that the climate is changing is overwhelming (Smith et al., 2009; Fussler, 2009). Historic emissions commit the earth to some degree of future warming regardless of mitigation progress, and will probably surpass the 2C threshold held by many as indicative of 'dangerous' interference (Ramanathan and Feng, 2008; Parry et al., 2009; Smith et al., 2009). Given failure to create an international framework for stabilizing emissions, 4C of global warming by 2100 looks increasingly likely (Parry et al., 2009; Adger and Barnett, 2009). Adaptation is unavoidable.

The realization of the inevitability of climate change has reinvigorated adaptation research, long the poor cousin of mitigation (Pielke et al., 2007). This work demonstrates that opportunities for adaptation are available, feasible, and can be mainstreamed into existing policy priorities (Stern, 2006; Karl et al., 2009; Costello et al., 2009; Garnaut, 2008). Importantly, the challenge of adaptation is not necessarily new, as humans have lived with climatic variability for a long time and developed management decisions to cope with this variability (Dovers, 2009; Smit and Wandel, 2006; Burton et al., 2002). Despite these opportunities, concerns have been noted regarding the ability of human systems to adapt due to the scale of

projected impacts, existing vulnerabilities, and insufficient attention to adaptation (Adger and Barnett, 2009). Even in developed nations, extreme events have highlighted significant deficiencies in prevention and preparedness (Ebi and Semenza, 2008; Hulme, 2003; Ford et al., 2010). Adaptive capacity will not necessarily translate to adaptation (O'Brien et al., 2006; Adger and Vincent, 2005; Repetto, 2009).

Understanding of the magnitude of the adaptation challenge, however, is incomplete. Is adaptation already taking place? Who is adapting, to what, and how? Does adaptation differ between and within nations, regions, sectors? Are adaptations consistent with the risks posed by climate change? We have snapshots on these questions. IPCC AR4 provides selected examples of adaptation in practice, a format employed by national level climate change assessments (Karl et al., 2009; Lemmen et al., 2008; Belanger et al., 2008). Case study research has also documented and examined adaptations being undertaken (Ford et al., 2010). On this basis it is generally understood that some if not enough adaptation is taking place, high income nations are more likely to be adapting than middle and low income nations, the most vulnerable are least likely to adapt, adaptation measures are seldom undertaken in response to climate change alone, reactive adaptations are more likely in the absence of government intervention, and it is believed that the more rapid climate change is, the more problematic adaptation will be (Smith et al., 2009; Stern, 2006; IPCC, 2007; World Bank, 2010). It has also been noted that our limited understanding of vulnerability and adaptation precludes developing adaptation interventions, with more research integrating

^{*} Corresponding author. Tel.: +1 514 398 4944.

E-mail addresses: lea.berrangford@mcgill.ca (L. Berrang-Ford), james.ford@mcgill.ca (J.D. Ford), Jaclyn.paterson@mail.mcgill.ca (J. Paterson).

¹ Tel.: +1 514 398 4966.

socio-economic and climate scenarios needed (Moss et al., 2010; World Bank, 2010).

Our ability to evaluate these assumptions and monitor adaptation progress, however, is constrained by an absence of measurable outcomes or indicators from which to judge if and how adaptation is occurring (Burton and May, 2004; Gagnon-Lebrun and Agrawala, 2007). Mitigation is a bounded problem that can be assessed with reference to the global concentration of greenhouse gases. Adaptation is messier, concerned with adjustments in human systems at different scales (local to global) and by different actors (e.g. government, individuals, households, etc.) and which may only be partially developed in response to climatic stimuli (Berkhout, 2005; Dovers and Hezri, 2010). Progress on adaptation is therefore rarely measured, arguably contributing towards the reluctance of governments to invest in adaptation interventions (Burton et al., 2002; Pielke, 1998).

Here we develop and apply a preliminary and exploratory systematic literature review methodology to track adaptation action globally. We use adaptation reporting in the English peer-reviewed literature as a proxy sample or indicator of adaptation action, identifying, characterizing, and comparing if and how adaptation is occurring. This enables us to re-examine commonly held assumptions on global adaptation while recognizing that many adaptations are undocumented or documented outside of the scientific literature. Peer reviewed studies however, represent a widely accepted and scientifically rigorous source for rapid and standardized assessment, forming the basis of numerous scientific syntheses (IPCC, 2007; MA, 2006; Arnell, 2010; Tompkins et al., in press).

2. Methodology

We use a systematic literature review approach to assess if how and adaptation is occurring at a global level. Systematic literature reviews involve reviewing documents according to clearly formulated questions and using systematic and explicit methods to select and critically appraise relevant research (Petticrew and Roberts, 2006; The Cochrane Collaboration, 2008). This approach, while common in the health sciences, has not been extensively applied to environmental and climate change studies but offers considerable promise in a field characterized by an exploding body of research but seemingly insufficient means to keep track of what is going on (Ford and Pearce, 2010). The IPCC for example, produces a comprehensive assessment on the state of knowledge on climate change approximately every 5 years, yet with 1000s of climate change articles being published each year it is increasingly being recognized that periodic updates are also needed (Hulme, 2009; Pearce et al., 2010; Ford and Pearce, 2010). The methodology outlined here offers one such approach.

2.1. Document selection

A keyword search was performed in the search engine ISI Web of Knowledge (WOK) using the English key topic terms “climat*chang*” AND “adapt*”. WOK was selected as it is one of the most powerful, current, comprehensive, and widely used search engines available for analysis of interdisciplinary, peer-reviewed literature (Jasco, 2005). The review focused on peer-reviewed literature documenting climate change adaptations published between 2006 and 2009. Literature prior to 2006 was not reviewed as this is covered by IPCC AR4 (IPCC, 2007) and TAR (IPCC, 2001). Documents not in English, outside of the search period and other than articles and reviews were excluded. This search retrieved 1741 documents. All retrieved documents were reviewed based on title and abstract to evaluate suitability for inclusion in the final review (Fig. 1). Inclusion and exclusion criteria are outlined in Table 1. In some cases, cursory or in-depth full-text review was conducted in order

to assess suitability. Excluded articles were categorized to allow descriptive evaluation of documents not included in the final review. A list of documents considered is provided in the Supplemental Materials.

Articles were selected to identify those reporting or discussing *intentional* human adaptation actions explicitly identified by the authors as adaptations to climate change, reflecting our goal of examining if adaptation is occurring. IPCC AR4 definitions were used to guide classification, inclusion/exclusion criteria, and sub-categorization of documents. Herein, *climate change* refers to any change in climate over time, whether due to natural variability or as a result of human activity. *Adaptations* include adjustments in human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptations predominantly relating to natural systems were excluded along with studies reporting predominantly risk or vulnerability assessments, mitigation, general sustainable development, and conceptual or theoretical approaches. Here we made a distinction between the articulation of *intentions* to act, and adaptation *actions* themselves; this review focuses exclusively on the latter. Actions can include mainstreamed activities designed to address multiple motivations, but require explicit recognition of climate change as a contributing motivator. A summary of definitions and classifications used for document selection is provided in Table 2.

2.2. Document review

Following document screening, 87 articles were retained for full review (Fig. 1). A questionnaire was then developed to survey selected articles to document and characterize if and how climate change adaptation is occurring. We developed a questionnaire to standardize analysis of articles and enable statistical testing to identify and examine key trends and associations. The questionnaire (available in Supplemental Materials) begins with questions on the general characteristics of the article in terms of authorship, year published, and region of interest. The main section has fixed, forced choice questions focusing on the nature adaptation action, informed by adaptation assessment frameworks proposed by Smit and others (Fussler, 2007; Smit et al., 1999, 2000), and focusing on: (i) the stimulus motivating the adaptive response; (ii) who or what adapts; and (iii) adaptation activities and outcomes. An extensive full-text review of all (87) articles was conducted using the questionnaire. In articles where multiple actions were presented, only the predominant adaptation action summarized in the article was assessed; there was generally insufficient information to critically assess secondary adaptations. A copy of the questionnaire and a detailed summary of the typology definitions and classifications are available in Supplemental Materials.

2.3. Analysis

All (1741) documents were retained in EndNote Web for external review and validation, and data were entered into an Excel spreadsheet. Descriptive and basic inferential statistics were used to summarize quantitative trends in the data. All references to statistical significance represent associations significant at the 95% confidence level using chi-squared analyses or Fishers exact tests, as appropriate. Analyses were conducted in Stata (Intercooled Stata v.9.2, StataCorp). ArcGIS (ESRI v.9.3.1) was used for data mapping.

3. Results

3.1. Reporting on adaptation actions is limited but increasing

Over half of all 1741 documents reporting on climate change and adaptation focus exclusively on adaptation in natural systems

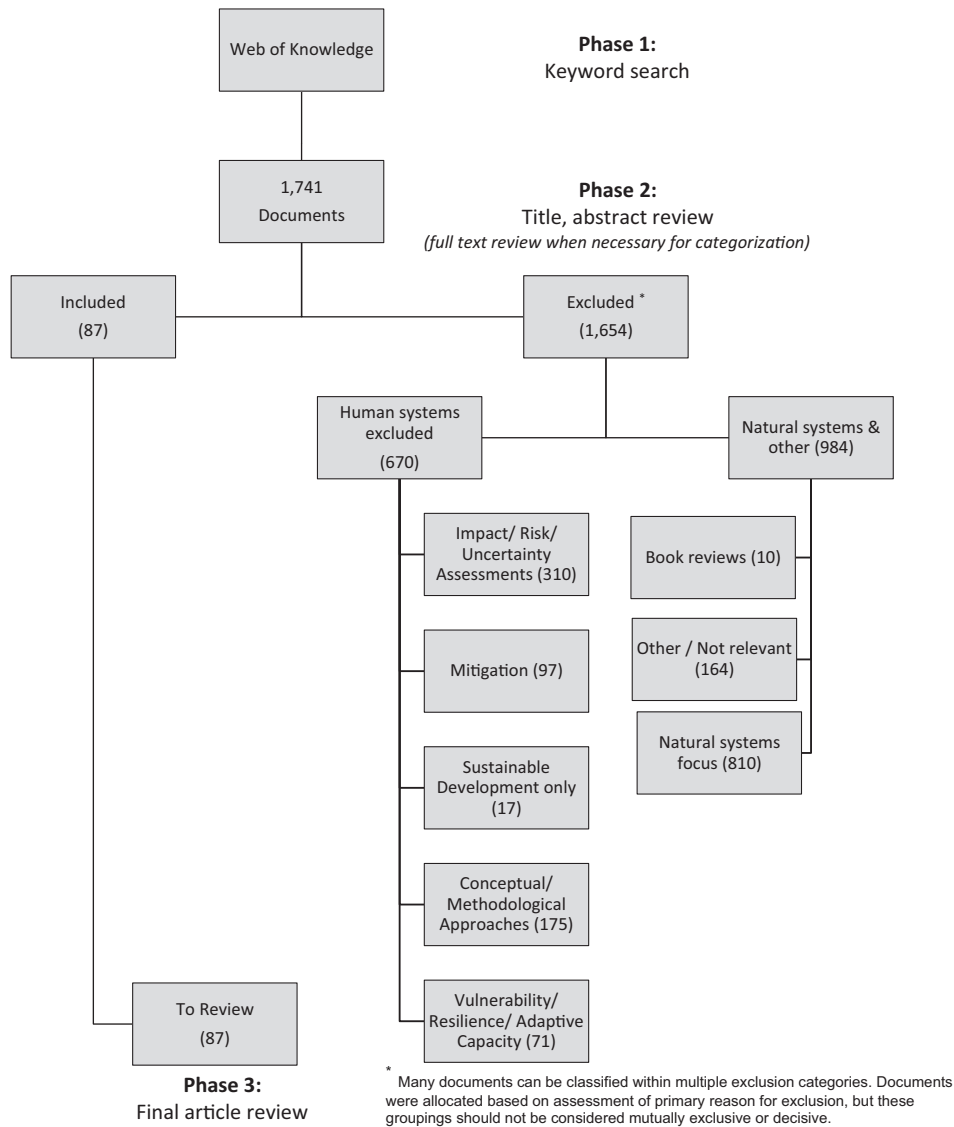


Fig. 1. Summary of document selection.

(Fig. 1). Just under half report on human systems, with the majority focusing on assessments of climate change risk, vulnerability, impacts, adaptive capacity, or conceptual approaches. Only 87 documents fit our inclusion criteria of intentional adaptation actions: 5% of the total or 13% of documents focusing on human systems. We posit several potential reasons for this deficit: (a)

Table 1
Inclusion and exclusion criteria for document selection.

Inclusion	Exclusion
Phase 1: keyword search	
English	Non-English
1 January 2006–1 July 2009	Pre-2006 or after 1 July 2009
Indexed in the ISI Web of Knowledge	Not available via ISI Web of Knowledge
Reviews and articles	Other (e.g. Editorials, Meetings, Abstracts)
Phase 2: title and abstract review <i>(full text review when required for categorization)</i>	
Human	Natural (e.g. plants, animals)
Adaptive response	Mitigation, vulnerability only
Practical focus	Conceptual/theoretical focus
Present	Prehistoric or future
Adaptation activities or actions	Predictive models and vulnerability assessments or intentions to act

adaptation activities are occurring but are not being – or have not yet been – translated into the peer-reviewed literature, (b) many adaptation policies and mechanisms are insufficiently developed to have progressed substantively beyond the assessment and planning stages (Gagnon-Lebrun and Agrawala, 2007; Barnett, 2010), and/or (c) political discourse on adaptation in human systems has not yet translated into activities so as to be detected and evaluated in the peer-reviewed literature (Burton, 2006; Pielke et al., 2007; Dovers and Hezri, 2010; Tompkins et al., in press). The number of publications reporting adaptation activities has, however, increased over the past 4 years, from 12 in 2006 to a projection of close to 50 papers in 2009 (Table 2 and Fig. 2a).

3.2. Adaptations are most likely to be stimulated by climatic variability and are often mainstreamed and proactive

The literature indicates that climate variability plays a more important role in stimulating adaptive response than long-term changes in average climatic conditions (Fig. 2b). Inter-annual or decadal variability and isolated extreme events were more frequently reported as adaptation stimuli than long-term changes in seasonal or annual temperature or precipitation. For example, adaptations were commonly associated with events such as floods,

Table 2
Description of search criteria classifications.

Included	<p>Human systems – adaptation</p> <p>The title and/or abstract of the study explicitly indicates that previous or currently practiced adaptive strategies are reported/mentioned/assessed/discussed in the paper. The full text of the document includes substantive reporting or discussion of an adaptation activity. The adaptive action must be set in place (excludes proposed strategies, empirical testing, predictive modeling, etc.). Initiatives that strengthened knowledge base, information sharing, improving data gathering, surveillance/forecasting systems and increased vulnerability/adaptive capacity/resilience to climate change were included. Articles dedicated to improving existing predictive models were not included</p>
Excluded	<p>Human systems excluded</p> <p><i>Impact/risk/uncertainty assessments</i></p> <p>Studies with a main focus on potential impacts (and residual impacts incorporating <i>conceptual</i> adaptations) and/or risks and/or uncertainty with respect to climate change in the past, present or future. Examples included empirical studies, reviews, theoretical discussions, climate change impacts on natural systems affecting forestry production/agriculture/farmed aquatic and terrestrial plants and animals and conceptual adaptations (not currently set in place) embedded in future climate change scenarios/predictive computer models. Articles that incorporated adaptation into impact assessment models (i.e. estimating residual impacts of climate change) were included in this category</p> <p><i>Mitigation</i></p> <p>All articles that focused on mitigation strategies, the reduction of greenhouse gas emissions, energy efficiency techniques, and any intervention, strategy or assessment related to increasing carbon sinks and/or reducing carbon emissions</p> <p><i>Sustainable development only</i></p> <p>Articles documenting or assessing sustainable development programs, processes and ideas without an explicit focus on adaptation to climate change</p> <p><i>Conceptual and methodological approaches</i></p> <p>Articles reviewing, summarizing, predicting, discussing, and assessing adaptation to climate change but providing no indication that adaptations were/are in practice. Articles in this category stressed the message: ‘we need to adapt now’, assessed methods and challenges of adaptation (including how to improve adaptive capacity and resilience to climate change) and examined the success of adaptive strategies via empirical tests. Many of the included documents are not mutually exclusive to other categories; documents that included potential adaptive strategies but were not clearly or predominantly appropriate for other categories were included in this category</p> <p><i>Vulnerability/resilience/adaptive capacity assessments</i></p> <p>Articles assessing vulnerability of a particular group/System to climate change based on environmental/social factors (e.g. geographical location, poverty level). Studies included <i>assessments</i> of resilience and adaptive capacity but did not include actual programs or processes set in place to improve resilience or adaptive capacity</p> <p>Natural systems and other</p> <p><i>Natural systems</i></p> <p>Any study focusing on the affects of climate change on the biological (flora, fauna) and physical (soil, land, water, climate) systems only. Based on the descriptions of Natural Physical Systems and Natural Biological Systems in the IPCC AR4. Impacts, risks, uncertainty, vulnerability and predictive modeling of Natural Systems are all included in this category. Prehistoric climate change papers and empirical studies examining crops focusing only on plant biology/ecology (i.e. without reference to yield/production) were included in this category. Managed Natural Systems that provide ecosystem services were considered human systems</p> <p><i>Other</i></p> <p>Book reviews (critiques of books on adaptation to climate change). Also included in this category were articles totally irrelevant to the topic. These included human adaptations in prehistory (predating written history)</p>

droughts, or heatwaves. Changes in the predictability of precipitation, as well as increased seasonal variability were reported as particularly important for water, agriculture, and forestry management. The most dominant stimulus motivating adaptation was changes in precipitation, particularly increased occurrence of floods or drought events. Adaptation activities are occurring in response to a mixture of climate change and other motivating factors (Fig. 2c): climate change was considered to be the sole motivating factor for adaptation actions in only 19% of documents, with 44% reporting climate change as a primary reason among several.

Adaptation activities have, to a large extent, been purposive, reflecting explicit intent and planning for anticipated future impacts. Seventy-eight percent of documents reported adaptations involving anticipatory action. Approximately one-half of documents reported adaptations that were reactive, occurring in response to an existing impact or stimulus. The anticipatory nature of adaptive actions is also reflected in the stated goals of adaptive responses. Planning for reduced future risk, development of networks and partnerships, and enhancement of knowledge or research were among the most frequently reported (Table 2). These trends, however, reflect the high proportion of adaptations from developed countries where proactive adaptations were more frequently reported. Notably, there was very little evidence of activities aimed at capitalizing on potential climate change benefits (7%); those that were reported, however, were significantly more likely to occur in low income countries. Proactive adaptive measures, in contrast to reactive activities, were significantly more likely to be stimulated by long-term changes in climatic means or isolated extreme events.

3.3. Long-term, proactive adaptation planning is more likely to be undertaken by government

Anticipatory responses were significantly more likely to be undertaken by higher levels of government, particularly the national level. Conversely, individual or household adaptive responses were significantly more likely to arise from a reactive response to existing stimuli. This suggests a gradient in anticipatory adaptive capacity, with institutions and governments showing potentially higher capacity or resources to proactively engage in adaptive initiatives.

Institutional and governmental mechanisms were the most frequently cited tools by which adaptations were implemented. This was followed by the provision of financial support. Financial provisions were significantly more likely to occur for adaptations occurring at the national level, though national participation alone was insufficient and was not associated with financial mechanisms.

Results indicate that adaptations at the individual or household level may occur more often in response to financial stimuli, including changing economic market conditions and resource availability, particularly diminishing or inequitable food supplies. Documents highlighting individual/household adaptations were over 8 times as likely to report market conditions and close to 3 times as likely to report resource availability as stimuli compared to documents not reporting adaptations at this scale. Conversely, documents highlighting multinational adaptations were significantly more likely to reference climate change *in general* as a stimulus.

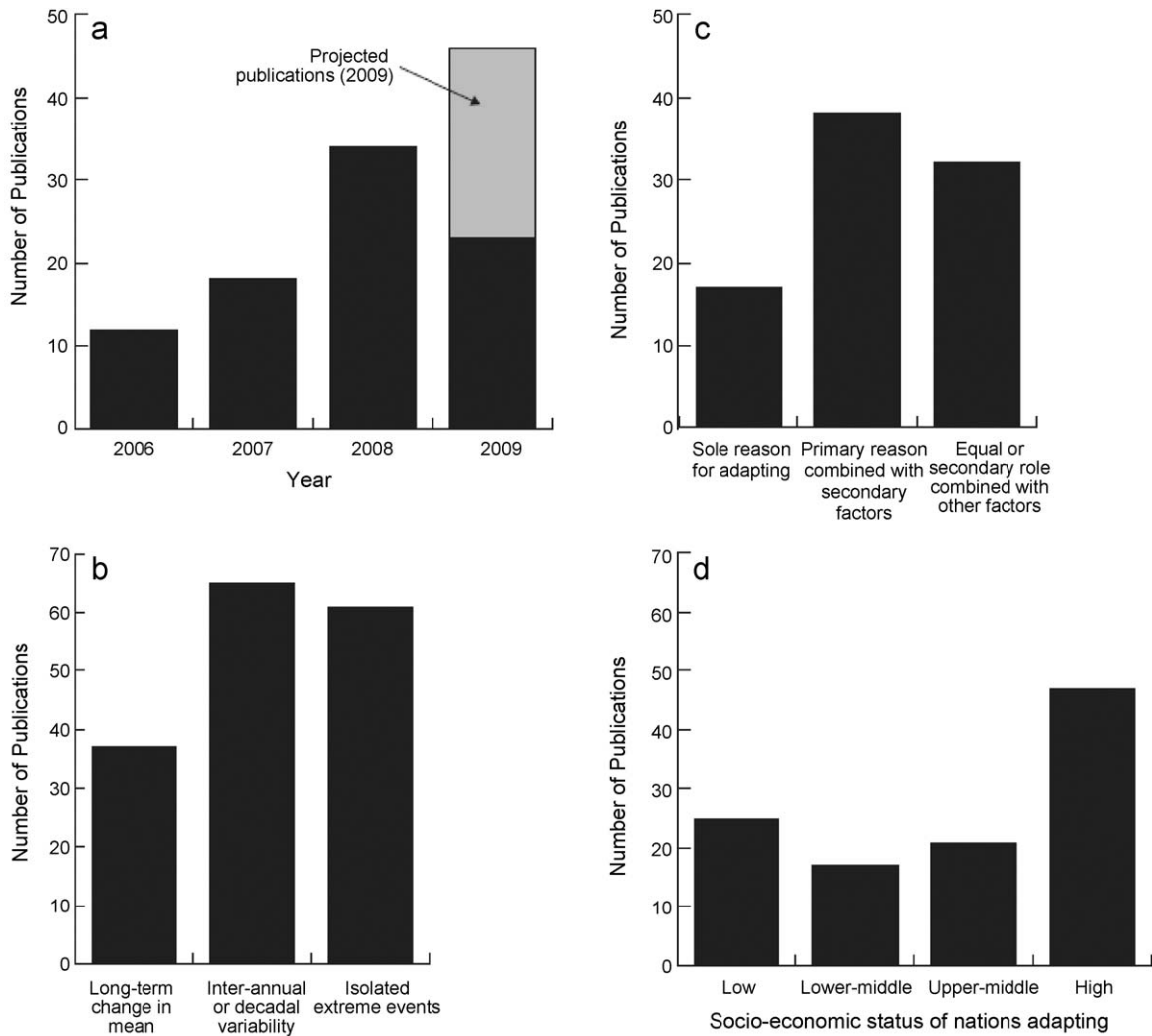


Fig. 2. (a) Number of publications reviewed, by year. The review included publications up to 1 July 2009 only, and therefore reflect only half of the year. A projection of the 2009 total publications (assuming homogenous publication intensity throughout the year) has thus been added. (b) Timeframe of climate change effects motivating adaptation. (c) Importance of climate change in motivating adaptation. (d) Distribution of publications reporting adaptations by socio-economic status of nation (values are not cumulative).

3.4. The global distribution of adaptation reports is inequitable

The highest number of reports related to activities in Europe (32 documents), followed by Africa (26), North America (21), Asia (17),

and South and Central America (15). Disparities in reporting of adaptations were, however, more prominent within regions and often dominated by one or two countries (Fig. 3 and Table 3). While Africa was represented in close to a third of adaptation

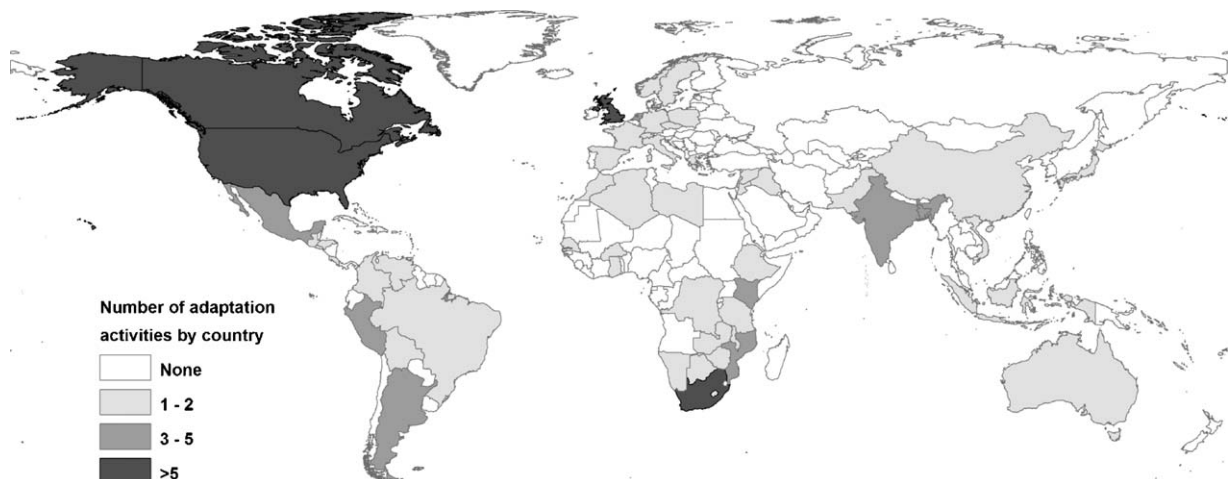


Fig. 3. Distribution of reporting on human adaptation to climate change. Values reflect the number of publications retrieved that report adaptation actions in each country.

Table 3
Summary of adaption reports and activities.

Variable	No. of articles (%)
<i>Who is reporting on adaptation and when?</i>	
Year	87 (100)
2006	12 (14)
2007	18 (21)
2008	34 (39)
2009	23 (26)
First author affiliation	86 (100)
Researcher	76 (87)
Government	10 (12)
Non-governmental organization	1 (1)
Civil society	0 (0)
<i>What stimulus is motivating the adaptive response?</i>	
Type of stimulus	Non-cumulative ^a
Climate change – precipitation	65 (75)
Socio-political-economic or sustainable development	61 (70)
Climate change – temperature	41 (47)
Non-climate change environmental change	34 (39)
Resource availability	28 (32)
Climate change – extreme storm events	26 (30)
Climate change – sea level rise	21 (24)
Market conditions	21 (24)
Climate change – other or general	14 (16)
Proximity of effect	Non-cumulative ^a
Biophysical effect (indirect)	72 (83)
Human impact (direct)	57 (66)
N/A	6 (7)
Importance of climate change in motivating adaptation	87 (100)
Sole reason for adapting	17 (19)
Primary reason combined with secondary factors	38 (44)
Equal or secondary role combined with other factors	32 (37)
Timeframe of climate change effects	Non-cumulative ^a
Long-term change in mean (E.g. seasonal or annual temperature or precipitation)	37 (43)
Inter-annual or decadal variability	65 (75)
Isolated extreme events	62 (71)
<i>Who or what system is adapting?</i>	
Spatial scale of adaptation	Non-cumulative ^a
Municipality/community	50 (57)
Individuals/households	29 (33)
National	23 (26)
Sub-national (Province/State/Region)	22 (25)
Multinational (2 or more nations)	6 (7)
Sectors involved in adaptation	
Utilities (including electricity, water, and flood management)	56 (64)
Agriculture, fishing, and/or forestry	48 (55)
Secure resources and food security	36 (41)
Infrastructure and transportation	33 (38)
Ocean and coastal management	27 (31)
Ecosystem management	23 (26)
Disaster risk management	21 (24)
Public health	17 (20)
Tourism	8 (9)
Culture	8 (9)
Industry and technology	7 (8)
Energy	4 (5)
Education	1 (1)
Stakeholders involved in adaptation	Non-cumulative ^a
Research or educational institutions	69 (79)
Government – national	66 (76)
Individuals, families, or community residents	61 (70)
Government – municipal	48 (55)
Government – State/Provincial/Regional	38 (44)
Government – International (2 or more nations)	26 (30)
NGO (Non-governmental Organizations)	24 (28)
Civil societies	9 (10)
Region where adaptation is occurring	Non-cumulative ^a
Europe	32 (37)
Eastern Europe 6 (7)	
Northern Europe 12 (14)	
Southern Europe 5 (6)	
Western Europe 9 (10)	
Africa	26 (30)
Eastern Africa 11 (13)	

Table 3 (Continued)

Variable	No. of articles (%)
Middle Africa 1 (1)	
Northern Africa 1 (1)	
Southern Africa 7 (8)	
Western Africa 6 (7)	
North America	21 (24)
Asia	17 (20)
Central Asia 0 (0)	
Eastern Asia 2 (2)	
Southern Asia 11 (13)	
Southeastern Asia 3 (3)	
Western Asia 1 (1)	
South and Central America (including the Caribbean)	15 (17)
Central America 4 (5)	
Caribbean 2 (2)	
South America 9 (10)	
Other	9 (10)
Oceania (including NZ and Australia) 5 (6)	
Antarctica 0 (0)	
Global (multiple nations and continents, unspecified nations) 4 (5)	
Focus on vulnerable groups/regions	
Coastal systems and low-lying areas	37 (43)
Socio-economically disadvantaged groups	32 (37)
Indigenous focus	17 (20)
Arctic	11 (13)
Women, elderly, and children	3 (3)
Economic status of nations adapting	Non-cumulative ^a
Low	25 (29)
Lower-middle	17 (20)
Upper-middle	22 (25)
High	47 (54)
<i>What are the adaptation activities and outcomes?</i>	
Type of adaptive strategy	Non-cumulative ^a
Proactive (i.e. planned or anticipatory)	68 (78)
Reactive (i.e. autonomous)	46 (53)
Primary goal of adaptation	Non-cumulative ^a
Prepare/prevent/reduce risk	66 (76)
Build trust/networks/partnerships	46 (53)
Secure income or resources	39 (45)
Enhance learning/research	38 (44)
Accommodate/cope	33 (38)
Protect/conserv	31 (36)
Improve monitoring	28 (32)
Promote awareness	27 (31)
Improve forecasting	26 (30)
Adjust	26 (30)
Spread risk	26 (30)
Retreat/avoid	21 (24)
Restore to original conditions	11 (13)
Capitalize on climate change benefits	6 (7)
Adaptation mechanism	Non-cumulative ^a
Institutional/guidelines	69 (79)
Government	67 (77)
Financial support	47 (54)
Technical	43 (49)
Community	39 (45)
Structural	36 (41)
Non-government	29 (33)
Education initiatives	20 (23)

^aCategory totals are non-cumulative since any given article may be classified into multiple non-exclusive categories.

reports, these were dominated by adaptations in East African countries and South Africa. In Europe, almost half of publications reporting adaptations were related to activities in Northern Europe, the vast majority referencing the United Kingdom. Similarly, Asian adaptation reports were dominated by Southern Asia, specifically India and Bangladesh. There was no evidence of dominance by particular nations for South and Central America. The dominance of reporting from the United Kingdom, East Africa, India, and Bangladesh suggests the potential for a bias towards Anglophone countries, presumably reflecting selection of English-only publications.

Countries with high socio-economic status were disproportionately represented in the sample, with 54% of documents referring to adaptations in these regions, compared to fewer than 30% in each of the other socio-economic classes (Fig. 2d). While there was a gradient of increasing representation towards higher income countries from lower-middle income status, low income countries were in fact represented more than lower-middle or upper-middle income regions. These results indicate disproportionate adaptive action and research in higher income countries, with additional targeted focus on highly vulnerable low-income regions. It is not clear, however, whether this is due to a real differential in adaptation action or to differences in reporting effort among nations.

Vulnerable sub-populations were referred to in over 80% of documents reviewed (e.g. poor, landless, marginalized). Only 3% of publications, however, referred to elderly, women or children; sub-populations identified as particularly vulnerable (Costello et al., 2009; World Bank, 2010; Adger et al., 2007). Reporting of Indigenous people vulnerability was more dominant in North American adaptation reports, particularly related to Arctic or sub-Arctic populations. There were, for example, only three reports of Indigenous adaptations in Africa and only one in each of the other global regions, contrasting with 11 references to Indigenous populations in North America. Publishing on adaptations involving socio-economically disadvantaged groups was significantly higher in documents from Africa, Asia and Central and South America, consistent with the highest populations of global poor.

3.5. Adaptation profiles differ between high and low income countries

There are distinct profiles of low and high income countries reporting on adaptation. In general, low income countries are characterized by reactive adaptations in response to short-term motivations, particularly changing market conditions. Most adaptations are occurring at the individual level with weak involvement of government stakeholders, and adaptation activities are more likely to occur in natural resource sectors such as agriculture, fisheries and forestry, or the securing of food resources. Adaptations are characterized by responsive activities such as avoiding or retreating, coping or accommodating, adjusting, spreading risk, and securing income or resources. Adaptation mechanisms are more likely to include community-level mobilization rather than institutional, governmental or policy tools.

In contrast, high income countries are characterized by more proactive or anticipatory adaptations stimulated by longer-term climatic changes such as temperature and sea level rise. Adaptations are more likely to include governmental participation, and involve non-resource sectors such as infrastructure and transportation. Adaptations are characterized by longer-term planning activities such as preparation for projected impacts, monitoring, increasing awareness, building partnerships, and enhanced learning or research. Institutional, governmental, and guideline-based mechanisms are more commonly reported for adaptations in high income countries.

Middle income countries (lower middle and upper middle) have a mixed profile of adaptations which does not support aggregate characterization, but are generally more similar to low income countries. Adaptations are, for example, more likely to be reactive and involve natural resource-based sectors.

4. Discussion

The majority of research on adaptation in the climate change field has focused on theorizing how human systems might or can adapt to climate change, examined the possibility for adaptation, or created inventories or wish lists of policy entry points (Barnett,

2010). This is reflected in the adaptation related chapters of the IPCC (e.g. chapters 17–19 and regional chapters). Fewer studies have systematically examined if and how adaptation is taking place. Exceptions include Tompkins et al. (in press) who review the experience of adaptation in the UK based on peer reviewed and 'grey' literature, defining adaptation in its broadest sense to include not only specific actions but also intentions to act and research. Alternatively, Arnell (2010) characterizes what we know about adaptation by reviewing all adaptation related articles in the journal *Climatic Change* to provide a snapshot of current understanding and characterize key research trends. Our approach is more expansive than Arnell (2010) in terms of the literature searched but more focused than Tompkins et al. (in press). While including grey literature would improve the depth of insights it would add considerable time and complications for a global scale analysis. Herein, a key strength of the methodology is its ability to produce a rapid, standardized, and transparent assessment of knowledge on a particular area of climate change: the kind of assessment promoted by Hulme (2009) and Ford and Pearce (2010) as necessary to compliment the more time consuming IPCC process.

Another key differentiation between this review and others is that our analysis is guided by a specific question: Are we adapting? The methodology is systematically designed to answer this question through statistical analysis of the literature and using adaptation reporting as a proxy for adaptation action. This compares with other literature reviews, including IPCC, which typically seek to establish what we know about a topic in general. Herein, our definition of adaptation is narrow and was aimed to test if actual adaptations are being implemented. As we argue in this discussion, while research initiatives and programs can be thought of as adaptation there is limited evidence, as yet, to indicate that more research will inevitably result in adaptation taking place, specifically in developing nations where findings may not be adequately translated to stakeholders or stakeholders may not have the ability to implement recommendations (Lornezoni et al., 2007; Head, 2010). The use of a survey to apply to each article is also novel to our approach, and enabled us to test for associations and characterize trends over time.

The review represents a proxy sample of published adaptations in the peer-reviewed English literature. We do not evaluate success, appropriateness, or durability of adaptations. The identification of a bias towards Anglophone countries indicates that adaptations in non-Anglophone countries are not being reported as frequently in the English-language literature. This has implications for global sharing of best-practice experiences and research, particularly given the use of English as the language of choice for global climate change discourse via IPCC. Comprehensive evaluation of multi-lingual literatures would provide insight into the role of language in affecting adaptation reporting.

Individual documents in many cases include reference to multiple categories for numerous variables and the resulting non-cumulative format of the variables means that statistical and causal associations are less likely and less reliable. The results should thus be considered tentative, representing a pilot study of a systematic review based approach for tracking adaptation. Many adaptations will be undocumented or documented outside of the peer-reviewed literature, while others will have taken place outside the sample timeframe of 2006–2009. These results represent a proxy sample or indicator of human adaptation, and must be validated by developments in adaptation assessment.

As we note in Section 1, generalizations concerning the question, are we adapting, abound in the literature. Here we statistically examine these generalizations. Our analysis supports some conclusions while questioning others. Limited reporting of adaptation actions in the literature is consistent with and adds

insight to the ‘adaptation deficit’ thesis (Adger and Barnett, 2009; Burton and May, 2004; Barnett, 2010). The deficit is not necessarily a lack of research: 1741 peer reviewed articles on adaptation have been published between 2006 and 2009. This scholarship, however, does not appear to be translating into adaptation actions at present, although it is noteworthy that between 2006 and 2009 reporting on adaptation actions increased. The data support the need for critical examination of how research is influencing or linking to the policy process (Vogel et al., 2007; Hulme, 2008), specifically claims that increased research on impacts, adaptation, and vulnerability are needed for adaptation interventions. As research in the hazards field demonstrates, more and/or improved research does not necessarily translate into policy intervention (White et al., 2001).

This research supports the contention that adaptation takes place in response to multiple stimuli – not just climate – reinforcing the importance of ‘mainstreaming’ or ‘no-regrets adaptation’ (Dovers, 2009). This is consistent with Tompkins et al. (in press) in their systematic review of adaptation in the UK, and further challenges the framing of international adaptation support provided through the Framework Convention on Climate Change (FCCC) with its focus on funding adaptations specifically associated with attributable climate change burden, i.e. additionality (Pielke et al., 2007; Burton and May, 2004). Particularly for low income nations, adaptation interventions need to have multiple climatic and non-climatic benefits to be supported by local to national stakeholders (Dovers, 2009).

The dominance of purposive/anticipatory adaptation is surprising and challenges conventional thinking, although such planning is largely limited to developed nations. This is a significant development: Gagnon-Lebrun and Agrawala (2007), reviewing National Communications to the FCCC in 2007, document *intentions* to adapt but limited *actions* in developed nations. Anticipatory adaptations are typically government led, and are particularly important in light of the prevalence of reactive adaptations identified in other sectors noted in this and other studies (Ford et al., 2010; Marshall, 2010; IPCC, 2007). The data support the belief that adaptation is an increasingly important component of climate policy at a national level (Parry et al., 2009; Tompkins et al., in press) spurred on by the widely recognized inevitability of climate change (Ramanathan and Feng, 2008), experience of impacts to-date, and completion of national level vulnerability and adaptation studies in a number of nations (e.g. UK, US, and Canada) (Tompkins et al., in press).

It is generally understood that adaptation will be more problematic with more rapid climate changes. This review, however, indicates that more dramatic climate-related stimuli – such as extreme weather events and increasing variability – are important for motivating adaptation responses in human systems. This is not to imply that adaptations are more likely to be successful with rapid change. What we hypothesize is that more dramatic and observable change acts as an ‘availability heuristic’ (Tversky and Kahneman, 1974) providing readily observable ‘evidence’ that the climate is changing. This is particularly important given the nature of climate change which has been described as a ‘hidden’ or ‘creeping’ hazards problem, involving slowly progressing, long-term and difficult to detect changes with invisible causes, the full dimensions of which will not be experienced for decades (Lorenzoni et al., 2005; Kasperson and Kasperson, 1991; Moser, 2005). The lack of immediacy of such creeping problems typically constrains policy action. Extreme events, however, as personally experienced and translated through the media, increase the saliency of climate change risks to the public and policy makers, challenge the assumption that human systems are insulated from nature, and increase the likelihood of adaptive action (Lorenzoni and Hulme, 2009; Moser, 2010).

Indeed, in their review of adaptation in the UK, Tompkins et al. (in press) similarly identify real or perceived climate change as the main motivator for adaptation.

The geographic distribution of adaptation action challenges the traditional north–south dichotomy which often captures climate change discourse. While low income countries are underrepresented in adaptation reporting, there are interesting anomalies including more reporting from Africa than North America, and considerable variation among nations *within* global regions. The adaptation deficit appears to be significant in middle-income nations who often have similar vulnerability profiles to low income countries but do not have access to adaptation funds through the FCCC. Nevertheless, differences in the types of adaptations between north and south are indicative of unequal adaptive capacity. Thus high income countries are more likely to be investing in proactive adaptations coordinated at a government level, which are expected to be more effective than the reactive responses common in low income nations (Stern, 2006; Costello et al., 2009; IPCC, 2007).

Examination of how adaptation is taking place reveals a number of key areas that are not being reported on. There are few reported adaptations being developed to take advantage of new and projected climate regimes, a key component of adaptation. This is consistent with predominance of scientific research focusing on the negative effects of climate change (IPCC, 2007). More importantly, while the majority of reports make reference to vulnerable populations, there is significant under-reporting on women, elderly, children, and non-Arctic Indigenous populations. This is a particular concern in light of ageing populations in the developed world (and hence increasing vulnerability to many climate risks), rapidly growing young population in many developing nations (Smith et al., 2009; Costello et al., 2009), and often heightened vulnerability among women and Indigenous peoples (Costello et al., 2009; IPCC, 2007; Ford et al., 2010).

5. Conclusion

Reviewing and characterizing the peer reviewed English literature offer a rigorous and standardized means of characterizing what we know about climate change adaptation. IPCC offers a review-based methodology to guide analysis, involving an extensive assessment of current knowledge based on input and review by experts. The merits of the IPCC are widely acknowledged, although the transparency of the process has been questioned: what literature is reviewed by IPCC? What search terms and databases were used to select relevant literature? How many articles were included in the analysis? Which articles were excluded and why? This opacity challenges a fundamental tenet of peer reviewed science – the ability to replicate studies to challenge and test interpretation. Systematic literature reviews common in the health sciences offer an alternative review model involving full disclosure of the search process and utilization of both quantitative and qualitative techniques to characterize current knowledge. Here we develop such an approach to track adaptation action, noting that the method offers considerable promise for other areas of climate change research. Our results offer preliminary insights on how adaptation is taking place. We have much to learn from what we are – and are not – doing, supporting the need for increased scrutiny of global adaptation.

Acknowledgements

Our thanks to two anonymous reviewers for constructive and insightful comments.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2010.09.012.

References

- Adger, W.N., Agrawala, S., Mirza, M.M.Q., et al., 2007. Assessment of adaptation practices, options, constraints and capacity. In: Parry, M.L., Canziani, O.F., Palutikof, J.P. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.
- Adger, W.N., Barnett, J., 2009. Four reasons for concern about adaptation to climate change. *Environ. Plann. A* 41, 2800–2805.
- Adger, W.N., Vincent, K., 2005. Uncertainty in adaptive capacity. *C.R. Geosci.* 337, 339–410.
- Arnell, N.W., 2010. Adapting to climate change: an evolving research programme. *Clim. Change* 100.
- Barnett, J., 2010. Adapting to climate change: three key challenges for research and policy—an editorial essay. *WIREs – Clim. Change* 9999.
- Belanger, D., Berry, P., Bouchet, V., et al., 2008. In: Seguin, J. (Ed.), *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity*. Health Canada, Ottawa.
- Berkhout, F., 2005. Rationales for adaptation in EU climate change policies. *Clim. Policy* 5, 377–391.
- Burton, I., 2006. Adapt and thrive: options for reducing the climate-change adaptation deficit. *Policy Options* 32–38 (December 2005–January 2005).
- Burton, I., Huq, S., Lim, B., et al., 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Clim. Policy* 2, 145–159.
- Burton, I., May, E., 2004. The adaptation deficit in water resource management. *IDS Bull.: Inst. Dev. Stud.* 35, 31–.
- Costello, A., Abbas, M., Allen, A., et al., 2009. Managing the health effects of climate change. *Lancet* 373, 1693–1733.
- Dovers, S., 2009. Normalizing adaptation. *Glob. Environ. Change: Hum. Policy Dimens.* 19, 4–6.
- Dovers, S., Hezri, R., 2010. Institutions and policy processes: the means to the ends of adaptation. *WIREs: Clim. Change* 1, 212–231.
- Ebi, K.L., Semenza, J.C., 2008. Community-based adaptation to the health impacts of climate change. *Am. J. Prev. Med.* 35, 501–507.
- Ford, J., Kesikitalo, E.C.H., Smith, T., et al., 2010a. Case study and analogue methodologies in climate change vulnerability Research. *WIREs – Clim. Change* 1 (3), 374–392.
- Ford, J.D., Pearce, T., 2010. What we know, do not know, and need to know about climate change vulnerability in the western Canadian Arctic: a systematic literature review. *Environ. Res. Lett.* 5, doi:10.1088/1748-9326/5/1/014008.
- Ford, J.D., Pearce, T., Prno, J., et al., 2010c. Perceptions of climate change risks in primary resource use industries: a survey of the Canadian mining sector. *Reg. Environ. Change* 10, 65–81.
- Ford, J., Berrang-Ford, L., Furgal, C., et al., 2010b. Vulnerability of aboriginal health systems in Canada to climate change. *Glob. Environ. Change* 20, 177–191, doi:10.1016/j.gloenvcha.2009.10.008.
- Fussler, H.M., 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustain. Sci.* 2, 265–275.
- Fussler, H.M., 2009. An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. *Clim. Change* 97, 469–482.
- Gagnon-Lebrun, F., Agrawala, S., 2007. Implementing adaptation in developed countries: an analysis of progress and trends. *Clim. Policy* 7, 392–408.
- Garnaut, R., 2008. *The Garnaut Climate Change Review*. Cambridge.
- Head, L., 2010. Cultural ecology: adaptation - retrofitting a concept? *Progress in Human Geography* 34 (2), 234–242.
- Hulme, M., 2003. Abrupt climate change: can society cope? *Philos. Trans. R. Soc. Lond. Ser. A: Math. Phys. Eng. Sci.* 361, 2001–2019.
- Hulme, M., 2008. Geographical work at the boundaries of climate change. *Trans. Inst. Br. Geogr.* 33, 5–11.
- Hulme, M., 2009. Mapping climate change knowledge: an editorial essay. *WIREs: Clim. Change* 1.
- IPCC, 2001. *IPCC Third Assessment Report (TAR): Climate Change 2001. Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.
- IPCC, 2007. *IPCC Fourth Assessment Report (AR4): Climate Change 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.
- Jasco, P., 2005. As we may search – comparison of major features of the Web of Science, Scopus, and Google Scholar citation-based and citation-enhanced databases. *Curr. Sci.* 89, 1537–1547.
- Karl, T.R., Melillo, J.M., Peterson, T.C., 2009. *Global Climate Change Impacts in the United States*. Cambridge University Press.
- Kasperson, R.E., Kasperson, J.X., 1991. Hidden hazards. In: Mayo, D.G., Hollander, R.D. (Eds.), *Acceptable Evidence: Science and Values in Risk Management*. Oxford University Press, New York.
- Lemmen, D., Warren, F., Lacroix, J., et al., 2008. *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Government of Canada, Ottawa.
- Lorenzoni, I., Hulme, M., 2009. Believing is seeing: laypeople's views of future socio-economic and climate change in England and in Italy. *Public Underst. Sci.* 18, 383–400.
- Lorenzoni, I., Pidgeon, N.F., O'Connor, R.E., 2005. Dangerous climate change: the role for risk research. *Risk Anal.* 25, 1387–1398.
- MA, 2006. *Millennium Ecosystem Assessment*.
- Marshall, N.A., 2010. Understanding social resilience to climate variability in primary enterprises and industries. *Glob. Environ. Change: Hum. Policy Dimens.* 20, 36–43.
- Moser, S.C., 2005. Impact assessments and policy responses to sea-level rise in three US states: an exploration of human-dimension uncertainties. *Glob. Environ. Change: Part A* 15, 353–369.
- Moser, S.C., 2010. Communicating climate change: history, challenges, process and future directions. *WIREs: Clim. Change* 1, 31–53.
- Moss, R.H., Edmonds, J.A., Hibbard, K.A., et al., 2010. The next generation of scenarios for climate change research and assessment. *Nature* 463, 747–756.
- O'Brien, K., Eriksen, S., Sygna, L., et al., 2006. Questioning complacency: climate change impacts, vulnerability, and adaptation in Norway. *Ambio* 35, 50–56.
- Parry, M., Lowe, J., Hanson, C., 2009. Overshoot, adapt and recover. *Nature* 458, 1102–1103.
- Pearce, T., Ford, J., et al., 2010. *Advancing Adaptation Planning for Climate Change in the Inuvialuit Settlement Region (ISR): A Literature Review and Gap Analysis. Regional Environmental Change*. doi: REC-D-09-00082R1. In Press. (On-line ahead of print).
- Petticrew, M., Roberts, H., 2006. *Systematic Reviews in the Social Sciences: A Practical Guide*. Blackwell Publications, Oxford, Malden, MA.
- Pielke, R.A., 1998. Rethinking the role of adaptation in climate policy. *Glob. Environ. Change: Hum. Policy Dimens.* 8, 159–170.
- Pielke, R.A., Prins, G., Rayner, S., et al., 2007. Climate change 2007: lifting the taboo on adaptation. *Nature* 445, 597–598.
- Ramanathan, V., Feng, Y., 2008. On avoiding dangerous anthropogenic interference with the climate system: formidable challenges ahead. *Proc. Natl. Acad. Sci. U.S.A.* 105, 14245–14250.
- Repetto, R., 2009. *The Climate Crisis and the Adaptation Myth*. WP 13. School of Forestry and Environmental Studies. Yale University, New Haven, CT.
- Smit, B., Burton, B., Klein, R.J.T., et al., 2000. An anatomy of adaptation to climate change and variability. *Clim. Change* 45, 223–251.
- Smit, B., Burton, I., Klein, R.J.T., et al., 1999. The science of adaptation: a framework for assessment. *Mitig. Adapt. Strateg. Glob. Change* 4, 199–213.
- Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Change: Hum. Policy Dimens.* 16, 282–292.
- Smith, J.B., Schneider, S.H., Oppenheimer, M., et al., 2009. Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern". *Proc. Natl. Acad. Sci. U.S.A.* 106, 4133–4137.
- Stern, N., 2006. *Stern Review on the Economics of Climate Change*. HM Treasury, London, UK.
- The Cochrane Collaboration, 2008. *Cochrane Handbook for Systematic Reviews of Interventions*.
- Tompkins, E., Adger, W.N., Boyd, E., et al., in press. Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Glob. Environ. Change*.
- Tversky, A., Kahneman, D., 1974. Judgment under uncertainty – heuristics and biases. *Science* 185, 1124–1131.
- Vogel, C., Moser, S.C., Kasperson, R.E., et al., 2007. Linking vulnerability, adaptation, and resilience science to practice: pathways, players, and partnerships. *Glob. Environ. Change: Hum. Policy Dimens.* 17, 349–364.
- White, G.F., Kates, R.W., Burton, I., 2001. Knowing better and losing even more: the use of knowledge in hazards management. *Glob. Environ. Change: Part B – Environ. Hazards* 3, 81–92.
- World Bank, 2010. *World Development Report – Development and Climate Change*. World Development Report, Washington, DC.