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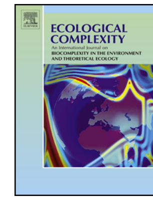

Original research article

Assessment of the historical environmental changes from a survey of local residents in an urban–rural catchment☆

Goro Mouri [a,*], Seirou Shinoda [b], Taikan Oki [c]

[a] Institute of Industrial Science (IIS), The University of Tokyo, Be505, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
[b] Information and Multimedia Center, Gifu University, 1-1 Yanagido, Gifu City 501-1193, Japan
[c] Institute of Industrial Science (IIS), The University of Tokyo, Be607, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan

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A B S T R A C T

When attempting to address the environmental problems of a catchment, it is important to consider changes in a long-term environmental context. However, the long-term data on the state of the environment that are required for such an examination are rarely documented. Such data collection typically requires several years of investigation and observation. In addition, as there may be a significant time lag between the occurrence of a phenomenon and its cause, subsequent environmental investigations of changing animal and plant states scaling up to 5 years may be inadequate. We conducted a long-term analysis of the environmental changes in five sub-catchments of the Nagara River, Japan, assessing a period of 30 years, using a questionnaire survey approach involving local communities. Four sub-catchments of the Yoshida River were also analyzed for comparison. In addition, we attempted to clarify the relationship between various environmental factors and the space–time response of animals and plants. The survey included eight topics: assumed information, hydrological characteristics, habitat conditions for living things, forest state, land cover conditions, river awareness, free-entry information, and respondent information. Our method also has academic significance in that it validates the environmental agent extraction technique using a questionnaire survey. Our results identify management strategies for minimizing biodiversity loss due to climate change. Forest management and human activities should be undertaken with care, and the environmental context going forward into the next century should be considered for integrated catchment management. Elsewhere, reduced greenhouse gas emissions, a much expanded network of protected areas, and/or efforts to provide corridors to ease species movements may be necessary at the global level.

1. Introduction

Many living things from around the world are on the verge of extinction. According to the International Union for Conservation of Nature (IUCN) Red List (Rodrigues et al., 2006; Currey et al., 2009; Szabo et al., 2012;), 8782 species of animals and 8509 species of plants are in danger of extinction. In Japan alone, 3155 species are in danger of extinction (Szabo et al., 2012; Miller, 2013).

Long-term observations and model projections indicate that freshwater ecosystems are highly vulnerable to and directly affected by climate change (Meyer et al., 1999; Oki and Kanae, 2006; Scholze et al., 2006; Fischlin et al., 2007; Bates et al., 2008; Susan and Lawrence, 2008; Moss et al., 2009; Mouri and Oki, 2010; Mouri et al., 2010a, 2012a, 2013a,b,c,d). Even with restrictive policies on greenhouse gas emissions, there is a strong possibility that the global mean temperature could rise by more than 2 °C (Allen et al., 2009). Furthermore, the impact on freshwater ecosystems may be exacerbated by other human pressures including habitat loss, pollution, and invasive species (Angold et al., 2006; Millennium Ecosystem Assessment, 2005). This has led some to conclude that policies aimed at preventing such changes are urgently required (Falloon and Betts, 2009; Parry et al., 2009). Despite growing calls for action, the scientific community still has relatively little to say about how to prepare freshwater ecosystems for climate change (Ormerod, 2009). To date, most efforts have been piecemeal and have focussed on gathering evidence of trends in physical drivers and biological impacts. Anticipated changes in thermal and hydrological regimes include higher water temperatures, longer ice-free seasons, increased water body stratification, earlier snowmelt, more extreme floods and droughts, increased

* Corresponding author. Tel.: +81 3 5452 6382.
E-mail address: mouri@rainbow.iis.u-tokyo.ac.jp (G. Mouri).

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sediment and nutrient transport, lower dissolved oxygen, and increased salinity (Andersen et al., 2006; Kundzewicz et al., 2007; Whitehead et al., 2009a,b; Mouri et al., 2010b, 2011a,b,c). Biological effects include changes in species physiology, phenology, dispersal, predation, and ultimately changes in ecosystem structure, productivity, and nutrient cycling (Markus, 2010; Pekka et al., 2009; Wilby, 2008; Mouri and Oki, 2010; Mobaied et al., 2012; Baral et al., 2013; Mouri et al., 2013d). Potential outcomes have been reviewed for groups of organisms such as phytoplankton (Thackeray et al., 2008), invertebrates (Durance and Ormerod, 2007), amphibians (Araújo et al., 2006), macrophytes (Franklin et al., 2008), fish (Attila et al., 2010; Graham and Harrod, 2009), and aquatic birds (Poiani, 2006). Others have provided useful syntheses of climate impacts for landscape units such as the coastal zone (Richards et al., 2008), wetlands (Harrison et al., 2008), uplands (Orr et al., 2008), glacier-fed rivers (Milner et al., 2009), lowland rivers (Johnson et al., 2009), lakes (Mooij et al., 2005), and for aquatic ecosystems more generally (Heino et al., 2009; Palmer et al., 2009; Wade, 2006).

Thorough appraisals of climate drivers and ecological responses are traditionally seen as important first steps towards developing adaptive management strategies for freshwater and pollution load, and concerns about the sustainability of some environmental policies have provided further impetus for research (Birch and McCready, 2009; Georgios et al., 2003; Hans, 2010; Ingram, 2008; Whitalla et al., 2004; Mouri et al., 2012a). Across Europe, there is growing recognition that the objectives and programmes of the European Union (EU) Water Framework Directive (WFD) and EU Habitats Directive are potentially climate-sensitive (Wilby et al., 2006). Although it is generally accepted that adapting to climate change involves rejecting basic assumptions about static conditions (which until recently have underpinned flood, water, and conservation management efforts), opinion is divided on how best to move forward (Milly et al., 2008; Mouri et al., 2011c). Others are asking more generally how biodiversity policies and management practices might be modified and implemented to address the impacts of climate change (Beiera et al., 2006; Hovardas and Poirazidis, 2007; Sutherland et al., 2006, 2009; Collins, 2009; Wamelink et al., 2009).

2. Objective

Although home to approximately 1 million people, the Nagara River catchment has robust biodiversity, pure and rich water resources, and is a major limpid river in Japan. However, while the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) water-quality values of the Nagara River and its tributaries are good, other aspects of the catchment environment seem to be worsening, based on observations including a sharp decrease in freshwater fish such as *Plecoglossus altivelis altivelis* (Mouri et al., 2010a). Local residents have voiced their increasing concern about the degradation of the Nagara River valley environment in the past 10 years. The establishment of a scientific technique that can evaluate the health of the catchment has become a pressing need. When attempting to address the environmental problems of a catchment, it is important to consider changes in a long-term environmental context. However, the long-term data on the state of the environment that are required for such an examination are rarely documented. Such data collection typically requires several years of investigation and observation. In addition, as there may be a significant time lag between the occurrence of a phenomenon and its cause, subsequent environmental investigations of changing animal and plant states scaling up to 5 years may be inadequate. We conducted a long-term analysis of the environmental changes in five sub-catchments of the Nagara River, Japan, assessing a period of 30 years, using a questionnaire survey approach involving local communities (Fig. 1). In addition, we attempted to clarify the relationship between various environmental factors and the space–time response of animals and plants.

The purpose of the questionnaire was to clarify the relationship between changing habitat characteristics and environmental factors. In survey-based studies, questionnaires are typically mailed to candidate participants selected at random using resident cards or other similar forms of information and then the investigator(s) await a reply. However, this requires time and significant cost. Furthermore, the recovery rate averages about 50%, which is usually not adequate. Therefore, we sent our questionnaire to children (elementary school, grades 4–6), students (junior high school, grades 1–3), and their guardians in

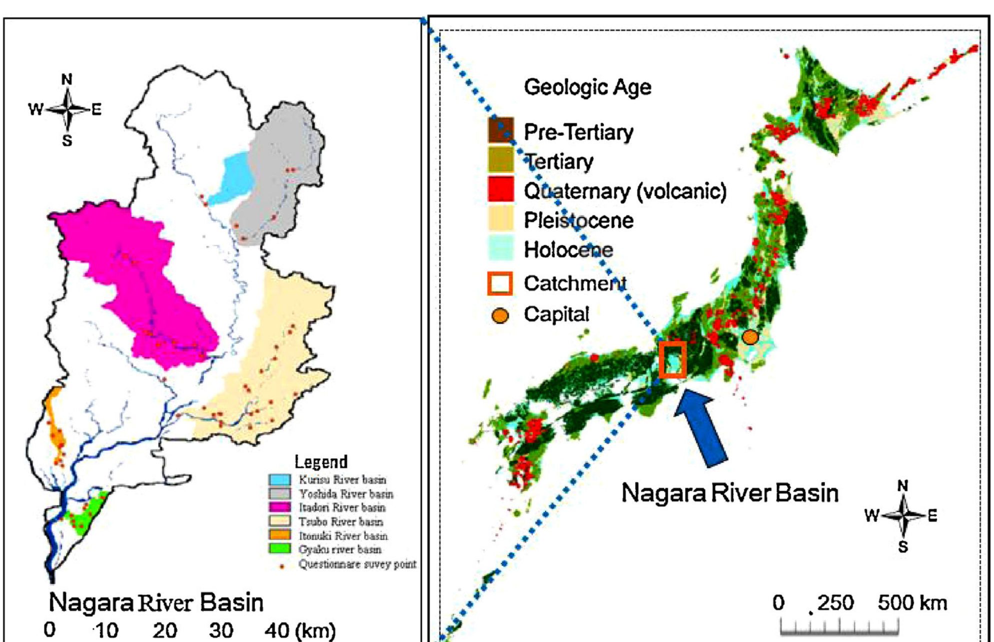

Fig. 1. The distribution of the sub-catchment in the Nagara River Basin, and questionnaire survey of cooperating elementary and junior high schools.