Journal of Agriculture and Ecology Research International
9(3): 1-10, 2016; Article no.JAERI.28293
ISSN: 2394-1073

SCIENCEDOMAIN ***international***
www.sciencedomain.org

River Ecosystem and Floristic Characterization of Riparian Zone at the Backcheon River, Sacheon-ci, Korea

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JAERI/2016/28293
Editor(s):
(1) Chandra Shekhar Kapoor, Department of Environmental Sciences, University College of Science, Mohan Lal Sukhadia University, India.
Reviewers:
(1) Aristeidis Mertzanis, Central Greece University of Applied Sciences, Karpenisi, Greece.
(2) Ender Makineci, Istanbul University, Turkey.
(3) Martin Potgieter, University of Limpopo, South Africa.
Complete Peer review History: http://www.sciencedomain.org/review-history/16151

Original Research Article

Received 13th July 2016
Accepted 31st August 2016
Published 11th September 2016

ABSTRACT

Environmental conservation is an interdisciplinary program that covers a variety of ecological systems and their interrelationships, including those with human society, plants, and animals. This study is to investigate the degree of environmental factors and the flora on the Backcheon River at three regions during four seasons. The low water's edge vegetation and flood way vegetation in this river were naturally formed a variety of vegetation communities. Land use in riparian zones at upper area of the Backcheon River was partly bush or grassland as natural floodplain. Whereras, land uses in riparian zones river levee at middle and low areas were arable land, urban, residential mixed. The BOD was within acceptable levels. The application of the Braun-Blanquet approach for plant classification in this area is presented in the article. According to the existing phytosociological data, 28 families, 63 genera, 69 species, 10 varieties, 22 associations, and 15 communities have been identified. Naturalized plants at the upper, middle, and low areas were 6, 14, and 17 species, respectively. Awareness of current conditions and relationships between land uses and resource goals is essential for successful restoration of riparian systems.

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Keywords: Environmental factors; flora; Backcheon River; vegetation communities.

1. INTRODUCTION

Plant communities are classified through a process of interaction between a phytosociologist and vegetation [1]. Similar plant communities appear in similar biotopes at a number of points in the landscape. The riparian zone is the place where aquatic systems merge with the terrestrial environment. Riparian vegetation has a particular structural function and is found a predictable distance from the river channel. The relationship between riparian forest and the river is important. It provides a number of benefits to aquatic and terrestrial habitat and the species that live there. Within the riparian area itself, further sources of variation can be found in channel morphology, sediment dynamics, and floodplain structure. Ultimately, all these factors influence species composition of riparian biota. Riparian vegetation is an ubiquitous feature of riverine landscapes that provides habitat and food sources, as well as some degree of erosion control [2]. Thus, riparian vegetation is increasingly being recognized for its importance in influencing the hydrology and morphology of fluvial systems [3].

Riparian lands can also include intermittent streams gullies and dips which sometimes run with water [4]. The riparian zone has been defined in various ways but is always inextricably linked to standing or flowing water bodies. A commonly used definition is that riparian zone is the area immediately alongside small creeks and rivers, including the river bank itself; gullies and dips which sometimes run with water; areas surrounding lakes; and wetlands and river floodplains which interact with the river in times of flood [5]. Riparian zones are characterized by a suite of vegetation that is tolerant of the physical conditions typically found in the riparian zone, including increased soil moisture, physical disturbance by flooding, and the gradient that occurs with distance from the water body [5]. The structure and function of stream ecosystems is largely determined by adjacent riparian vegetation [6]. Minshall [7] noted the strong association between stream macro-invertebrates and terrestrial biomes.

The Backcheon River is started at Waryong Mountain (801.4 m) and ends at the Pacific Ocean. Probably one of the most important roles of riparian vegetation in this river is as a buffer between terrestrial activities and aquatic ecosystems. Apart from being a crucial ecosystem linking the land and ocean systems, the Backcheon River serves as a prominent geological agent in the temperate regions. The water budget of all streams and rivers is determined by climate and by other watershed attributes such as topography, soil type, bedrock substrata, groundwater discharge, and vegetation. A river system comprises the whole river corridor—the river channel, riparian zone, floodplain, and alluvial aquifer. The river was divided into three regions: upper, middle, and low regions. The purpose of this study is to investigate river morphology and the flora on the Backcheon River at three regions if the three regions were different river naturality (river ecosystem) and floristic characterization. Therefore, it is only necessary for these indicators to demonstrate an appropriate trajectory towards the intended reference ecosystem condition.

2. MATERIALS AND METHODS

2.1 Surveyed Regions

This study was carried out on the Backcheon River, located at Yonghyeon-myeon province (upper region: 34°977′088″N/128°083′815″E, low region: 35°055′262″N/128°042′942″E), Sacheon-ci in Korea (Fig. 1). Located to the northern east of the city of Sacheon-ci, the Backcheon River is approximately 4.18 kilometers in length with a varying width of between 4.4 and 21.8 meters. The flora and vegetation on the Backcheon River were investigated at three regions and adjacent areas during four seasons. 20 sites (plots) at each region were randomly chosen for each combination of site x region, so that, overall, 60 sites were sampled for the complete experiment. The quadrat sizes were 1 m x 1 m for herbs and 5 m x 5 m for trees.

2.2 Floristic Analysis

All plants of riparian vegetation were sampled in the field for the purpose of identification. The system of plant classification system was followed by Lee [8]. Naturalized plants were followed by Korea National Arboretum [9]. Abundance and cover degree are usually estimated together in a single combined estimation or cover-abundance scale from Braun-Blanquet [10]. In order to relate the model to the field situation in which usually Braun-Blanquet figures are recorded, the % occupancy figures were transformed in to the ordinal transform scale from 1 (one or few individuals) to 9 (75~100% cover of total plot area, irrespective of number of individuals) [11]. The relative net contribution degree (r-NCD) was obtained by summing up the NCD values for those species belonging to particular taxa under consideration [12].

2.3 Index of Degree of River Structure

The three regions of Backcheon River were divided by the geographic location with considering length of the river. Index of degree of river naturality according to the environment of river was also analyzed according to Table 1. River terminology was followed by Hutchinson [13]. The test for biochemical oxygen demand (BOD) is a bioassay procedure that measures the oxygen consumed by bacteria from the decomposition of organic matter [14]. The change in DO (dissolved oxygen) concentration is measured over a given period of time in water samples at a specified temperature. The method for BOD was used to a standard method of the American Public Health Association (APHA) and is approved by the U.S. Environmental Protection Agency (USEPA) [15].

Table 1. Index of degree of river naturality according to the environment factors

Item	Estimated index and scores				
	1	2	3	4	5
The low water's edge vegetation	Naturally formed a variety of vegetation communities	Naturally formed various vegetation communities by natural erosion (sediment exposure) were absent	Natural weeds, shrubs, and mixed	Artificial vegetation composition	Vegetation blocked by stonework etc.
Flood way vegetation	Naturally formed a variety of vegetation communities	Naturally formed various vegetation communities by natural erosion (sand bar) were absent	Both of natural vegetation and artificial vegetation	Artificial vegetation with Parks, lawns, and so on	Remove vegetation artificially
Land use in riparian zones within river levee	Bush or grassland as natural floodplain	Arable land (paddy fields, orchards)	Arable land, urban, residential mixed	About 1/2 urban, residential mixed	1/2 or more urban, residential
Land use in flood plains beyond river levee	State of nature without artificial vegetation, manmade structures	Arable land or artificial vegetation	Artificial vegetation or natural vegetation mixed	About 1/2 park facilities, playground facilities	Impervious man-made structures, parking, etc.
Transverse direction of artificial structures	Absent	Bypass reservoir or slope waterway reservoir	Fish migration reservoir	Reservoir of height 0.3-0.4 m, fish migration difficulty	Fish move completely blocked
Water quality (BOD)	Class 1 (crystal clear)	Class 2 (clear relatively)	Class 3 (tan, the bottom green algae)	Class 4 (blackish brown, the floor is not looked)	Class 5 (an ink color, odor)
Sleep width /river width ratio	20% or more	20 ~ 10%	10 ~ 5%	5 ~ 1%	Less than 1%

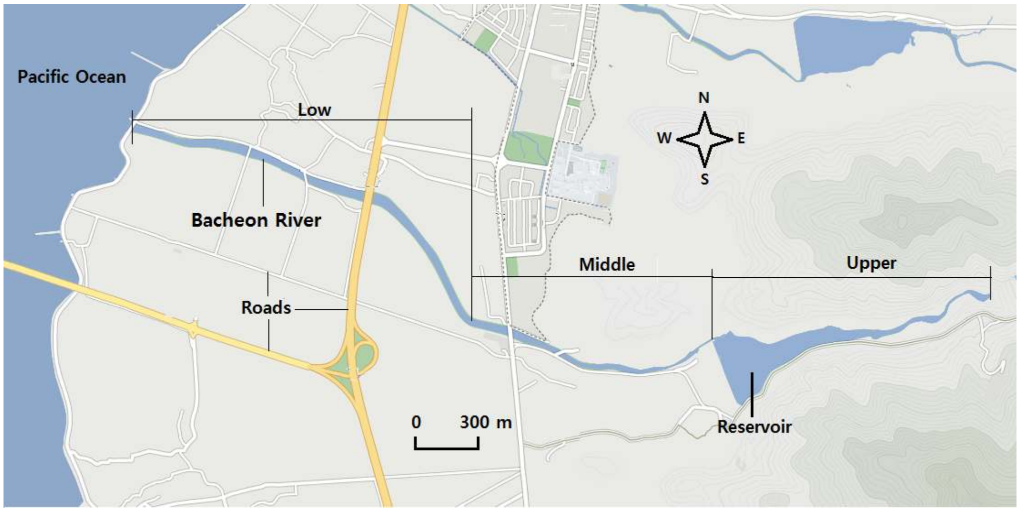

Fig. 1. Location of the study area and the three detailed internodes at the Backcheon River

3. RESULTS

3.1 Upper Region (Upstream)

The river width at this region is about 4.4 m. The low water's edge vegetation and flood way vegetation were naturally formed a variety of vegetation communities (Table 2). Land use in riparian zones was partly bush or grassland as natural floodplain. Most land uses of flood plains beyond river levee were state of nature without artificial vegetation and manmade structures. Transverse direction of artificial structures was one reservoir of above height 10.0 m. Thus fish could not move completely blocked. The average value of BOD was 2.83 mg/l. The oxygen-demand parameter BOD at upper region was within acceptable levels. The ratio of sleep width/river width was 10~20%. The value for index of degree of river naturality according to the environment factors was a mean of 1.714. Near shore and riparian vegetation provides habitat for many wildlife species (Table 3). At total area, the application of the Braun-Blanquet approach for plant classification in this area is presented in the article. According to the existing phytosociological data, 28 families, 63 genera, 69 species, 10 varieties, 22 associations, and 15 communities have been identified. Left and right riparian areas at upper area were distributed Pinaceae vegetation (*Larix leptolepis, Pinus densiflora,* and *Pinus rigida*) and Fegaceae vegetation (*Quercus acutissima, Quercus dentata,* and *Quercus variabilis*). Riverbed area was dominated by *Salix gracilistyla* community. Dominant species in flood plains were *Equisetum arvense* and *Trifolium repens.* The survey region was a total of 33 taxa, including 20 families, 31 species, and two varieties. The numbers of naturalized plants were 6 species. In some cases the quantitative and qualitative levels illustrated considerably. The total transformed Braun-Blanquet value and r-NCD at upper area were 72 and 1,029, respectively.

Table 2. Estimated index and scores of river naturality according to the environment factors at the Backcheon River

Region	The low water's edge vegetation	Flood way vegetation	Land use in riparian zones within river levee	Land use in flood plains beyond river levee	Transverse direction of artificial structures	Water quality (BOD)	Sleep width /river width ratio	Mean
Upper	1[a]	1	1	1	5	1	2	1.714
Middle	3	4	3	2	1	2	2	2.429
Low	3	5	3	2	1	2	2	2.571

[a]*The scores were based on Table 1*

3.2 Middle Region (Middle-stream)

The river width at the region is about 9.5 m. The low water's edge vegetation was naturally formed weeds, shrubs, and mixed with various vegetation communities (Table 2). The flood way vegetation was artificial vegetation with parks, lawns, and so on. Land uses in riparian zones river levee were arable land, urban, residential mixed. Land use in flood plains beyond river levee was arable land or artificial vegetation. Transverse direction of artificial structures was absent. The average value of BOD was 3.04 mg/l. The oxygen-demand parameter BOD was within acceptable levels. The ratio of sleep width/river width was 10~20%. The value for index of degree of river naturality according to the environment factors was a mean of 2.429.

Left and right riparian areas were distributed Cruciferae vegetation (*Capsella bursa-pastoris*, *Capsella flexuosa*, *Lepidium apetalum*, and *Thlaspi arvense*) (Table 3). The survey region was a total of 45 taxa, including 17 families, 40 species, and 5 varieties. The numbers of naturalized plants were 14 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 88 and 1,257, respectively.

3.3 Low Region (Downstream)

The river width at the region was about 21.8 m. The low water's edge vegetation was natural weeds, shrubs, and mixed (Table 2). The flood way was removed from naturally formed vegetation. Land uses in riparian zones within river levee were arable land, urban, residential mixed. Land use in flood plains beyond river levee was arable land or artificial vegetation. Transverse direction of artificial structures was absent. The average value of BOD was 4.15 mg/l. The oxygen-demand parameter BOD was not good at low region. The ratio of sleep width/river width was 10~20. The value for index of degree of river naturality according to the environment factors was a mean of 2.571. There were occurred in *Equisetum arvense*, *Lepidium virginicum*, *Prunus serrulata* var. *spontanea* and so on (Table 3). Left and right riparian areas were distributed Polygonaceae vegetation (*Persicaria blumei, Persicaria sieboldi, Persicaria thunbergii, Rumex acetocella,* and *Rumex crispus*). Flood plains were distributed Gramineae vegetation (*Avena fatua*, *Imperata cylindrica* var. *koenigii*, and *Miscanthus sacchariflorus*). The survey region was a total of 38 taxa, including 16 families, 34 species, and 4 varieties. The numbers of naturalized plants were 17 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 95 and 1357, respectively.

4. DISCUSSION

Vegetation ecology, the study of the plant cover and its relationships with the environment, also called synecology, is a complex scientific undertaking, both regarding the overwhelming variation of its object of study in space and time, and its intricate interactions with abiotic and biotic factors. It is also a very modern science with important applications in social activities, notably nature management, in particular the preservation of biodiversity, sustainable use of natural resources, and detecting 'global change' in the plant cover of the Earth [16]. Braun-Blanquest [10] seemed to confirm the development when he stated that the essential association features should be found in a stand in order to assign it to that association [16]. The values for index of degree of river naturality according to the environment factors, Braun-Blanquet value and r-NCD were increased from upper region via middle to low region (Tables 2 and 3). Species showing the high r-NCD value in the tree community were *Larix leptolepis*, *Salix gracilistyla*, and *Castanea crenata* (Table 3). They are only found in upstream area. In addition, species showing the high r-NCD value in the naturalized species community were mainly found in middle and downstream areas. The pattern at small scales has been interpreted as evidence that native plants can competitively exclude invasive species. Large-scale patterns have been understood to result from environmental heterogeneity, among other causes [17]. The riparian communities interact with one another and adjust according to environmental conditions. Naturally formed a variety of vegetation communities upper region at the Backcheon River have changed both of natural vegetation and artificial vegetation at low region in this river. Dierschke [18] stated that the basic unit for the prodroma is the association, the rank of which is determined by the constant occurrence of at least one character-species and which is defined by its characteristic species combination. Native vegetation in the middle and low Backcheon River areas has been heavily degraded and largely replaced with exotic species. This is mainly due to clearing, increased nutrient levels and modification of flow regimes in the waterways.

Table 3. List of vascular plants and r-NCD at the Backcheon River

Family	Species	Region				r-NCD		
		Upper	Middle	Low		Upper	Middle	Low
Equisetaceae	*Equisetum arvense* L.	3	2	4		42.9	28.6	57.1
Ginkoaceae	*Ginko biloba* L.	1	1	1		14.3	0	0
Pinaceae	*Larix leptolepis* (S. et Z.) Gordon	6				85.7	0	0
	Pinus densiflora S. et Z.	3				42.9	0	0
	Pinus rigida Mill.	1				14.3	0	0
Salicaceae	*Salix gracilistyla* Miq.	4				57.1	0	0
Fegaceae	*Castanea crenata* Sieb. Et Zucc	4				57.1	0	0
Fegaceae	*Quercus acutissima* Carruth.	2				28.6	0	0
	Quercus dentata Thunb. ex Murray	2				28.6	0	0
	Quercus variabilis Blume	1				14.3	0	0
Moraceae	*Morus alba* L.		1			0	14.3	0
Cannabinaceae	*Humulus japonicus* S. et Z.	2				28.6	0	0
Polygonaceae	*Persicaria blumei* Gross		5	4		0	71.4	57.1
	Persicaria sieboldi Ohki			4		0	0	57.1
	Persicaria thunbergii H. Gross		2	5		0	28.6	71.4
	Polygonum aviculare L.		3			0	42.9	0
	Rumex acetocella L.		3	4	NAT	0	42.9	57.1
	Rumex acetosa L.	2				28.6	0	0
	Rumex conglomeratus Murr.	2	3	4	NAT	28.6	42.9	57.1
	Rumex crispus L.		3	4	NAT	0	42.9	57.1
Chenopodiaceae	*Chenopodium album* var. *centrorubrum* Makino		1	1		0	14.3	14.3
	Chenopodium ficifolium Smith			1	NAT	0	0	14.3
Amaranthaceae	*Amaranthus lividus* L.		1		NAT	0	14.3	0
Phytolaccaceae	*Phytolacca americana* L.			1	NAT	0	0	14.3
Ranunculaceae	*Ranunculus chinensis* Bunge		2	2		0	28.6	28.6
	Ranunculus japonicus Thunb.		1	2		0	14.3	28.6
Cruciferae	*Capsella bursa-pastoris* (L.) Medicus		2			0	28.6	0
	Capsella flexuosa With.		3			0	42.9	0
	Lepidium apetalum Willd.		3		NAT	0	42.9	0

Family	**Species**	**Region**				**r-NCD**		
		Upper	**Middle**	**Low**		**Upper**	**Middle**	**Low**
	Lepidium virginicum L.			3	NAT	0	0	42.9
	Rorippa indica (L.) Hiern	2				28.6	0	0
	Thlaspi arvense L.		2	2	NAT	0	28.6	28.6
Rosaceae	*Agrimonia pilosa* Ledeb.	1				14.3	0	0
	Potentilla fragarioides var. *major* Max.	2				28.6	0	0
	Prunus serrulata var. *spontanea* (Max.) Wils.			1		0	0	14.3
	Rosa multiflora Thunb.	2				28.6	0	0
Leguminosae	*Amorpha fruticosa* L.	2	2		NAT	28.6	28.6	0
	Amphicarpaea edgeworthii var. *trisperma* Ohwi		3			0	42.9	0
	Astragalus sinicus L.		1		NAT	0	14.3	0
	Kummerowia striata (Thunb.) Schindl.		2	3		0	28.6	42.9
	Pueraria thunbergiana Benth.	5				71.4	0	0
	Trifolium pratense L.		2	2	NAT	0	28.6	28.6
	Trifolium repens L.	3	4	4	NAT	42.9	57.1	57.1
Aceraceae	*Acer pseudo-sibolianum* (Paxton) Kom.	1				14.3	0	0
Oxalidaceae	*Oxalis corniculata* L.		1	1		0	14.3	14.3
Violaceae	*Viola mandshurica* W. Becker	2				28.6	0	0
Onagraceae	*Oenothera odorata* Jacq.	2	3	3	NAT	28.6	42.9	42.9
Umbelliferae	*Oenanthe javanica* (Bl.) DC.	2	2			28.6	28.6	0
Oleaceae	*Forsythia koreana* Nakai		2			0	28.6	0
Plantaginaceae	*Plantago asiatica* L.	2	2	3		28.6	28.6	42.9
Caprifoliaceae	*Lonicera japonica* Thunb.	1				14.3	0	0
Compositae	*Ambrosia artemisiifolia* var. *elatior* Descourtils			2	NAT	0	0	28.6
	Artemisia princeps Pampan.	2	3	4		28.6	42.9	57.1
	Aster ciliosus Kitamura		1			0	14.3	0
	Bidens bipinnata L.			1		0	0	14.3
	Cirsium japonicum var. *ussuriense* Kitamura		1			0	14.3	0
	Cosmos bipinnatus Cav.		2	4	NAT	0	28.6	57.1
	Conyza canadensis L.		1		NAT	0	14.3	0
	Erechtites hieracifolia Raf.			1	NAT	0	0	14.3
	Erigeron annuas (L.) Pers.		1	1	NAT	0	14.3	14.3

Family	Species	Region				r-NCD		
		Upper	**Middle**	**Low**		**Upper**	**Middle**	**Low**
	Galingosa ciliate Blake	1			NAT	14.3	0	0
	Taraxacum officinale Weber			1	NAT	0	0	14.3
	Xanthium strumarium L.	1		1	NAT	14.3	0	14.3
Typhaceae	*Typha orientalis* Presl			2		0	0	28.6
Gramineae	*Avena fatua* L.		1	1	NAT	0	14.3	14.3
	Argostis clavata var. *nukabo* Ohwi.		1			0	14.3	0
	Cymbopogon tortilis var. *goeringii* Hand-Mazz.		1			0	14.3	0
	Digitaria sanguinalis (L.) Scop.	1	3			14.3	42.9	0
	Echinochloa crus-galli (L.) Beauv.		2			0	28.6	0
	Eleusine indica (L.) Gaertner		1			0	14.3	0
	Imperata cylindrica var. *koenigii* Durand et Schinz			1		0	0	14.3
	Miscanthus sacchariflorus Benth.	2		4		28.6	0	57.1
	Miscanthus sinensis var. *purpurascens* Rendle	2	2			28.6	28.6	0
	Phragmites japonica Steud.		3	6		0	42.9	85.7
	Poa sphondylodes Trin.		1			0	14.3	0
	Setaria viridis (L.) Beauv.			2		0	0	28.6
	Zoysia japonica Steud.	3		3		42.9	0	42.9
Cyperaceae	*Cyperus amuricus* Max		1			0	14.3	0
	Cyperus difformis L.		1	2		0	14.3	28.6

NAT: Naturalized plants

Cowan [19] identified several major channel conditions that affect roughness: bed material, degree of surface irregularity, variations in channel cross section, relative effects of obstructions, degree of meandering, and effects of vegetation. Importantly, vegetation can directly or indirectly affect all these conditions, with the possible exception of bed material, thus indicating it often has a major influence on channel roughness and on how channels dissipate stream energy during periods of high flow. Herbaceous riparian vegetation increases local friction on stream banks by creating flexible and three-dimensional barriers to flow. Riparian graminoids (grasses, sedges, rushes) and shrubs are particularly effective at trapping sediments during high flows and helping to maintain stable stream banks. The characteristic geomorphology, plant communities, and associated aquatic and wildlife species of riparian systems are intrinsically linked to the role of water as both an agent of disturbance and a critical requirement of biota [20]. The Backcheon River represents such many river characters. For the past years, riparian areas of this river have often been converted to cropland because of soil fertility and convenient access to irrigation water. Recently many riparian areas of this river have been lost or degraded for commercial and industrial developments. Upstream area is still eco-friendly the low water's edge vegetation, flood way vegetation, land use in riparian zones within river levee, land use in flood plains beyond river levee, and water quality (BOD) (Table 2). Midstream and downstream areas are under challenging natural environments by industrial development. Namely, the floodplains of the Backcheon River have been converted to agricultural or horticultural fields, housing or industrial areas, restricting the river bed to a small channel; although the levees can be set back to some degree, the historic floodplains cannot realistically be reclaimed by the river. When more and more industrial development goes to upstream area, the river environment of upper river characteristics can be bad also. This study reflects this probability. Awareness of current conditions and relationships between land uses and resource goals is essential for successful restoration of riparian systems.

5. CONCLUSION

The floristic of riparian zones at Backcheon River are diverse at three regions of this river and closely related to the disturbance regime of the river ecosystems. Today and future, the rehabilitation and restoration of riparian vegetation is a major subsect of ecosystem. Many nature restoration projects are ongoing through Korea. It is necessary the current understanding of natural riparian vegetation in local regions.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/16151