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Integrated Environmental  
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**Ecosystem services, environmental stressors and decision  
making: How far have we got?**

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3 1 **ARTICLE TITLE**  
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5 2 Ecosystem services, environmental stressors and decision making: How far have we got?  
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12 5 Ecosystem services, stressors and decision making  
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17 7 **AUTHORS**  
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19 8 Lorraine Maltby\*<sup>†</sup>, Clifford Duke<sup>‡</sup>, Joke Van Wensem<sup>§</sup>  
20  
21

22 9  
23

24 10 **AFFILIATIONS**  
25

26  
27 11 <sup>†</sup> Department of Animal and Plant Sciences, The University of Sheffield, Sheffield,  
28

29 12 S10 2TN, UK. Email address: l.maltby@sheffield.ac.uk  
30

31 13 <sup>‡</sup> Ecological Society of America, 1990 M Street NW, Suite 700, Washington, DC, 20036 USA.  
32

33 14 Email address: csduke@esa.org  
34  
35

36 15 <sup>§</sup> Soil Protection Technical Committee, PO Box 30947, 2500 GX The Hague, The Netherlands.  
37

38 16 Email address: vanwensem@tcbodem.nl  
39  
40  
41 17  
42  
43  
44 18  
45  
46

47 19 *\*Address correspondence to Lorraine Maltby, Department of Animal and Plant Sciences, The*  
48

49 20 *University of Sheffield, Sheffield, S10 2TN, UK. Telephone: +44 114 222 4827. Fax: +44 114*  
50

51 21 *222 0002. Email address: l.maltby@sheffield.ac.uk*  
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3 22 Explicit consideration of the benefits that humans receive from ecosystems, commonly called  
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5 23 ecosystem services, has the potential to improve environmental management decision making.  
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8 24 The importance of ecosystem services to human well-being was highlighted by the Millennium  
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10 25 Ecosystem Assessment (MEA 2005) and in 2009 Daily et al. proposed a conceptual framework  
11  
12 26 and sketched out a strategic plan for delivering on the promise of ecosystem services: that is  
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15 27 increasing the recognition of environmental benefits in decision making. This paper, along with  
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17 28 others published around the same time (Fisher et al. 2009; De Groot et al. 2010), raised a number  
18  
19 29 of challenges that had to be addressed to mainstream the ecosystem services approach into  
20  
21 30 environmental decision making. These challenges included: understanding the provision of  
22  
23 31 ecosystem services; understanding the value of services; developing metrics and methods for  
24  
25 32 quantifying the production and flows of ecosystem services; and developing models and methods  
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27 33 for predicting how particular decisions will affect ecosystem services.  
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32 34 Five years on, how far have we got in addressing these challenges and what are the  
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34 35 outstanding issues? A joint Pellston Workshop, organised by the Society of Environmental  
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36 36 Toxicology and Chemistry (SETAC) and the Ecological Society of America (ESA), was held in  
37  
38 37 Shepherdstown, West Virginia, USA, from September 28 to October 3, 2014 to address these  
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40 38 questions. Building on previous SETAC and ESA activities on ecosystem services (e.g. Daily et  
41  
42 39 al. 1997, Stahl et al. 2009, Van Wensem and Maltby 2013), the workshop drew on the strengths  
43  
44 40 of the SETAC and ESA communities to bring together 29 key thinkers from industry (10),  
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46 41 academia/NGOs (9) and government (10) from Europe (11) and central/north America (18) to  
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48 42 review progress in applying the ecosystem services concept to risk assessment and natural  
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50 43 resource management. All participants were invited based on their expertise as individual  
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52 44 scientists. The focus was on environmental stressors – defined broadly to include chemical,  
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3 45 physical and biological drivers of change in ecosystems. The objective of the Pellston Workshop  
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5 46 was to develop consensus about, and practical guidance for, the application of the ecosystem  
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7 47 services concept to stressor risk assessment and environmental decision making as part of a  
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9 48 movement towards sustainability. Discussions about ecosystem services centered on current and  
10  
11 49 potential applications in setting protection goals, ecological production functions, inclusion in  
12  
13 50 risk assessment, and use in natural resource management and restoration activities. Each of these  
14  
15 51 four themes was developed in separate workgroups and discussed with all participants in plenary  
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17 52 sessions. The outcomes of these discussions are presented in this special issue and key findings  
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19 53 are summarised below.

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22 54         The general presumption is that ecosystem services approaches improve environmental  
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24 55 decision making as they make the connections between ecosystem properties and process and  
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26 56 human well-being explicit. But is there evidence for this? Van Wensem et al. (this issue)  
27  
28 57 identified three criteria that characterise ecosystem services approaches: connects impacts all the  
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30 58 way from ecosystem changes to changes in human well-being; considers all relevant ecosystem  
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32 59 services affected by the decision; considers and compares the changes in well-being of different  
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34 60 stakeholders. They illustrated the application of these criteria using case studies at different  
35  
36 61 spatial scales and from different jurisdictions, and concluded that ecosystem services approaches  
37  
38 62 were generally compatible with environmental policy and decision making at scales from  
39  
40 63 supranational to local. However, whereas six of the seven case studies met at least 2 of the 3  
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42 64 criteria, only one met all three criteria in full. Most case studies did not include an explicit  
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44 65 consideration of how different stakeholders were affected by a decision. Van Wensem et al. (this  
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46 66 issue) recommend the wider application of these criteria as part of a rigorous test of the general  
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3 67 hypothesis that ecosystem services approaches improve decision making with regards to the  
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6 68 protection of natural resources.  
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8 69 One of the key challenges in using ecosystem services approaches to inform  
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10 70 environmental decision making is translating environmental impacts on ecosystem structure and  
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12 71 process to changes in ecosystem service delivery (Olander & Maltby 2014). Bruins et al. (this  
13  
14 72 issue) addressed the use of ecological production functions (EPFs) to link effects of  
15  
16 73 environmental stressors on receptors in ecosystems and multiple ecosystem service endpoints. It  
17  
18 74 is clear from their analysis that, despite the important role of EPFs in environmental management  
19  
20 75 and decision making, the limited availability of relevant datasets and poor understanding of  
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22 76 critical linkages among ecological components delivering services is severely impeding the  
23  
24 77 development and application of EPFs. Bruins et al. (this issue) argue that EPFs should ideally  
25  
26 78 estimate final ecosystem services and that they are most useful for decision making if they are  
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28 79 quantitative.  
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34 80 The central role of EPFs in incorporating ecosystem services in risk assessment and  
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36 81 resource management was echoed by Munns et al. (this issue) and Moore et al. (this issue).  
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38 82 Munns et al. (this issue) present a number of recommendations for developing risk assessment  
39  
40 83 and management within an ecosystem services framework, which include clearly linking  
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42 84 assessment endpoints to human health and well-being and selecting endpoints using approaches  
43  
44 85 similar to those developed by EFSA (2010) and USEPA (Munns et al. 2015). ES assessment  
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46 86 endpoints are viewed as being compatible with, and complementary to, conventional endpoints.  
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48 87 Further, an ecosystem services approach provides a common currency that enables integration of  
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50 88 human health and ecological risk assessments. The use of conceptual models is recommended to  
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52 89 evaluate policy options, identify co-benefits and communicate risk and associated management  
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3 90 decisions. The outcome of the risk assessment should be communicated in a form that is  
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6 91 amenable to valuation, and targeted monitoring should be used to evaluate the effectiveness of  
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8 92 decisions and enable adaptive management.  
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10 93 Moore et al. (this issue) evaluated ecosystem-based natural resource management (ES-  
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12 94 NRM) as a framework for informing decisions where changes in the provision of key ecosystem  
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15 95 services can be assessed under alternate landscape and resource management scenarios. ES-  
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17 96 NRM can be applied to: maintain or enhance existing service provision; restore service  
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20 97 provision; transform degraded areas to provide alternative services; or replace lost services at an  
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22 98 alternative location. An important consequence of applying an ES-NRM framework is the shift  
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24 99 in focus from a limited number of ecosystem components deemed by risk assessors to be  
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27 100 important to ecosystem structure and function to protection goals and assessment endpoints  
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29 101 relevant to broad aspects of societal well-being. As such, the framework can provide a  
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31 102 transparent approach for balancing economic, ecological and societal drivers in resource  
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34 103 management decisions and for identifying the consequences and trade-offs that result from such  
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36 104 decisions.  
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38 105 There has been considerable progress since the call to arms by Daily et al. in 2009. The  
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41 106 workshop concluded that the ecosystem services approach is compatible with existing  
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43 107 environmental policies, regulatory processes and assessment frameworks and that many of the  
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46 108 tools to enable the application of an ecosystem services framework to risk assessment and  
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48 109 resource management are currently available. An ecosystem services framework provides a  
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51 110 mechanism for integrating across single stressor/single media environmental policies and for  
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53 111 involving stakeholders in environmental decision making. As such it has the potential to deliver  
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55 112 more holistic and effective environmental management at a landscape scale. However, the  
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3 113 workshop also identified the need for a robust test of the hypothesis that ecosystems services  
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5 114 approaches improve decision making, change decisions and improve outcomes. Such an  
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8 115 evaluation would inform the development and future use of the ecosystem services approach by  
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10 116 highlighting successes, identifying barriers to acceptance and targeting integration into policy  
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12 117 where it can be most effective. The lack of post-decision monitoring to evaluate the effectiveness  
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15 118 of decision-making and to inform adaptive management was highlighted as a particular concern.  
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17 119 A recurring theme of the workshop was a recognition of the essential role that EPFs play  
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20 120 in the translation of stressor exposure or management interventions to changes in ecosystem  
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22 121 service delivery, coupled with a frustration with the limited availability of rigorous quantifiable  
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24 122 EPFs. This must be addressed if ecosystem service thinking is to be fully incorporated into  
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27 123 environmental management decisions, but it should not, in itself, be an argument for not  
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29 124 applying an ecosystem services approach; qualitative approaches can be used.  
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31 125 The workshop addressed the implementation of ecosystem service approaches in risk  
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34 126 assessment, resource management and decision-making from an environmental sciences  
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36 127 perspective and did not focus on the value and valuation of ecosystem services. Valuation was  
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39 128 considered as part of the broader context and different viewpoints on ecosystem service  
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41 129 valuation and types of valuation methods were discussed. In addition to reflections in Munns et  
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43 130 al. (this issue) and Moore et al. (this issue), these discussions resulted in three opinion pieces by  
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46 131 workshop participants that outline the case for valuation of ecosystem services based solely on  
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48 132 monetization (Callow 2015) versus inclusion of non-monetized values (Kapustka and McCormick  
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50 133 2015, Munns and Rea 2015).  
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