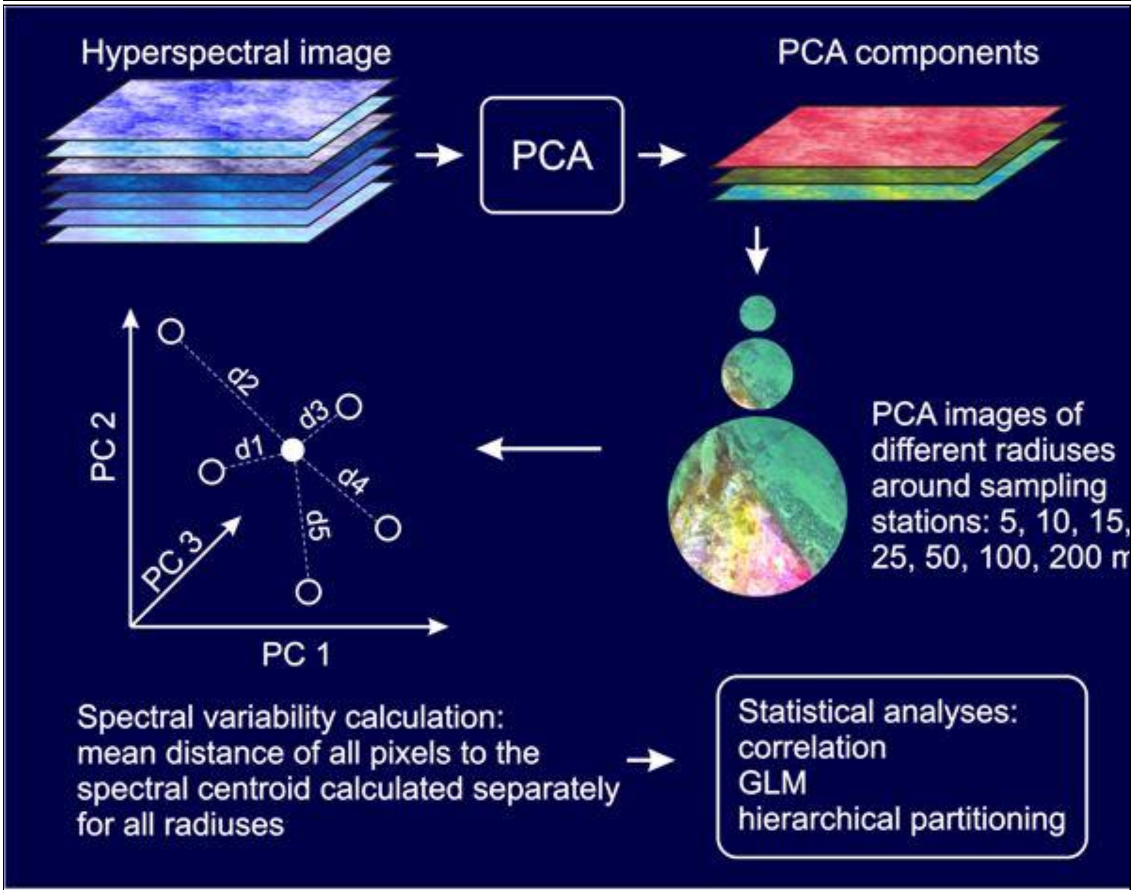
Name of indicator	2.7 Spectral variability index
Type of Indicator	State indicator
Author(s)	Kristjan Herkül
Description of the indicator	Spectral variability index is based on the spectral variation hypothesis that predicts a positive correlation between spectral heterogeneity of a remotely sensed image and biodiversity. Based on the results of a recent study (Herkül *et al*. 2013), the variability of air-borne hyperspectral imagery is positively correlated with benthic biodiversity variables. Spectral variability index quantifies the variability in a remotely sensed (air-borne or space-borne) imagery that, in turn, indicates benthic biodiversity. The method is potentially useful in extensive shallow water areas that are difficult to reach with a vessel.
Relationship of the indicator to marine biodiversity	A positive correlation between spectral variability of remotely sensed imagery and biodiversity has been shown in terrestrial plant communities (e.g. Rocchini 2007, Oldeland *et al*. 2010, White *et al*. 2010). Recent study (Herkül *et al.* 2013) revealed that spectral variability of a remotely sensed hyperspectral imagery also reflects the biodiversity of shallow water benthic habitats.
Relevance of the indicator to different policy instruments	Potentially relevant for MSFD descriptor 1.
Relevance to commission decision criteria and indicator	1.6.1. Condition of the typical species and communities 1.7.1. Composition and relative proportions of ecosystem components (habitats and species)
Method(s) for obtaining indicator values	Georeferenced remotely sensed imagery of a sea area is needed for the calculation of spectral variability index. High resolution multispectral or hyperspectral imagery is preferred input for the calculation. The imagery must reflect seabed properties i.e. the method can be used only in shallow and very clear waters. Principal component analysis can be used to reduce the redundant information in hyperspectral data prior to calculating values of spectral variability. The values of spectral variability are calculated in each cell of a predefined grid. The suitable cell size depends on the extent of the area to be assessed and the spatial resolution of the remotely sensed imagery. Spectral variability is measured as a mean distance from spectral centroid of a given cell. Spectral centroid is calculated as the mean value of each band or principal component in a given cell. The distance (difference) of each pixel from the spectral centroid is then determined within each cell. The mean distance of all pixels from the spectral centroid in a given cell is considered as the mean spectral variability of that cell (see Figure 1). The mean value of spectral variability over all cells in a given area serves as the value of spectral variability index. See Rocchini (2007), Oldeland *et al*. (2010), and Herkül *et al.* (2013) for more detailed description of the calculation of spectral variability. For the purposes of biodiversity monitoring, the method is more suitable for trend analysis based on a time-series of hyperspectral imagery than for episodic state assessments.
Documentation of relationship between indicator and pressure	The relationships between the indicator and pressures have not been tested, because there are no time-series of high-resolution remotely sensed imagery available for empirical testing. However, it is known that anthropogenic pressures lead to the loss of biodiversity (Worm *et al.* 2006). The impoverishment of marine benthic biodiversity due to anthropogenic pressures is expected to be reflected by the spectral variability index, but this must be quantified in further specific studies.
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	Not available. As the method is more suitable for trend analysis based on time-series of remotely sensed imagery than for episodic state assessments, trend-based assessment of the environmental status rather than comparison with reference conditions is recommended. Specially dedicated research is needed in order to develop methods for assessment of the environmental status.
Method for determining GES	Not available. Trend-based assessment of GES can be considered – stable or increasing values of the index can be considered as GES while decrease indicates non-GES. Specially dedicated research is needed in order to develop methods for assessment of the environmental status.
References	Herkül K, Kotta J, Kutser T, Vahtmäe E. 2013. Relating remotely sensed optical variability to marine benthic biodiversity. PLoS ONE, 8(2), e55624 Oldeland J, Wesuls D, Rocchini D, Schmidt M, Jürgens N. 2010. Does using species abundance data improve estimates of species diversity from remotely sensed spectral

	heterogeneity? Ecological Indicators, 10: 390-396 Rocchini D. 2007. Effects of spatial and spectral resolution in estimating ecosystem α-diversity by satellite imagery. Remote Sensing of Environment, 111: 423-434. White JC, Gómez C, Wulder MA, Coops NC. 2010. Characterizing temperate forest structural and spectral diversity with Hyperion EO-1 data. Remote Sensing of Environment, 114: 1576-1589 Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JB, Lotze HK, Micheli F, Palumbi SR, Sala E, Selkoe KA, Stachowicz JJ, Watson R. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science, 3: 787-790.
Illustrative material for indicator documentation	 Figure 1. Principal illustration of data processing and spectral variability calculation.