Name of indicator	1.5 The length at sexual maturation of female pikeperch (*Sander lucioperca*) in monitoring catches.
Type of Indicator	State indicator
Author(s)	Lauri Saks, Kristiina Jürgens, Antti Lappalainen, Eevi Kokkonen, Outi Heikinheimo, Aare Verliin, Markus Vetemaa, Ülle Talvik
Description of the indicator	The indicator describes the average size (TL) at which female pikeperch of monitored populations reach maturity. This indicator should be considered as index of the population's size and age distribution and should be associated to fishing pressure (both commercial and recreational) on local fish communities. Decrease in the values of this indicator may be symptom of strong fishing pressure which may have lead to life-history shift in local pikeperch populations. The latter can further lead to decrease in the mean trophic level of the community, which in turn may lead to decline in local biodiversity (Fig 1).
Relationship of the indicator to marine biodiversity	Generally, higher frequencies of sexually mature (older and larger) individuals are considered to be in correlation with the health of fish stocks (Piet *et al*. 2010). At the same time fishing effort (especially recreational but also commercial) is often targeted at large predatory fish and in circumstances of heavy (size-selective) fishing pressure, the proportion of large, sexually mature piscivores will decrease in the community (e.g. Allendorf 2009). It is known that the size at sexual maturation is under strong evolutionary pressure in fish (e.g. Stearns 1992). At the same time earlier maturation is often associated with slower growth (e.g. Vainikka & Hyvärinen 2012). As fast growing individuals which reach sexual maturity in relatively large size are removed from the spawning stock by selective fishing, life-history shifts are prone to occur in local populations towards the strategies of slower growth and/or maturation in smaller size (Fig 2; see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013). Larger individuals have a more specific role in the ecosystem than smaller individuals as they usually occupy higher trophic level than smaller fish. Such shifts in the structure of local fish communities may, however, be symptomatic for decrease in the mean trophic level of the community, which in turn may lead to decline in local biodiversity (Fig 1).
Relevance of the indicator to different policy instruments	Similar indicators (e.g. Mean size of perch (*Perca fluviatilis*) at their first sexual maturation in monitoring catches) are used as indicators for fishing pressure under the descriptor 3 of MSFD by Estonia (Martin 2013). This indicator can be used as for MSFD D1 and D3.
Relevance to commission decision criteria and indicator	1.3.1. Population demographic characteristics (e .g. body size or age class structure, sex ratio, fecundity rates, survival/ mortality rates)
Method(s) for obtaining indicator values	Data on local mean size of female pikeperch at first sexual maturation (L50) is gathered during annual monitoring (trawl or fyke-net) catches. Monitoring is carried out during spring, before the spawning season of the pikeperch. Level of maturation is determined by visual inspection of dissected fish. L50 is determined using logistic regression model (Fig. 3; results in Table 1) where individual total length (TL) is an independent variable and the level of sexual maturity is a dependent variable (Chen & Paloheimo 1994).
Documentation of relationship between indicator and pressure	Evolutionary life-history shift towards reduction in size at first maturation as response to heavy fishing has been reported for several fish species (see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013). Determining L50 has been successfully used for such studies at the population level (e.g. Chen & Paloheimo, 1994; O'Brien, 1999). Associations between indicator values and fishing pressure were tested by comparing monitoring areas with different pikeperch fishery regulations. In Pärnu area (Gulf of Riga) the minimum catchable size limit is TL=44 cm and only gillnets with minimum mesh size of 48 mm (knot to knot = 96 mm streched mesh) are allowed. Gillnet fisheries in the Helsinki area have mesh size limitations at 50 mm (knot to knot = 100 mm streched mesh). In the Archipelago Sea, there are mesh size limitations or recommendations at 43 mm or 45 mm (knot to knot = 86 mm or 90 mm streched mesh). The minimum catchable size limit for pikeperch is TL=40 cm in the Helsinki area, and TL=37 cm in the Archipelago Sea. Evidently, L50 values for monitoring areas with alternative pikeperch fishery regulations differed markedly (Table 1, Fig 4). The lowest indicator values were recorded from Archipelago Sea with long history of strong size-selective fishing pressure. The indicator values for Helsinki and Pärnu area were considerably higher. Still, only one measurement was higher than estimated target value (and also in this case only in the comparison with conservative target value). Thus, if compared to historic data, indicator values (for at least Pärnu area) during recent years were lower than recorded in the past (Fig. 4). These results indicate that that size-selective fishing pressure may have played a role in the development of the current size structure of these pikeperch populations (similarly with several

	documented cases; see e.g. Hutchings & Reynolds 2004, Olesen *et al*. 2005, Conover 2007; Enberg *et al*. 2012, Pukk *et al*. 2013).
Geographical relevance of indicator	2. Regional
How Reference Conditions (target values/thresholds) for the indicator were obtained?	The target values were selected on the basis of historical data on Pärnu area (Erm, 1981). The size at which approximately 50% of females individuals were mature was between (conservative estimate) TL=40.3 cm and (optimistic estimate) TL=41.4 cm (Erm 1981, transformed according to Saat *et al*. 2007). However, as pikeperch growth rate is dependent on several environmental factors (temperature, food availability) substantial inter-location variability in L50 reference conditions may be expected to occur. Thus, if possible, the indicator baseline values should be adjusted to local conditions.
Method for determining GES	The situation is considered to be subGES if the indicator values are lower than locally determined reference conditions (e.g. L50 lower than 40.3 cm in Pärnu area; Fig 4).
References	Allendorf, F.W. & Hard, J.J. 2009.Human-induced evolution caused by unnatural selection through harvest of wild animals.Proc. Natl Acad. Sci. USA 106: 9987–9994 Chen, Y. & Paloheimo, J.E. 1994. Estimating fish length and age at 50% maturity using a logistic type model. Aquat. Sci., 56, 206-219. Conover, D.O. 2007. Fisheries: Nets versus nature. Nature, 450, 179-180. Enberg, K., Jørgensen, K., Dunlop, E.S., Varpe, Ø., Boukal, D.S., Baulier, L., Eliassen, S. & Heino, M. 2012. Fishing-induced evolution of growth: concepts, mechanisms and the empirical evidence. Marine Ecol**.**, 33, 1–25**.** Erm, V. 1981. Koha. Valgus, Tallinn. HELCOM, 2012. Development of a set of core indicators: Interim report of HELCOM CORESET project. PART A. Description of the selection process. Balt. Sea Environ. Proc. No. XXX A (http://www.helcom.fi/BSAP_assessment/ifs/ifs2012/en_GB/CoastalFish/ Hutchings, J.A. & Reynolds, J.D. 2004. Marine fish population collapse: consequences for recovery and extinction risk. BioScience 54, 297-309. Martin, G., (ed). 2013 Eesti mereala Hea Keskkonnaseisundi indikaatorid ja keskkonnasihtide kogum. Aruanne MSFD artikkel 9 ja 10 nõuete täitmiseks. Eesti Mereinstituut. Tallinn. Olsen, E.M., Lilly, G.R., Heino, M., Morgan, M.J., Brattley, J. & Dieckmann, U. 2005. Assessing changes in age and size at maturation in collapsing populations of Atlantic cod (*Cadus morhua*). Can. J. Fisheries Aquatic Sci. 62, 811-823. Piet, G.J., Albella, A.J., Aro, E., Farrugio, H., Lleonart, J., Lordan, C., Mesnil, G., Petrakis, G., Pusch, C., Radu, G. & Rätz, H.-J. 2010. Marine Strategy Framework Directive. Task Group 3 Report. Commertially exploited fish and shellfish. (Doerner, H. & Scott, R., eds). EU and ICES, Luxembourg. Pukk, L., Kuparinen, A., Järv, L., Gross, R. & Vasemägi, A. 2013. Genetic and life-history changes associated with fisheries-induced population collapse. Evol. Appl. 6, 749-760. Saat, T., Saat, T. & Nursi, A. 2007. Total length – standard length relationship in Estonian fishes. In Book of abstracts of the XII European congress of ichthyology (Buj, I., Zanella, L. & Mrakovicic, M., eds), p 141. European Ichthyological Society. Stearns, S.C. 1992. The evolution of life histories. Oxford University Press, Oxford. Vainikka, A. & Hyvärinen, P. 2012. Ecologically and evolutionarily sustainable fishing of the pikeperch *Sander lucioperca*: Lake Oulujärvi as an example. Fisheries Res. 113, 8–20.
Illustrative material for indicator documentation	

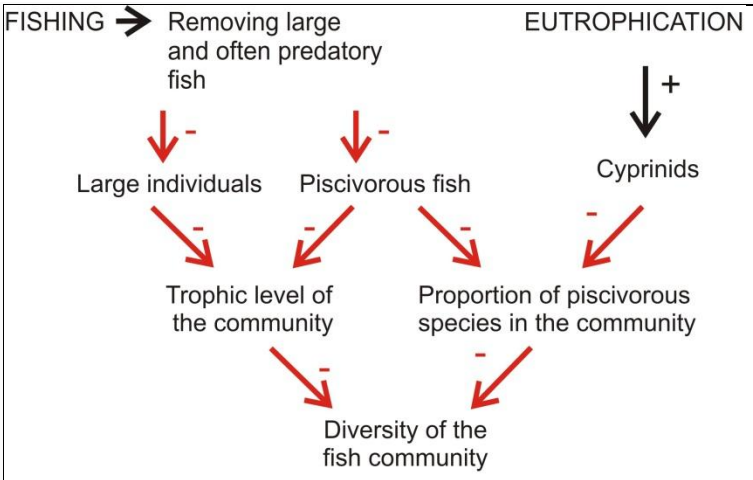

Figure 1. Relationship between biodiversity of the fish community and anthropogenic pressures (modified from HELCOM 2012b)

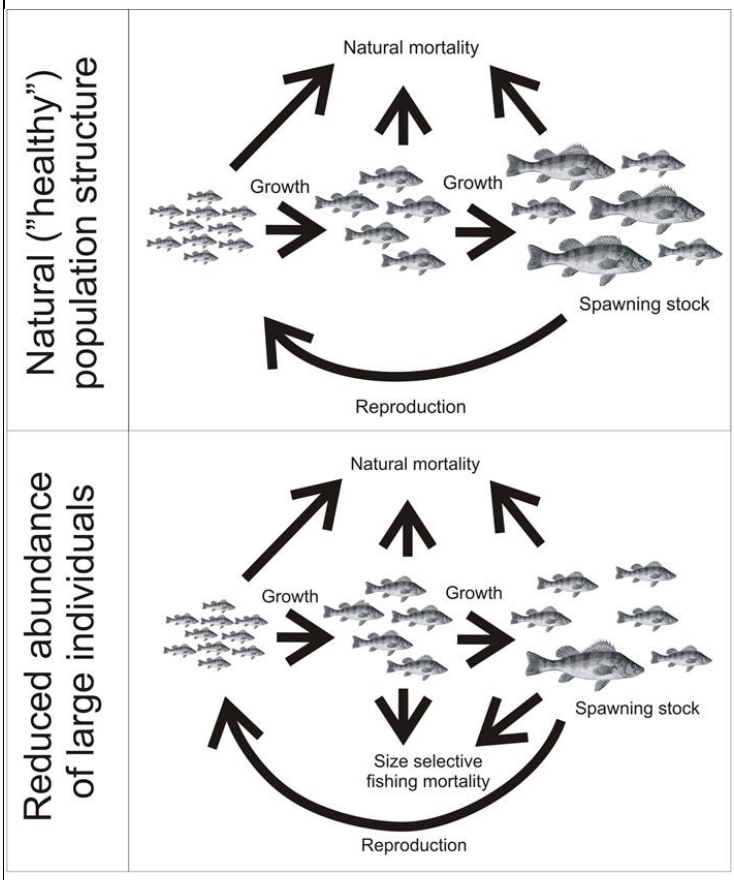

Figure 2. Strong fishing effort can shift the natural population structure. The individuals which grow faster are removed from the spawning stock by size-selective fisheries and thus alternative life-history strategies (slow growth and/or early maturation) prevail.

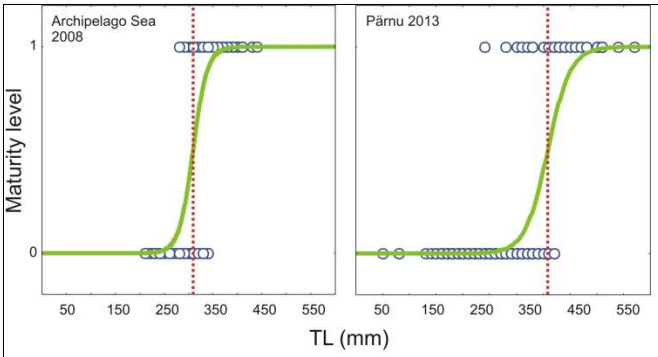

Figure 3. L50 is determined using logistic regression model where individual total length (TL) is independent and the level of sexual maturity is dependent variable (Chen & Paloheimo 1994). Red dashed line denotes respective L50 values.

Table 1. Indicator values in areas with different pikeperch fishery regulations.

Location	Year	L50	Model χ^2	p	N (0's; 1's)
Helsinki	2012	35.1	101.25	<0.00001	42; 76
	2013	35.3	62.33	<0.00001	30; 53
Pärnu	2011	38.4	106.86	<0.00001	153; 31
	2012	36.3	59.24	<0.00001	56; 17
	2013	40.8	122.41	<0.00001	245; 32
Archipelago Sea	2004	31.2	36.85	<0.00001	60; 152
	2005	31.2	27.48	<0.00001	23; 76
	2006	31.6	26.90	<0.00001	17; 37
	2008	30.9	65.29	<0.00001	33; 67
	2009	27.4	26.86	<0.00001	17; 154

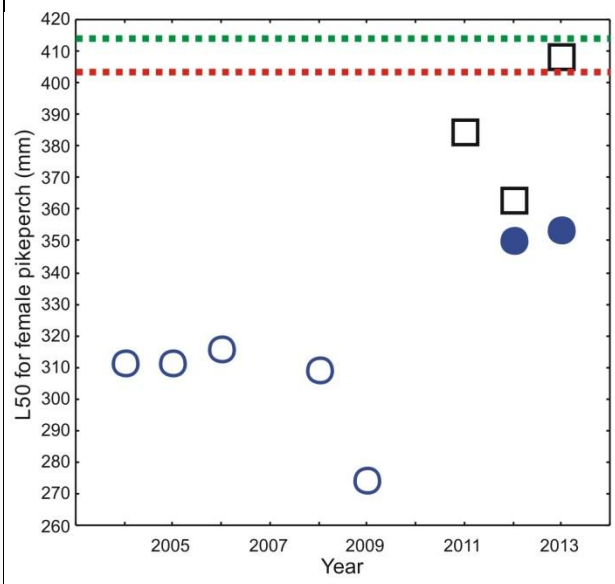

Figure 4. Indicator values in areas with different pikeperch fishery regulations. Empty circles denote Archipelago Sea, filled circles denote Helsinki and empty squares denote Pärnu area. Green dashed line marks the upper (optimistic, TL=41.4 cm) and red dashed line the lower (conservative, TL=40.3 cm) target values for Pärnu area.