Republic of Estonia
Ministry of the Environment

Report on the assessment methodology and initial results of lacustrine ecosystem services in the CleanEST project (C.2)

Tallinn 30.11.2022

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This report was created during the LIFE IP CleanEST project. The latter is financed by the European Commissions' LIFE programme and the Estonian government. LIFE programmes' financing contract number is LIFE17 IPE/EE/000007. The report reflects the authors' viewpoints and the European Commission is not responsible for the further use of the information provided in said report.

1. Methodology

The methodology for mapping of ecosystem services of marine and inland waters was developed in Estonia in 2016 in the cooperation of Peipsi CTC, University of Life Sciences, Tallinn University, University of Tartu, Estonian Environment Agency, SEI Tallinn and Norwegian Institute for Nature Research (Kosk et al., 2016)[1]. In that project the most important ecosystem services provided by water bodies were selected, matrices for a quick evaluation of the provision of services and indicators for mapping various aspects of the services were developed. In the CleanEST project that methodology is taken as a reference, it is developed further and applied on selected water bodies in the Viru sub-catchment. The selection of water bodies includes those, which will presumably experience a change in the provision and consumption of ecosystem services because of project actions. In essence, two separate methodologies will be developed, one for riverine ecosystem services (completed in 2021[2]) and one for lacustrine ecosystem services (the current report). Riverine and lacustrine ecosystems provide different services, and often the indicators that can be used in the assessment do not coincide even for services that are provided by both of these ecosystem types. Both of these methodologies will be designed so that they would be applicable in other regions in Estonia as well. Assessment methods for marine ecosystem services will not be developed in the CleanEst project, because it is dealt with in other projects carried through in Estonia.

The classification of ecosystem services in Kosk et al. (2016) is based on the most widely accepted classification of ecosystem services, developed by the European Environmental Agency, the CICES classification[3]. That classification is required to be used in LIFE projects also by the European Commission[4]. Since the work of Kosk et al. (2016), a newer CICES classification (v5.1) has been published. Therefore, the newer classification is used in the CleanEST project and the list of ecosystem services provided by water bodies has been adjusted compared to Kosk et al. (2016). Most adjustments in the list of lacustrine ecosystem services compared to Kosk et al. (2016) include merging or dividing services. In addition, some services, thought to be relevant enough, but absent from the list, have been added (Table 1). Because of these modifications, the list of relevant ecosystem services provided by riverine ecosystems has increased from 16 to 19.

Table 1. Differences in the list of relevant riverine ecosystem services between the CleanEST methodology and Kosk et al. (2016) methodology

CleanEST methodology	Kosk et al. (2016) methodology	Justification
Animal and plant material collected for the purposes of maintaining or establishing a population	Not included	Fish and crayfish collection both for relocation or breeding is practiced actively in Estonia.
Regulating and maintaining service: Regulation of the chemical condition of freshwater by buffer zones on shores	Not included	In the CleanEst project ecosystem services should (according to the project proposal) be assessed on the shores of water bodies as well.
Regulating and maintaining service: Global climate	Not included	Lacustrine ecosystems act as an important carbon sink. Therefore, the large number and area of

[1] Kosk, A., Seer, E., Säde, M., Rakko, A., Ott, I., Raet, J., Piirsoo, K., Sepp, K., Kalpus, K., Külvik, M., Villoslada Pecina, M., Römer, S., Vilbaste, S., Lode, E., Tõnisson, H., Terasmaa, J., Puusepp, L., Aps, R., Orav-Kotta, H., Kotta, J., Kotta, I., Kopti, M., Fetissov, M., Aan, A., Pääsukene, K., Väljataga, K., Narusk, K., Altoja, K., Klein, L., Piirsalu, E., Nõmmann, S., Nõmmann, T, Freimann, K., van Dijk, J., Sandlund, O.T. 2016. *Development methods for assessment and mapping of ecosystem services of marine and inland waters. Summary.* Peipsi Center for Transboundary Cooperation, Tartu.

[2] Vainu, M. 2021. *Report on the assessment methodology and initial results of riverine ecosystem services in the CleanEST project (C.2)* Estonian Environment Agency, Tallinn.

[3] https://cices.eu/

[4] *Assessing ecosystems and their services in LIFE projects*. *A guide for beneficiaries*. n.d. LIFE.

regulation by carbon sequestration and accumulation		standing water bodies in Estonia make it an important ecosystem service.
Not included	Regulating and maintaining service: Maintenance of hydrodynamics and flood protection	Though floods are caused by water bodies, the functioning of that service is more dependent on the status of the surrounding terrestrial ecosystem, than the water body itself. Also, the functioning of that service does not affect the water body. For that reason that service is considered to be a terrestrial ecosystem service and it has already been assessed in Estonia in the ELME project as a service provided by terrestrial ecosystems.
Cultural service: Conditions supporting active recreation	All active and passive means of recreation (excl. recreational fishing and crayfish catching) are lumped together as the cultural service: Environmental conditions suitable for recreation.	Distinguishing these two services simplifies the assessment of the provision and consumption of these services, because of several forms of recreation that would otherwise have to be taken into account under a single service.
Cultural service: Conditions supporting passive recreation	All active and passive means of recreation (excl. recreational fishing and crayfish catching) are lumped together as the cultural service: Environmental conditions suitable for recreation.	Distinguishing these two services simplifies the assessment of the provision and consumption of these services, because of several forms of recreation that would otherwise have to be taken into account under a single service.
Cultural service: Conditions supporting recreational fishing and hunting	Considered as separate services: Environmental conditions suitable for leisure fishing and hunting, and Catching of crayfish.	Treating crayfish catching as a separate service is not justified, as it is too insignificant practice in Estonia.
Cultural service: Conditions that enable aesthetic experiences	Conditions that enable aesthetic experiences and inspiration for creative work were lumped together as a single service: Source of inspiration for creative activity.	Distinguishing these two services is justified as CICES v.5.1 lists them separately and the provision and consumption of these two services is clearly different. Water bodies that are polluted or aesthetically unpleasant could provide inspiration, whereas they do not provide aesthetic experiences. From the viewpoint of consumption, the practical outcome of the inspiration service is a painting, novel or movie, but the consumption of the service of aesthetic experiences may not have any practical outcome at all, or it may be a documentary photograph.
Not included	Cultural service: Source of inspiration for creative activity	Though flowing water bodies provide inspiration for people, which makes it an important service, it is not possible to measure how much a water body provides inspiration. Inspiration may be provided by all water bodies, regardless of their characteristics. Additionally, it is

		almost impossible to properly measure the consumption of the service, because it would require an extensive research of all the assessed water bodies to identify all the creative works that depict these water bodies. It is impractical to include a service in the assessment methodology whose provision is indistinguishable and consumption is unmeasurable.
Cultural service: Maintaining protected species	Regulating and maintaining service: Protected species and key species, natural habitats and maintenance of the balance between them	The main motivation why certain species are declared protected is their bequest value, which is not always directly correlated to how endangered or crucial for the functioning of the ecosystem they are. Thus, that service is considered to be a cultural, rather than regulating and maintaining service.

In Kosk et al. (2016) the DPSIR indicator system from the European Environmental Agency was suggested to be used for mapping of ecosystem services. It consists of five interconnected indicator blocks:

- D – driving force;
- P – pressure;
- S – state;
- I – impact;
- R – response.

These indicators are connected in the following way: the demand for a service or the driving force (D) initiates the consumption of or the pressure (P) on the service, which causes changes in the provision or state (S) of the service. That manifests in the ecosystem, changes the processes taking place in the ecosystem (as well as its structure and functions), which provide services to the society. If a service loses its value for the society, the well-being of the society suffers and that is measured with the impact indicator (I). If the change in provision or state of the ecosystem and its impact has been detected, measures of response (R) can be taken. The reason for taking measures is to decrease the pressure (P) on or the consumption of the service caused by the driving force (D). That cycle enables the ecosystem and it services to restore in a way that benefits can increase (Figure 1).

In the current methodology, the indicator system has been simplified and the indicators for the driving force, impact and response have been left out and only the status (provision) and pressure (consumption) indicators are considered. These two are the most essential for characterising the functioning of ecosystem services and data for these indicators is either readily available or is obtainable with more or less effort. The indicators for driving force should reflect the demand for a service. As the data on these indicators is lacking in Estonia and it is not possible to measure these as water body specific, then including these in the current methodology is not rational. The impact indicators are not dealt with, as it is basically impossible to measure the direct and discrete impact for the society of some, especially regulating and maintaining and cultural services. The response indicators are also not considered.

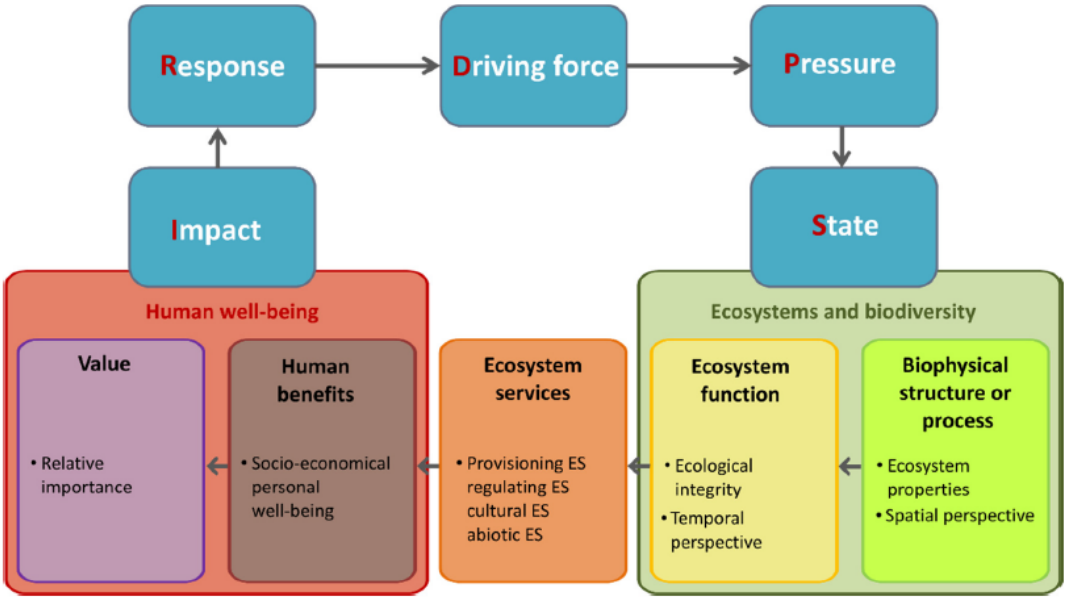

Figure 1. The connection between DPSIR environmental indicators system and ecosystem services (Kosk et al. 2016, ref. Mononen et al, 2015[5]).

Therefore, the PS-indicators are interpreted in the assessment of ecosystem services in the CleanEST project as follows:

- P-indicator characterises the pressure on the service and/or the amount of consumption of the service. For provisioning and cultural services, that indicator is therefore called as the consumption indicator. For the maintaining and regulating services, that indicator measures only the anthropogenic pressure on the functioning of that service and not the consumption component. The reason is that there is no direct human consumption of maintaining and regulating services, as the benefits provided by these services assure a suitable environment for human existence in general. In fact, the consumption of a service indicates anthropogenic pressure on a service as well, as too intense consumption could wear the service out, but for the sake of comprehensibility and usage of economic terms, the indicator is called consumption indicator for the services with measurable consumption.
- S-indicator characterises the status of the service or the provision of the service or the functioning of the service. The better the status of the service, the better it functions and the higher is its provision. For the sake of comprehensibility and usage of economic terms, the indicator is called as the provision indicator for all services.

According to the indicator classification of the European Commission funded MARS project[6] the S-indicator corresponds to the *Capacity* indicator, which shows the potential of the ecosystem to provide ecosystem services. The P-indicator generally corresponds to the *Flow* indicator (excl. for regulating and maintaining services), which shows the actual use of the ecosystem services.

The list of indicators in the ecosystem services assessment methodology for the CleanEST project is based (with some modifications) on the list of indicators in Kosk et al. (2016) (Table 2).

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[5] Mononen L., Auvinen A.-P., Ahokumpu A.-L., Ronka M., Aarras N., Tolvanen H., Kamppinen M., Viirret E., Kumpula T., Vihervaara P. 2015. National ecosystem service indicators: Measures of social–ecological sustainability. *Ecological Indicators*, doi:10.1016/j.ecolind.2015.03.041

[6] Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A. 2015. *Cook-book for water ecosystem service assessment and valuation.* Joint Research Centre, Luxembourg.

Table 2. Relevant lacustrube ecosystem services and their consumption or pressure (P) and provision or status (S). Pink colour indicates provisioning services, green colour regulating and maintaining services and blue colour cultural services

*Fish stock for professional fishing CICES v5.1 – 1.1.6.1	P Amount of professional catch from the river (t/yr) S Stock of fish species used for professional fishing (t/yr)
*Animal and plant material collected for the purposes of maintaining or establishing a population CICES v5.1 – 1.2.2.1, 1.2.1.1	P Number of animals caught for relocation or breeding material (pcs/yr) S Composite index of significance of the provision of the service of maintaining or establishing a population (index)
*Surface water for drinking CICES v5.1 – 4.2.1.1	P Number of drinking water intakes (no) P Abstraction of surface water for drinking water (m^3/s) S Average minimal monthly discharge that exceeds environmental flow (m^3/s) S Accordance of water quality to quality requirements of water used to produce drinking water (quality class)
Surface water used for other non-drinking purpose CICES v5.1 – 4.2.1.2	P Number of surface water intakes of water used for non-drinking purposes (pcs) P Abstraction of surface water for non-drinking purposes (m^3/s) S Average minimal monthly discharge that exceeds environmental flow (m^3/s)
Mud stock CICES v5.1 – 4.2.3.1	P Amount of mud mined (thousand m^3/yr) S Size of mud stock (thousand m^3)
Reed stock CICES v5.1 – 1.1.5.2, 1.1.5.3	P Industrially harvested reed (t/yr) S Area of reed-bed connected to the water body (ha)
Surface water used as an energy source CICES v5.1 – 4.2.1.3	P Number of installed heat pumps (no) S Area of lake bottom between the depth of 2 to 10 m (ha)
Maintaining nursery populations and habitats CICES v5.1 – 2.2.2.3	P Hydromorphological status (status class) P Water quality status (status class) S Status of aquatic biota (index)
Dilution, meditation, sequestration and accumulation of wastes or toxic substances in surface water CICES v5.1 – 2.1.1, 5.1.1.1, 5.1.1.3	P Nutrient load via point source pollution (point-source pollution index) P Nutrient load via diffuse pollution N+P (diffuse pollution index) S Water quality status (status class)
Regulation of the chemical condition of freshwater by living organisms (buffer zones on shores) CICES v5.1 – 2.2.5.1	P Share of recently (in 4–5 years) clear-cut land or forests with similar disturbance in the shore area of the water body (%) P Share of non-natural land cover in the shore area of the water body (%) S Share of full-grown forests in the shore area of the water body (%) S Share of natural land cover in the shore area of the water body (%)
Global climate regulation by carbon sequestration and accumulation CICES v5.1 – 2.2.6.1	P Anthropogenic reduction of the area of the water body (%) P Anthropogenic reduction of the phosphorus concentration of the water body (%) P Anthropogenic increase of the water exchange rate of the water body (%) S Water body area (ha) S Phosphorus concentration of the water body (mg/l) S Ratio of lake catchment area to lake area S Water exchange rate of the water body (times/yr)

Conditions supporting active recreation CICES v5.1 – 3.1.1.1	P Number of people using the water body for boating (pcs/yr) P Number of people using the water body for swimming and visitors of water parks (pcs/yr) P Number of hikers/walkers on the shore area of the water body (pcs/yr) S Attractiveness of the water body for boating (index) S Access distance by car (m) S Number of swimming places and water parks on the shore of the water body (pcs) S Length of roads/trails suitable for walking/hiking on the shore area of the water body (km)
Conditions supporting recreational fishing and hunting CICES v5.1 – 3.1.1.1	P Number of recreational fishers (pcs/yr) P Number of crayfish catchers (pcs/yr) P Number of beaver and waterfowl hunters (pcs/yr) S Attractiveness for fishing (grade) S Legal possibility for recreational fishing (yes/no) S Crayfish abundance (grade) S Legal possibility for crayfish catching (yes/no) S Number of days allowed for waterfowl hunting (days) S Number of beaver families on the water body (pcs)
Conditions supporting passive recreation CICES v5.1 – 3.1.1.2	P Number of users of rest stop sites on the shore of the water body (pcs/yr) P Number of nights spent in accommodation facilities near the water body (pcs/yr) P Number of unique nature observations in the shore area of the water body (pcs/yr) S Number of rest stop sites on the shore of the water body (pcs) S Number of accommodation facilities on the shore of the water body (pcs) S Share of natural land cover in the shore area of the water body (%) S Number of residential properties adjacent to the water body (pcs)
Conditions that enable scientific investigation CICES v5.1 – 3.1.2.1	P Number of scientific publications (pcs) P Number of public monitoring data (pcs) S *All water bodies are considered equally valuable for scientific investigation therefore no indicator is determined.*
Conditions that enable education and training CICES v5.1 – 3.1.2.2	P Number of educational trips in nature and public schools related to the water body (pcs/yr) S Number of educational programmes in nature and public schools related to the water body (pcs)
Conditions that enable aesthetic experiences CICES v5.1 – 3.1.2.4	P Number of photos in the web depicting the water body (pcs) S Attractiveness for landscape watching (index)
Provision of cultural, religious and national symbols CICES v5.1 – 3.1.2.3, 3.2.1,1, 3.2.1.2	P Number of visitors of natural symbolic sites (pcs/yr) S Number of natural symbols (pcs) S Number of folklore items related to the water body (pcs)
Maintaining protected species CICES v5.1 – 3.2.2.2	P Hydromorphological status (status class) P Water quality status (status class) S Amount of protected species (index) S Status of protected species (grade)

* The service *Conditions that enable creative work* is also an important riverine ecosystem service, but as it is impossible to distinguish the provision of that service for different water bodies and measuring the consumption of that service is problematic (Table 1), then it is not included in the assessment.

For comparative mapping of the provision or consumption of ecosystem services, the quantified indicator data has to be transformed (normalised) to a common scale. Kosk et al. (2016) have suggested using a five-step scale: 0 – does not provide that service; 1 – provides insignificantly; 2 – provides moderately; 3 - provides significantly; 4 – provides very significantly. In the CleanEST project, the same scale is used. It is comparable to the scale suggested to be used in LIFE projects by the European Commission[7]. Though, according to that scale, „zero“ should indicate unknown provision, „one“ very poor/bad/non-functional provision, and „five“ very good/high provision. Therefore, the two scales are shifted by one unit, but are both five-step scales in their essence.

Kosk et al. (2016) does not provide suggestions for normalising indicator data for the five-step scale. Therefore in the CleanEST project the class limits for each indicator were developed, based on available data and expert decision. If the provision or consumption of a service is described by more than one indicator (e.g. the provision of the service „Maintaining protected species“), then the general value will be calculated using weights of each specific indicator. The weights were set based on expert decision.

If the normalised values for the provision and consumption of each ecosystem service per each assessed water body have been derived, the ecosystem services index – ÖSTI (Kosk et al. 2016) can be calculated. It allows evaluating which water bodies provide less and which more ecosystem services and helps to pinpoint the water bodies where the improvement of ecosystem services requires the largest effort.

The relevance of various services for the society is not equal, though, therefore weights have to be applied in order to calculate ÖSTI. For calculating these weights, each member of the working group, participating in the development of the current methodology, ordered the services based on their importance for the Estonian society. They also assessed the difference of importance of the most important and least important services. Based on these ratings, the weights of the services were calculated (Table 3).

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[7] *Assessing ecosystems and their services in LIFE projects*. *A guide for beneficiaries*. n.d. LIFE.

Table 3. The order of Estonian riverine ecosystem services based on their impact on the society and weights used for calculating the ÖSTI

No.	Ecosystem service	Weight
1	Maintaining nursery populations and habitats	10,0
2	Maintaining protected species	8,5
3	Conditions supporting active recreation	8,0
4	Dilution, meditation, sequestration and accumulation of wastes or toxic substances in surface water	7,5
5	Conditions supporting recreational fishing and hunting	7,5
6	Conditions supporting passive recreation	7,25
7	Regulation of the chemical condition of freshwater by living organisms (buffer zones on shores)	7,0
8	Conditions that enable aesthetic experiences	6,5
9	Surface water for drinking	6,0
10	Surface water used for other non-drinking purpose	5,5
11	Animal and plant material collected for the purposes of maintaining or establishing a population	4,75
12	Global climate regulation by carbon sequestration and accumulation	4,75
13	Fish stock for professional fishing	4,5
14	Provision of cultural, religious and national symbols	4,25
15	Conditions that enable education and training	4,25
16	Conditions that enable scientific investigation	3,75
17	Reed stock	2,5
18	Mud stock	2,5
19	Surface water used as an energy source	1,0

The equation for calculating the index of ecosystem services provision/status ($ÖSTI_p$) is:

$$ÖSTI_p = \frac{\sum_i^n (kx_p)}{4 * \sum_i^n (k)}, \text{ where} \quad (1)$$

ÖSTIp – index of ecosystem services provision; *n* – number of evaluated ecosystem services, *k* – weight of the i-th ecosystem service (based on Table 3); x_p – the provision/status of the i-th ecosystem service (according to Kosk et al., 2016, simplified for the evaluation scale of 0 to 4).

The equation for calculating the index of ecosystem services consumption/pressure ($ÖSTI_c$) is:

$$ÖSTI_c = \frac{\sum_i^n (kx_c)}{4 * \sum_i^n (k)}, \text{ where} \quad (2)$$

ÖSTIc – index of ecosystem services consumption; *n* – number of evaluated ecosystem services, *k* – weight of the i-th ecosystem service (based on Table 3); x_c – the consumption/pressure of the i-th ecosystem service (according to Kosk et al., 2016, simplified for the evaluation scale of 0 to 4).

For the calculation of $ÖSTI_c$ the services whose larger consumption does not result in increased pressure on the lacustrine ecosystem are not taken into account. Such services are: Conditions that enable aesthetic experiences, Conditions that enable education and training, Conditions that enable scientific investigation, and Provision of cultural, religious and national symbols.

Marko Vainu from the Estonian Environment Agency (KAUR) is responsible for developing and applying the methodology for mapping of ecosystem services. The whole methodology and results of its application has been discussed and harmonised in the CleanEST ecosystem services working group, which includes: Olav Ojala (Ministry of the Environment), Üllas Ehrlich (Tallinn University of Technology), Timo Kark (KAUR), Aija Kosk (Estonian University of Life Sciences/Tallinn University of Technology), Vallo Kõrgmaa (Estonian Environmental Research Centre – EKUK), Einar Kärgenberg (KAUR), Mart Reimann (Tallinn University), Sander Sandberg (State Forest Management Centre), Indrek Tamm (EKUK), Mart Thalfeldt (KAUR), Uudo Timm (KAUR), Jaanus Terasmaa (Tallinn University), Tanel Ader (Ministry of the Environment), Sirje Vilbaste (Estonian University of Life Sciences).

2. Results

The provision and consumption of ecosystem services of two standing water bodies in the Viru sub-basin were assessed with the developed methodology. These two water bodies were Aidu Quarry Lake and Lake Uljaste (Figure 3). Aidu Quarry Lake is a former oil-shale quarry filled with groundwater. Project CleanEST strives towards improving the provision of ecosystem services in such artificial water body. Lake Uljaste was chosen for testing the assessment methodology, because it is a natural lake, in contrast to Aidu Quarry Lake. There are no project actions directed towards that lake, though. The consumption of some services, where the collection of data is most difficult, of L. Uljaste were not assessed, as it was selected only for evaluation purposes. Data from 2019 and 2020 were used for the assessment.

Figure 3. Location of the assessed lacustrine water bodies.

The ecosystem services provision index (*ÖSTIp*) values for Aidu Quarry L. and L. Uljaste were 0.55 and 0.49, respectively. It shows that there is no significant difference in the total provision of services by these two lakes. But as the Quarry Lake is more diverse, then the total provision is slightly bigger. The index of ecosystem services consumption (*ÖSTIc*) was calculated only for Aidu Quarry Lake, as some data was missing for L. Uljaste. The value of the index is 0.36. It is difficult to put that value into perspective, as there are no other lakes to compare it with. It is possible to compare it with the respective values of 20 flowing water bodies in the Viru sub-basin[8]. For these, the index ranged from 0.43 to 0.23. Therefore, the anthropogenic pressure and the consumption of the services of Aidu Quarry Lake may be considered average.

[8] Vainu, M. 2021. *Report on the assessment methodology and initial results of riverine ecosystem services in the CleanEST project (C.2)* Estonian Environment Agency, Tallinn.

The results of the assessment of ecosystem services provision/status and consumption/pressure are given in tables 5 and 6.

Table 5. Provision/status classes of assessed ecosystem services. 0 – does not provide that service; 4 – provides very significantly

Water body	Fish stock	Pop. maintaning	Drinking water	Other water	Mud	Reed	Energy	Habitats	Water quality	Buffer zones on shores	Climate regulation	Active recreation	Rec. fishing and hunting	Passive recreation	Science	Education	Aesthetics	Symbols	Important species
Aidu Quarry L.	0	1	2	0	0	0	4	3	1	3	2	3	3	2	4	4	4	0	3
L. Uljaste	0	1	1	0	0	0	3	2	2	4	2	2	3	2	4	0	3	2	3

Table 6. Consumption/pressure classes of assessed ecosystem services. 0 – no consumption/pressure; 4 – very high consumption/pressure

Water body	Fish stock	Pop. maintaning	Drinking water	Other water	Mud	Reed	Energy	Habitats	Water quality	Buffer zones on shores	Climate regulation	Active recreation	Rec. fishing and hunting	Passive recreation	Science	Education	Aesthetics	Symbols	Important species
Aidu Quarry L.	0	0	0	0	0	0	0	3	0	0	0	4	3	2	2	0	4	0	3
L. Uljaste	0	0	0	0	0	0	0	2	0	0	0	-	-	-	2	0	3	-	2