DTP-PAC2-PA4 (PA04-Water quality) project

# Ship noise and water wave measurement on the Hungarian section of the Danube

## Background study

## 2022

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# 1. Introduction

The aim of the Hungarian TEN-T Inland Waterway Development Program (Improving the Navigability of the Danube) is to develop a multimodal transport corridor that manages inland waterway transport and environmental and ecological objectives in a coordinated way, taking into account the socio-economic functions of the waterway. The most important element of the waterway quality (navigability) requirements for the Danube is the provision of barrier-free traffic conditions for ships and their convoys with a standard draft of 25 decimetres and a carrying capacity of 1300-1600 tons in European international navigation at least 300 days a year.

The 5th action of the priority area of the EU Danube Region Strategy water quality (EUSDR PA4) aims to support measures enabling the migration of fish in the Danube basin. To this end, the Ministry of Foreign Affairs and Trade, as the co-coordinator of the EUSDR PA4 area, within the framework of the DTP-PAC2-PA4 (PA04-Water quality) project for the preparation of e-learning material on the topic "Investigation of the effect of noise and waves caused by shipping on the fish species living in the affected aquatic environment" intends to provide on-site measurements and the preparation of a background/fundamental study (DT223 Development of a study as background document for pilot e-learning material). The investigation is linked to the planned interventions of the Hungarian TEN-T inland waterway development (improving the navigability of the Danube) program and gives an opportunity to get an idea of the impact of intensive ship traffic on spawning and fish-nursery sites, on breeding and migrating fish stocks.

In order to implement the above tasks, the Ministry of Foreign Affairs and Trade commissioned the Len-Mag-Duett joint venture to carry out noise measurements on the jointly designated river sections and prepare a study based on them.

# 2. The related legal background (shipping, noise pollution) - Hungarian and international regulations

**2.1. Hungarian shipping laws**

- Belgrade Convention on the Order of Navigation on the Danube (Act XIII of 1949)
  The Convention applies to the navigable part of the Danube, which extends from Kelheim to the Black Sea and flows into the sea through the Sulina Canal. The Danube Commission established by the Convention has established the shipping regulations that the Danube states and the Boards of Directors are obliged to take into account with regard to navigation on the Danube.
- Decree of the Ministry of National Development 57/2011 on the rules of water transportation. (XI.22.) (Shipping Regulations)
  The Shipping Regulations establish the rules of water transport, which are included in Annex 1 of the regulation.
- Government Decree 261/2008 on the water transport of passengers. (XI. 3.)
  The law deals with the integration of shipping activities into the international transport system, the fulfilment of obligations under international agreements, the state and local government tasks of water transport, the personal and material conditions for the continuation of water transport activities, and the administration of water transport.
  The law defines the state tasks related to shipping:
  - the elaboration and organization of the implementation of shipping development concepts,
  - to determine the order of navigation and to perform its official functions,
  - development and maintenance of the navigable waterway in state-owned waters,
  - definition of the support system necessary for the proper operation and development of national public ports and border ports,
  - ensuring the conditions for rail and road connections to national public ports.
- CXLI law of 2005 on the promulgation of the Budapest Convention on the Contract for the Carriage of Goods by Inland Waterways (CMNI)
  Transmits draft resolution calling for the implementation by Governments of the provisions of the 2 Protocols formerly annexed to the draft CMNI Convention.

This Convention is applicable to any contract of carriage according to which the port of loading or the place of taking over of the goods and the port of discharge or the place of delivery of the goods are located in two different States of which at least one is a State Party to this Convention. If the contract stipulates a choice of several ports
of discharge or places of delivery, the port of discharge or the place of delivery to which the goods have actually been delivered shall determine the choice.

Defines:

- the rights and obligations of the contracting parties,
- the transport documents,
- the liability of the carrier,
- the claims period,
- the limits of contractual freedom,
- the supplementary provisions,
- the declarations concerning the scope of application, and
- the final provisions.

➢ Government Decree 219/2007 on river information services. (VIII. 15.)

That is regulating the roles and responsibilities of the RIS (*River Information Services*) authority and RIS operator/provider. In this context the National Transport Authority is the designated RIS authority that has contracted RSOE as RIS provider after public procurement.

➢ Decree of the Ministry of National Development 45/2011 on the professional and operational rules of river information services. (VIII. 25.)

Stipulates operational regulatory cases and the compulsory use of AIS (tracking) devices for skippers, with the consideration of the corresponding ship types and parameters.

### 2.2. EU shipping legislation

➢ Regulation (EEC) No 3921/91 laying down the conditions under which non-resident carriers may transport goods or passengers by inland waterway within an EU country

The regulation builds upon the general principles of equality of treatment and freedom to provide services, whereby non-resident carriers should be allowed to carry out national transport services (‘cabotage’) on inland waterways in the EU. It lays down the following conditions: carriers may temporarily carry out cabotage services, without having to set up a registered office, provided that they are established in an EU country in accordance with its legislation and that they are entitled to transport goods or persons internationally by inland waterway; carriers may only use vessels owned by :EU residents or EU-country nationals, or legal persons with their registered office in an EU country and in which EU-country nationals hold a majority interest.

- Regulation (EC) No 1356/96 on common rules applicable to the transport of goods or passengers by inland waterway between EU countries with a view to establishing freedom to provide such transport services.

Regulation aims to ensure that operators who transport goods or passengers by inland waterway are allowed to carry out transport operations between EU countries and to transit through them without discrimination on grounds of nationality or place of establishment, if they:

- are legally established in an EU country and are entitled in that country to carry out international transport of goods or passengers by inland waterway and use vessels which are registered in an EU country;
- satisfy the conditions of Regulation (EEC) No 3921/91.

Special rules on the rights of operators from non-EU countries exist under the Revised Convention for the Navigation of the Rhine (Convention of Mannheim) and the Convention regarding the Regime of Navigation on the Danube (Belgrade Convention), or may arise from other international agreements or treaties to which the EU is a party.

- Commission regulation (EC) No 415/2007 of 13 March 2007 concerning the technical specifications for vessel tracking and tracing systems referred to in Article 5 of Directive 2005/44/EC of the European Parliament and of the Council on harmonised river information services (RIS) on inland waterways in the Community.

  This Regulation defines the technical specifications for vessel tracking and tracing systems in inland waterway transport.

- Commission regulation (EC) No 416/2007 of 22 March 2007 concerning the technical specifications for Notices to Skippers as referred to in Article 5 of Directive 2005/44/EC of the European Parliament and of the Council on harmonised river information services (RIS) on inland waterways in the Community

  This Regulation defines the technical specifications for Notices to Skippers.

### 2.3. Noise exposure regulations

- Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise.

This Directive relating to the assessment and management of environmental noise was adopted in 2002. Directive 2002/49/EC did not have many antecedents. Since the mid-1970s, European Union (further in the text – EU) had identified noise as a serious environmental problem, but quickly qualified it as a local problem. This had the consequence that EU institutions were (reluctantly) disposed to look at noise issues as a problem which concerned EU to the extent that noisy products - vehicles, airplanes, machinery, motor boats, - were traded and circulated freely within EU.

Legislative standards could then be introduced in order to reduce the level of noise which emanated from the specific product. However, the problem of noise as it affected residential areas, urban agglomerations or individual citizens, was considered a problem that was, according to the subsidiarity principle a matter for Member States to deal with. EU, therefore, concentrated its activities as looking at fixing uniform sound levels (emission limit values for noise) for new products, but left the care to minimise the impact of these sound levels on humans very largely to the Member States.

European Commission did not discuss the option of setting binding quality levels for noise, i.e., levels which were not to be exceeded in a given area or during a given time of the day (for example at night). It rather concentrated on the possibility of further reducing the noise emissions from products.

The Green Paper did not lead to a broad discussion on the protection against noise pollution. In particular the transport administrations and the car, railway and aircraft industries at a Member State and at EU level objected to the establishment of EU quality limit values for noise. This was consequent from their point of view, as the noise emanating from vehicles, railways and airplanes was monitored by the transport sector, while quality limit values would be developed and monitored by the environ-mental sector. This discussion finally ended with the adoption of Directive 2002/49/EC.

In the Green Paper on Future Noise Policy, the Commission addressed noise in the environment as one of the main environmental problems in Europe. This Directive should inter alia provide a basis for developing and completing the existing set of Community measures concerning noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery, and for developing additional measures, in the short, medium and long term, but it does not deal with environmental noise in the water.

- ISO 3740:2019(en) Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards.

  For many users of machinery, equipment and products, the control of noise is a major issue which requires effective exchange of acoustical information. In this context, the main flow of information goes from the manufacturer to the purchaser, installer or user of the machines and products to describe the generated sound. In particular, information on source airborne noise emission is desired. Therefore, the sound power level, as the major parameter characterising airborne noise emission of sound sources, needs to be determined by measurement.

  However, such measurements are only useful if the conditions under which they are carried out are specified; they yield defined acoustical quantities, and they are taken with standardized instruments.
- ISO 18405:2017 Underwater acoustics — Terminology

  This standard defines terms and expressions used in the field of underwater acoustics, including natural, biological and anthropogenic (i.e. man-made) sound. It includes the generation, propagation and reception of underwater sound and its scattering, including reflection, in the underwater environment including the seabed (or sea bottom), sea surface and biological organisms. It also includes all aspects of the effects of underwater sound on the underwater environment, humans and aquatic life. The properties of underwater acoustical systems are excluded.
- ISO 17208-1:2016 Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes.

  This standards specifies the general measurement system, procedure, and methodology used for the measurement of underwater sound from ships under a prescribed operating condition. It does not specify or provide guidance on underwater noise criteria or address the potential effects of noise on marine organisms.

  The resulting quantities are based on the root-mean-square sound pressure levels (SPL), herein used synonymously with sound pressure level or SPL measured in the far field of the ship and normalized to a distance of 1 m and reported in one-third octave bands . The result of these measurements is called "radiated noise level". The underwater sound pressure level measurement is performed in the geometric far field and then adjusted to the

1 m normalized distance for use in comparison with appropriate underwater noise criteria.

ISO 17208-1:2016 is applicable to any and all underway surface vessels, either manned or unmanned. It is not applicable to submerged vessels or to aircraft. The method has no inherent limitation on minimum or maximum ship size. It is limited to ships transiting at speeds no greater than 50 kn (25,7 m/s). The measurement method smooths the variability caused by Lloyd's mirror surface image coherence effects, but does not exclude a possible influence of propagation effects like bottom reflections, refraction and absorption. No specific computational adjustments for these effects are provided in this part of ISO 17208. A specific ocean location is not required to use this part of ISO 17208, but the requirements for an ocean test site are provided.

## 3. The noise pollution from vessels affecting fish populations

Noise is ubiquitous, and the anthropogenic noise is increasing in many environments due to increases in transportation and the exploration for and exploitation of energy sources. While humans and animals are adapted to deal with natural levels of ambient noise, increased ambient noise levels from human activities can potentially have a variety of adverse effects. These could include noise-induced hearing loss and auditory system damage, temporary hearing loss (called Temporary Threshold Shift or TTS), and masking of communication and other important biological sounds (e.g., Adler et al. 1992; Buck et al. 1984; Clark 1991; Le Prell et al. 2012; Miller 1974; Ryals et al. 1999). Increased noise can also cause behavioural and/or physiological changes such as increased stress, sleep loss, and hormonal changes (Miller 1974; Brumm 2004). Moreover, in water, high intensity signals can damage non-auditory tissues (e.g., Cudahy & Parvin 2001; Halvorsen et al. 2012a) and result in death, although death has rarely been documented except when animals are exposed to very high intensity impulsive sound (e.g., Caltrans 2001).

While relatively little is known about the effects of man-made sounds on fishes, a good deal may be inferred about the potential effects, and approaches to the study of those effects, from the wealth of data available from humans and laboratory animals (Buck et al. 1984; Clark 1991; Le Prell et al. 2012; Miller 1974; Passchier-Vermeer & Passchier 2000). However, it has been difficult to reach a clear consensus on the causal relationships between man-made noise levels and these various adverse effects in fishes (see Popper & Hawkins 2012).

One difficulty in understanding the effects on fishes is that while most humans have very similar auditory capabilities and sensitivities, the same is not true for all species or even for closely related species (e.g., Dooling 1982; Fay 1988; Ladich & Fay 2013)

There is a considerable amount of data on these effects for humans and some terrestrial animals, but far fewer data on marine mammals (e.g., Southall et al. 2007) and fishes (e.g., Popper & Hastings 2009). However, given the well-documented and long history of adverse consequences of elevated noise on humans and other animals, including hearing loss, masking, stress, behavioural and physiological changes, sleep disturbances, and changes in feelings of well-being (Miller 1974), it is likely that there is a similar range of effects in other species, including fishes and other aquatic animals.

Greatest masking of communication signals like speech occurs when the frequency spectra of the speech signal and the noise are very similar. According to this concept, a signal can only be heard if its level within a given frequency band is proportional to the level of the masker within that bandwidth (Fletcher 1940). So-called "power spectrum model" of hearing, also means that masker energy in frequency regions outside a "critical band" of frequencies around the signal frequency do not significantly interfere with perception of the target signal. Though the data from fish are limited, in practical terms this means that the spectrum and the levels of both the man-made noise and the signal the animal is trying to hear are the critical variables for determining how detrimental a certain noise is for an animal.

Over the past decades it has become apparent that man-made noise also has the potential to impact the lives of aquatic organisms, including sharks, bony fishes, marine turtles, and marine mammals (reviewed in Southall et al. 2007; Normandeau Associates 2012; Popper & Hawkins 2012). While there is strong evidence that very intense, and particularly impulsive, sounds can damage tissues and potentially result in mortal effects (e.g., Bolle et al. 2012; Casper et al. 2012, 2013a, b; Halvorsen et al. 2012a, b; Hastings et al. 2008; McCauley et al. 2003; Popper et al. 2007), far more fish are likely to be exposed to sounds at some distance from the source where the intensity is lower that nearer the source and any effects are likely to be behavioural rather than physical. Moreover, in addition to behavioural effects resulting from impulsive sounds, it is also highly likely that general and continuous increases in background sounds, such as those produced by shipping and other wind farm operation may have behavioural effects on fishes. Effects may range from only small, and inconsequential, changes in behaviour to long-term effect on reproduction or feeding. However, very little is known about potential behavioural effects of sound on fishes (e.g., Slabbekoorn et al. 2010; Normandeau Associates 2012).

### 3.1. The effect of waves caused by wessels affecting fish populations

Engineering in large river systems in Europe has resulted in a strong reduction of natural shoreline structures. Within this altered situation, navigation induced wave wash has a strong and cumulative effect on riverine fish recruitment and, hence, contributes to the general ongoing decline of native fish stocks in inland waterways. While the ship is under way, further influences can be observed in terms of wake and splash, variation in speed and turbidity of the water.

The effect of waves caused by ships has already been investigated from a water engineering point of view (Krouzecky et al., 2013 and Liedermann et al., 2009), however, these studies are based on wave theoretical parameters, characteristic wave heights, wavelengths, etc. emphasis was placed on its definition. Experts (Fleit Gábor, Baranya Sándor, Krámer Tamás, Józsa János) of the Budapest Technical University, Department of Water Engineering and Water Management investigated the hydrodynamic effects of ship-induced waves in the coastal zone of the Hungarian Danube, with particular emphasis on tangential stresses on the seabed. Local increase in bottom shear stress may detach macroinvertebrates and eggs from the substrate, which in most cases is lethal for them.

Ship-induced waves can affect on fish juvenile in littoral parts. It is possible to observe the influence of waves on the structure of fish assemblies in the exposure gradient. Increased wave exposure can disturb sediments and cause a loss of habitat. The early life history stages of riverine fish their nursery zones generally located in shallow areas with low current and higher water temperatures. Ship induced wave wash causes the following impacts on fish during their early life history stages: 1) short-term dislocation of suitable larval and juvenile fish habitats due to wake and splash; 2) water velocities during ship passages frequently exceed maximum swimming performances of 0+fish; and 3) suspended solids concentrations in the inshore habitats increase dramatically and limit the foraging efficiency of young of the year fish (YOY) (Kuzera-Hirtzinger at all 2008).

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## 4. Short presentation of the Hungarian TEN-T inland waterway development (improving the navigability of the Danube) program

Sustainable mobility is a clear objective of the Europe 2020 strategy for smart, sustainable and inclusive growth and of the Common European Transport Policy. Inland waterway transport has a relatively low environmental impact (3.5 times less carbon dioxide emissions per tonne- kilometre than lorries) and is therefore considered an important mode of transport. The Rhine and Danube, linked by the Danube-Main-Rhine Canal, provides a direct link between eleven countries along a 3,500 km stretch from the North Sea to the Black Sea. The Danube is thus the backbone of the region. However, the development of waterways into a shipping corridor must go hand in hand with the development of modern and efficient intermodal ports to allow shipping to be integrated with rail and road transport.

On the stretch of the Danube between the border between Bős and the south (i.e. on the territory of Hungary), however, neither the navigation parameters provided for in the AGN Convention nor those in the new 2013 Danube Commission Recommendation are met.

This is why it is necessary to develop the parameters of the TEN-T waterway network, the Danube, to the core network level in our country as well. At the international level, it is also important to improve the navigation parameters of the Danube as an international waterway, which can facilitate the growth of inland waterway freight transport. The aim is to increase the number of sailing days by developing waterborne transport to the extent permitted by the natural environment and, at the same time, to develop port infrastructure on the basis of demand, taking into account water protection and ecological aspects.

By 2030, 30% of road freight over 300 km will have to be carried by other modes, such as rail or waterways, and 50% by 2050, thanks to efficient green freight corridors. Achieving this goal will also require the development of appropriate infrastructure. Of the 416 km long total Hungarian Danube section (1849-1433 fkm[1]), only the 378 km section between 1811 fkm and 1433 fkm is considered navigable, as the section of the main branch of the Hungarian Danube from Rajka (1849 fkm) to Szap (where the lower section of the Bősi/Gabcikovo water step

[1] „fkm” is river kilometre

canal reconnects to the Danube, 1811 fkm) is not navigable by large vessels. Thus, the Programme's planning area also covers this section.

“The objective is a fully operational EU-wide TEN-T "core network" by 2030 and a high quality, high capacity network with associated information services by 2050.

By 2050, all airports in the core network should be connected to the rail network, preferably at high speed; adequate connections should be provided between all major seaports and the rail freight system and, where possible, the inland waterway system."

The Hungarian National Strategy for Transport Infrastructure Development (NTS) also sets out this task, stating that "there has been no significant change in the field of navigability in waterborne transport over the last decade. The navigability of the Danube, as a Helsinki corridor, with vessels of 2.5 m draught and a carrying capacity of 1,300 to 1,600 tonnes is currently not met in the Danube section in Hungary, as vessels can only navigate with draught restrictions for part of the year depending on the water conditions. Thus, one of the important tasks remains to ensure the navigability of the Danube as a Helsinki corridor in accordance with the principles of sustainable development. ”

# 5. Material and method

The measurements were carried out in the period between April 6-23, 2022. The names and GPS positions of jointly designated river sections are given in Table 1 and illustrated in Figure 1:

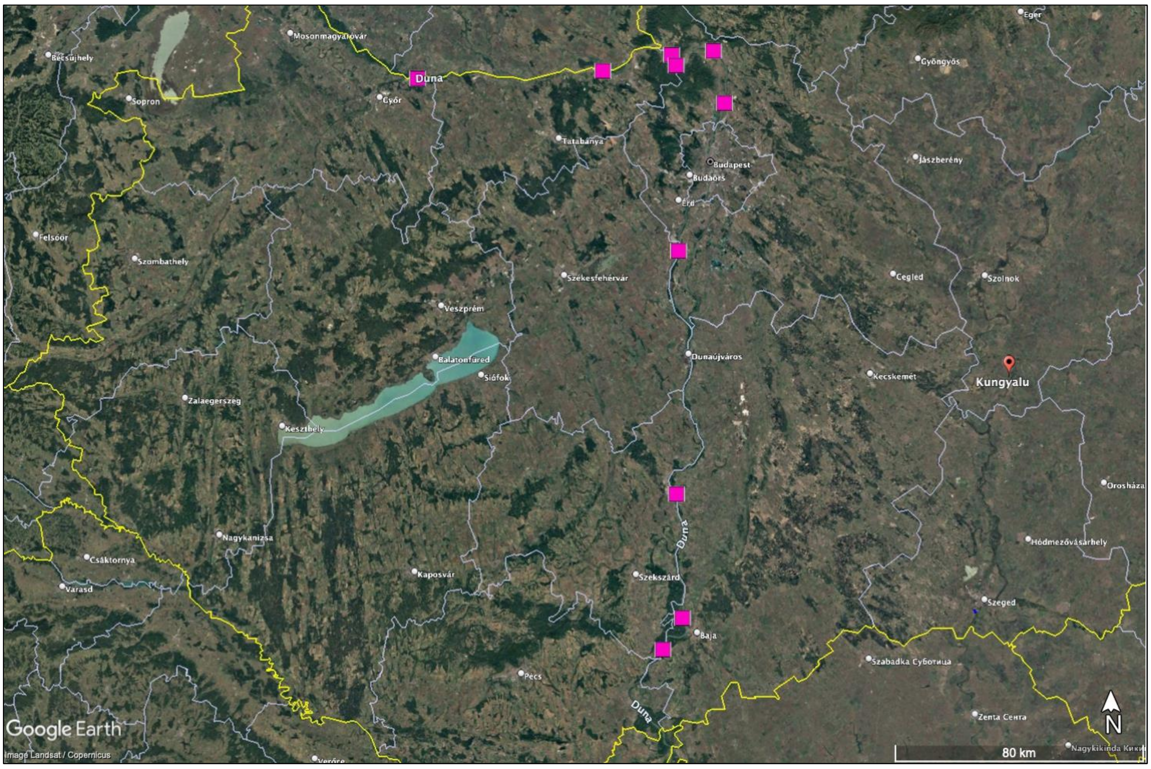



Figure 1: an overview map of the measurement sites

Table 1: GPS position of measurement sites

| S.n. | River km | Measurement site | | WGS_X | WGS_Y |
|---|---|---|---|---|---|
| 1. | 1791 | Gönyű | near the Erebe Islands | 47,73923 | 17,82601 |
| 2. | 1729 | Tát | over the Tát island | 47,75655 | 18,60832 |
| 3. | 1704 | Pilismarót | near small boat port | 47,79946 | 18,90031 |
| 4. | 1700 | Nagymaros | small boat port opposite Dömös | 47,76964 | 18,91897 |
| 5. | 1684 | Vác | Kompkötő island | 47,80888 | 19,07709 |
| 6. | 1666 | Dunakeszi | near Szürkő island | 47,66138 | 19,11971 |
| 7. | 1614 | Szigetújfalu | right river bank, Ercsi | 47,24922 | 18,91519 |
| 8. | 1524 | Uszód | near the reef | 46,56950 | 18,89225 |
| 9. | 1484 | Baja | near the estuary of the Grébeci-Danube branch | 46,22211 | 18,90922 |
| 10. | 1468 | Szeremle | under Sugovica estuary | 46,13462 | 18,82755 |

We monitored the real-time Danube ship traffic. The determination of the ship's speed and exact position was carried out with the "Automatic Identification System" (AIS).

The current position of the ships was determinated using global positioning systems (GPS).


Purpose of measurements: underwater noise measurement and measurement of the strength of waves when ships pass by.

Device type SVAN 979 Class 1 Sound Analyser (Serial No.21030) and the B&K 8103 hydrophone and B&K 2647-B charge amplifier connected to the measuring instrument with a AO-0531-D030 mounted cable. The measurement settings of the instrument were as follows:

Device function 1/3 Octave (45 filters with centre frequencies 0.8 Hz ÷ 20 kHz)

Leq/RMS integration Linear

Statistics detector Linear

Integration period Infinity

Logger step 1 s

Linear operating range to IEC 61672 22 dBA Leq÷140 dBA Peak

Total measurement range 12 dBA Leq÷140 dBA Peak

Frequency range 3.15 Hz ÷ 20 kHz

Measurement of the wave intensity was recorded by means of a portable vane anemometer (SEBA-Mini Current Meter M1 [imp./s]). To ensure that the anemometer was always oriented in the wave direction, it was arranged on a vertical axis with a vane (photo 1-3).

Measurement results downloaded and analysed with the use of SvanPC++ software. The noise level of the ship's noise source was calculated with the SoundPLAN software.


Photo 1-3: the measuring instruments prepared for measurement

We performed seven measurements at one measurement point in the division below:

| S.N. | Ship type | direction |
|---|---|---|
| 1. | background noise level | |
| 2. | Pushtow with x cargo barges | down |
| 3. | | up |
| 4. | Motor freighter | down |
| 5. | | up |
| 6. | Passanger ship, Cruise ship | down |
| 7. | | up |

Pushtow with x cargo barges

Motor freighter

Passanger ship, Cruise ship

# 6. Short presentation of sampling sites (with photo documentation)

**1. GÖNYŰ**

The measurement site was in the Erebe Islands area. The island group formed from alluvial reefs. The Danube is about 10-20 meters away, there are many backwaterss. This bay is protected from the waves of ships.


The fish fauna of the region consists of the following species (Györe et al 2007.):

- The common bleak (*Alburnus alburnus*) is a small freshwater coarse fish of the cyprinid family.
- The asp (*Aspius aspius*) is the only piscivorous species in the family Cyprinidae. In its early juvenile phase feeds on crustaceans, bottom fauna, terrestrial insects.Asp is classified on the IUCN Red List as a species of 'Least concern', though locally threatened by river engineering projects.

- Barbus (*Barbus barbus*) is a genus of ray-finned fish in the family Cyprinidae. Lives in the deeper, faster-flowing upper reaches of rivers with stony or gravel bottom (barbel zones). Feeds chiefly on benthic invertebrates, such as small crustaceans, insect larvae, molluscs, mayfly and midge larvae. Males assemble at spawning grounds and follow ripe females, often with much splashing, to shallow water.
- White bream (*Blicca bjoerkna*) regarious and frequents stagnant waters of lakes and reservoirs, rivers and canals with calm waters. They are predominantly nocturnal species and feed mostly on benthic invertebrates. This species graze upon aquatic invertebrate (zooplankton, molluscs and chironomids) and penetrate sediment.
- Prussian carp (*Carassius auratus gibelio*) is considered an alien fish species in the River Danube. Feeds on zooplankton, benthic invertebrates, plant material and detritus.
- The common nase (*Chondrostoma nasus*) is a European potamodromous cyprinid fish. They inhabit moderate to fast-flowing large to medium sized rivers with rock or gravel bottom. Feeds chiefly on detritus, phytoplankton and other plants )benthic algae/weeds).
- Pike (E*sox lucius)* is a highly successful species of brackish and freshwater fish. Adults of this species feed mainly on fish, but will also feed on frogs and crayfish.
- Common chub (*Squalius cephalus*) is a European species of freshwater fish in the carp family Cyprinidae. It frequents both slow and moderate rivers, as well as canals and still waters of various kinds. The larvae and juveniles prefer rather shallow habitats along shorelines and these smaller fish have a varied diet of aquatic and terrestrial animals[5] while the large, solitary adults prey mainly on freshwater shrimp and small fishes.
- The ide (*Leuciscus idus*), or orfe, is a freshwater fish of the family Cyprinidae found in larger rivers, ponds, and lakes. Winter time it schools in clean, deep water, moving into shallow freshwater to spawn in the spring. The ide feeds on insect larvae, molluscs, worms, crustaceans and vegetation. Larger individuals feed on fish like Roach and Common bleak.
- The common dace (*Leuciscus leuciscus*) is a species of freshwater ray-finned fish from the family Cyprinidae. Inhabits moderate to fast-flowing large streams to large rivers with rock or gravel bottom. The common dace is considered tolerant of anthropogenic pressure. It is a feeding generalist (i.e. debris, small invertebrates, etc.) but usually has a high plant content in its diet.
- The Europen perch (Perca fluviatilis) are a widespread species of predatory freshwater fish. They were found to feed on benthic organisms from November

until April, on benthos and plankton during May and June and on perch fry and zooplankton from July until October.

- The roach (*Rutilus rutilus*) is a freshwater fish of the family Cyprinidae, native to most of Europe and western Asia. It is a feeding from zooplankton to benthic food (chironomids, molluscs, Dreissena mussels).
- The zander (*Sander lucioperca*) is a species of ray-finned fish from the family Percidae. Adults inhabit large, turbid rivers and eutrophic lakesand estuaries. Feed mainly on gregarious, pelagic fishes. Males are territorial and spawning with female, usually in turbid water and at 1-3 m depth.
- The common rudd (*Scardinius erythrophthalmus*) is a herbivorous bentho-pelagic freshwater fish. The rudd is a potential pest in many areas, due to consumption of native plants; as it is omnivorous it can shift its diet to plants, unlike most native fishes. Experiments demonstrated that it might be putting vulnerable aquatic communities at risk. It has a wide tolerance to a variety of habitats, which contributed to its wide distribution.

## 2. TÁT

The measurement site was over the Tát island. The dead channel on the right side of the island is protected from the waves of ships an ideal spawning and nursing habitats for lithophilic and phytophilic fish species. The species list of the fish fauna is similar to that described in the Gönyű region.


### 3. PILISMARÓT

The measurement site was near small boat port. About 1 km below the estuary of Pilismarót Bay. The approximately 400-hectare bay provides ideal conditions for fish spawning and is a perfect fish nursing habitat for phytophilic fish species. This bay is protected from the waves of ships. The species list of the fish fauna is similar to that described in the Gönyű region.

In the case of all three types of vessels going up and down, the measurement results measured at this point were used to calculate the level of the noise source.

The sound pressure measurement was taken at a depth of 1 meter at the edge of the coast, approximately 100 meters from the fairway.


## 4. NAGYMAROS

The measurement site was near small boat port opposite Dömös, approximately 1.5 kilometers above the estuary of the upper bay of Visegrád. this bay is protected from the waves of ships. The species list of the fish fauna is similar to that described in the Gönyű region, but it was supplemented with sterlet and the pigo. These fish species mainly live in the Danube branch in Szentendre, which is free of boat traffic. The small passenger boats plying here do not make much noise.

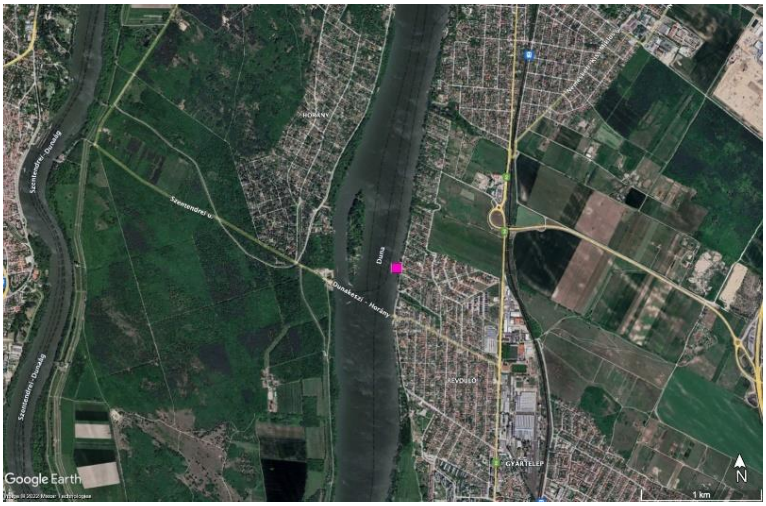
- The sterlet (Acipenser ruthenus) is a relatively small species of sturgeon from Eurasia native to large rivers. This species has declined throughout its native range and is considered vulnerable by the IUCN. The sterlet's main source of food is benthic organisms; they commonly feed on crustaceans, worms, and insect larvae.
- The pigo (Rutilus pigus) is a species of freshwater fish in the roach genus Rutilus of the family Cyprinidae, that lives in the calm, deep waters of lakes and rivers. Occurs in small groups. Feeds in invertebrates, algae and detritus. Moves to shallow parts of rivers to spawn.


## 5. VÁC

The measurement site was near Kompkötő island. On the left side of the island is an artificial bay, which is an ideal spawning and nursing habitat for fish. this bay is protected from the waves of ships. The species list of the fish fauna is similar to that described in the Nagymaros.


## 6. DUNAKESZI

The measurement site was near Szürkő island. On the right side of the island is an artificial bay, which is an ideal spawning and nursing habitat for fish. this bay is protected from the waves of ships. The species list of the fish fauna is similar to that described in the Nagymaros.




## 7. SZIGETÚJFALU

The measurement site was on the right river bank, near ferry beetwen Ercsi and Szigetújfalu. In this section no dead channels, but there is a significant natural population of sterlet here. In the Nagymaros described a species list of the fish fauna, which is supplemented by five species of fish. These are the following:

- The Vimba bream (*Vimba vimba*), , is a cyprinid fish species native to Europe. Feeds mainly on small molluscs and insect larvae. Breeds in riffles in shallow, fast-flowing streams and rivers on gravel.
- The common bream (*Abramis brama*), is a European species of freshwater fish in the family Cyprinidae. Feed on insects, particularly chironomids, small crustaceans, mollusks and plants. Larger specimens may feed on small fish. Juveniles feed on zooplankton.
- The common carp (*Cyprinus carpio*) is a freshwater fish species in the family Cyprinidae. Prefer warm, deep, slow-flowing and still waters, such as lowland rivers. Adult carp are considered to be an omnivorous species utilising a relatively high proportion of animal prey in its diet, mainly chironomids and other benthic invertebrates.
- The wells (*Silurus glanis*) is the largest-bodied European freshwater fish. A nocturnal predator, foraging near bottom and in water column. Larvae and juveniles are benthic, feeding on a wide variety of invertebrates and fish. Adults prey on fish and other aquatic vertebrates.
- The tench (Tinca tinca) is a fresh- and brackish-water fish of the order Cypriniformes found throughout Eurasia from Western Europe. The carnivorous fish consumes on detritus, plant materials, zooplankton, insects and a variety of benthic animals:, amphipods, crayfish, gastropods and small bivalves.


**8. Uszód**

The measurement site was near the reef. The channel on the right side of the reef is an ideal spawning and nursing habitat for fish. In the Szigetújfalu described a species list of the fish fauna, which is supplemented by one species of fish. This is the following:

- The burbot (*Lota lota*) is only member of Lotidae family which lives in freshwater. Active at night or appearing at the time of day just before the sun goes down, or just after the sun rises, when the light is not bright. Fry and juvenile burbot feed mainly on benthic invertebrates. Adults largely predatory, taking small fish as well as fish eggs.

**9. BAJA**

The measurement site was near the estuary of the Grébeci-Danube branch. This shallow water is an ideal spawning and nursing habitat for fish. The species list of the fish fauna is similar to that described in the Uszód.


## 10. SZERELME

The measurement site was near the estuary Sugovia. Sugovica, also known as Kamarás-Danube, is a tributary of the Danube. This tributary is an ideal spawning and nursing habitat for fish. The species list of the fish fauna is similar to that described in the Uszód.


# 7. Presentation of measurement results

## 1. GÖNYŰ

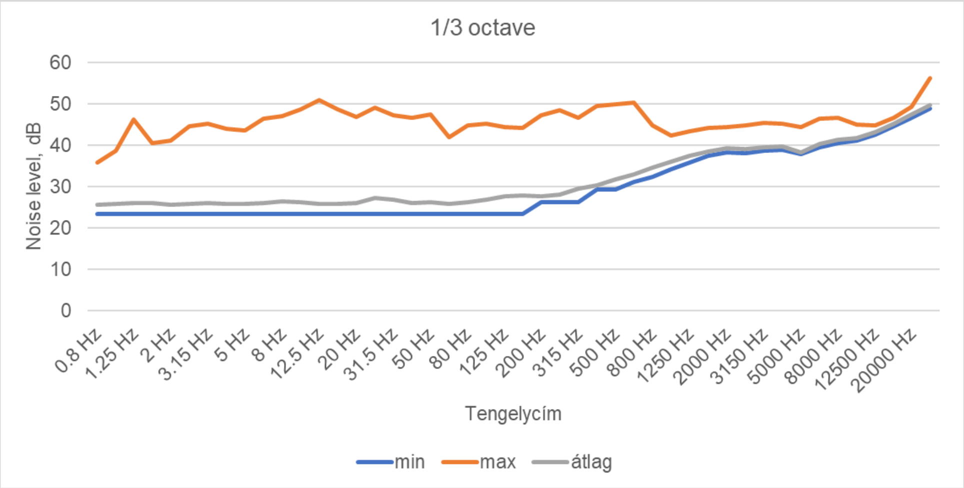
Values marked in yellow indicated the modelled noise level generated by the vessel are indicated below. For a direct noise source, this is two and a half times the base noise level. For this reason, migratory fish (e.g. sturgeon, catfish, barbel) living near the bottom, will certainly be forced to leave their habitat.

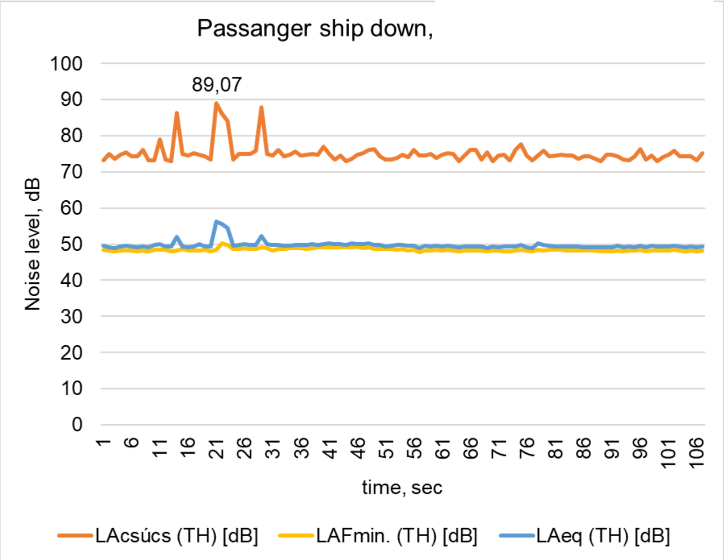
| S.N. | Ship type | | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | | | **50,26** | **49,36** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| | | | | | **source noise level (calculated)** | **133,6** | **127,7** | | |
| | | | | | **rate of increase (C/M)** | **65%** | **71%** | -1% | -2% |
| 3. | Pushtow with 4 cargo barges | | 6 | up | noise level (measured) | 97,18 | 83,41 | 49,6 | 49,2 |
| | | | | | **source noise level (calculated)** | **150,2** | **136,4** | | |
| | | | | | **rate of increase (C/M)** | **54%** | **64%** | -1% | -0,5% |
| 4. | Motor freighter | | 13,5 | down | noise level (measured) | 90,93 | 80,66 | 50,6 | 49,1 |
| | | | | | **source noise level (calculated)** | **144** | **133,7** | | |
| | | | | | **rate of increase (C/M)** | **58%** | **66%** | 1% | 0% |
| 5. | Motor freighter | | 9,5 | up | noise level (measured) | 95,7 | 83,1 | 50,1 | 49,5 |
| | | | | | **source noise level (calculated)** | **148** | **136,1** | | |
| | | | | | **rate of increase (C/M)** | **55%** | **64%** | 0,5% | 0% |
| 6. | Passanger ship, Cruise ship | | 18 | down | noise level (measured) | 97,51 | 87,7 | 50,1 | 49,6 |
| | | | | | **source noise level (calculated)** | **150,5** | **140,7** | | |
| | | | | | **rate of increase (C/M)** | **54%** | **60%** | 0,5% | 0% |
| 7. | Passanger ship, Cruise ship | | 12 | up | noise level (measured) | 99,12 | 87,7 | 50,1 | 49,3 |
| | | | | | **source noise level (calculated)** | **152,1** | **140,7** | | |
| | | | | | **rate of increase (C/M)** | **53%** | **60%** | 0,5% | 0% |

| S.N. | Ship type | direction | wawe intensity [imp./s] | wave height [cm] |
|---|---|---|---|---|
| water depth in the measuring point – 0,7 m | | | | |
| 1. | Pushtow with x cargo barges | down | 33 | 15 |
| 2. | | up | 41 | 20 |
| 3. | Motor freighter | down | 31 | 22 |
| 4. | | up | 39 | 28 |
| 5. | Passanger ship, Cruise ship | down | 36 | 42 |
| 6. | | up | 43 | 51 |

## 2. TÁTISZIGET

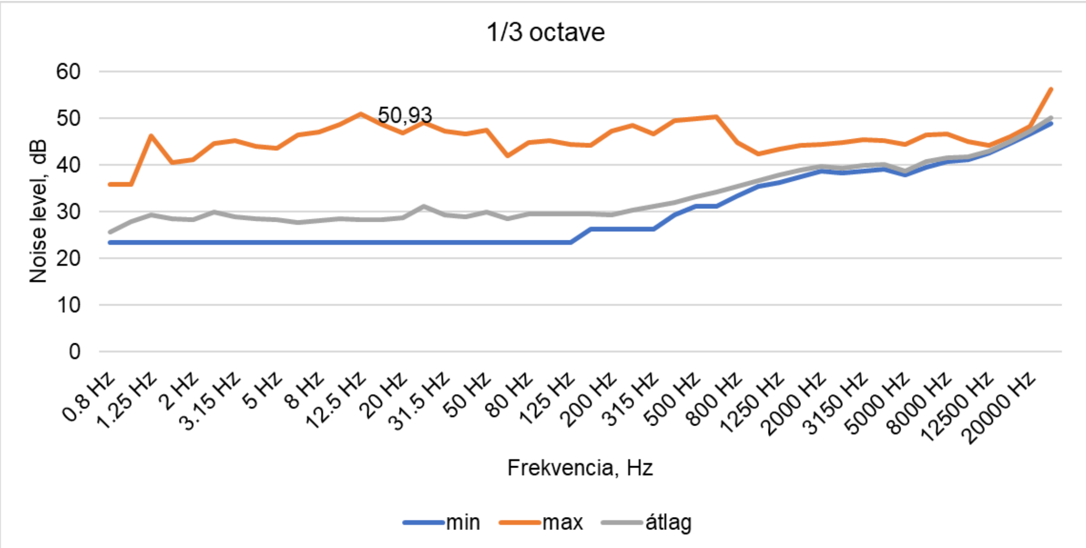
| S.N. | Ship type | TÁTISZIGET | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **76,3** | **52,4** | **48,72** | **47,69** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 4 cargo barges | | 6 | up | noise level (measured) | 97,2 | 83,4 | 49,6 | 49,2 |
| 4. | Motor freighter | | 13,5 | down | noise level (measured) | 90,9 | 80,7 | 50,6 | 49,1 |
| 5. | Motor freighter | | 9,5 | up | noise level (measured) | 95,7 | 83,1 | 50,1 | 49,5 |
| 6. | Passanger ship, Cruise ship | | 23,5 | down | noise level (measured) | 89,1 | 63,3 | 49,7 | 47,8 |
| 7. | Passanger ship, Cruise ship | | 17 | up | noise level (measured) | 89,1 | 63,3 | 47,8 | 49,7 |

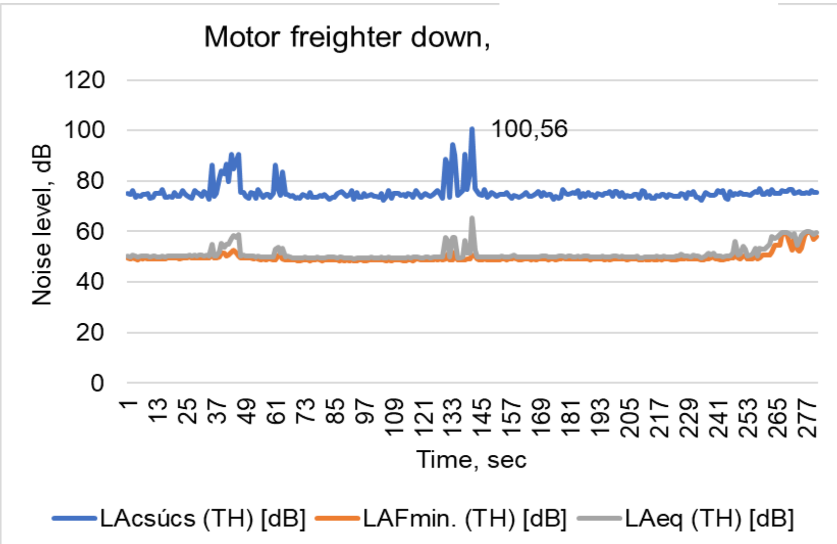


## 3. PILISMARÓT

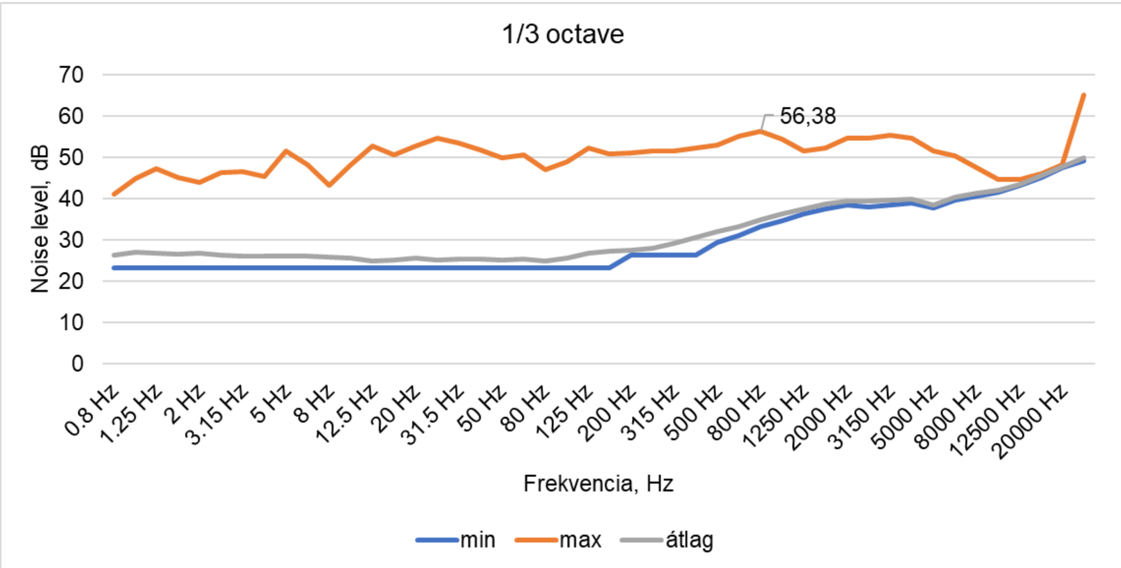
| S.N. | Ship type | PILISMARÓT | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **77,0** | **52,0** | **49,66** | **48,41** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 4 cargo barges | | 6 | up | noise level (measured) | 97,18 | 83,41 | 49,6 | 49,2 |
| 4. | Motor freighter | | 18 | down | noise level (measured) | 90,93 | 80,66 | 50,6 | 49,1 |
| 5. | Motor freighter | | 13 | up | noise level (measured) | 100,6 | 72,0 | 49,8 | 49,3 |
| 6. | Passanger ship, Cruise ship | | 19 | down | noise level (measured) | 89,07 | 63,25 | 49,7 | 47,8 |
| 7. | Passanger ship, Cruise ship | | 17 | up | noise level (measured) | 89,07 | 63,25 | 47,8 | 49,7 |

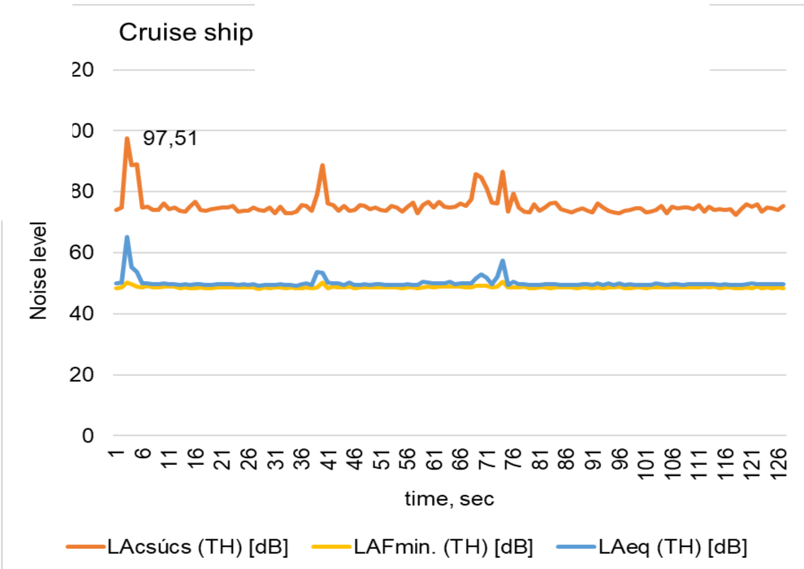


## 4. NAGYMAROS

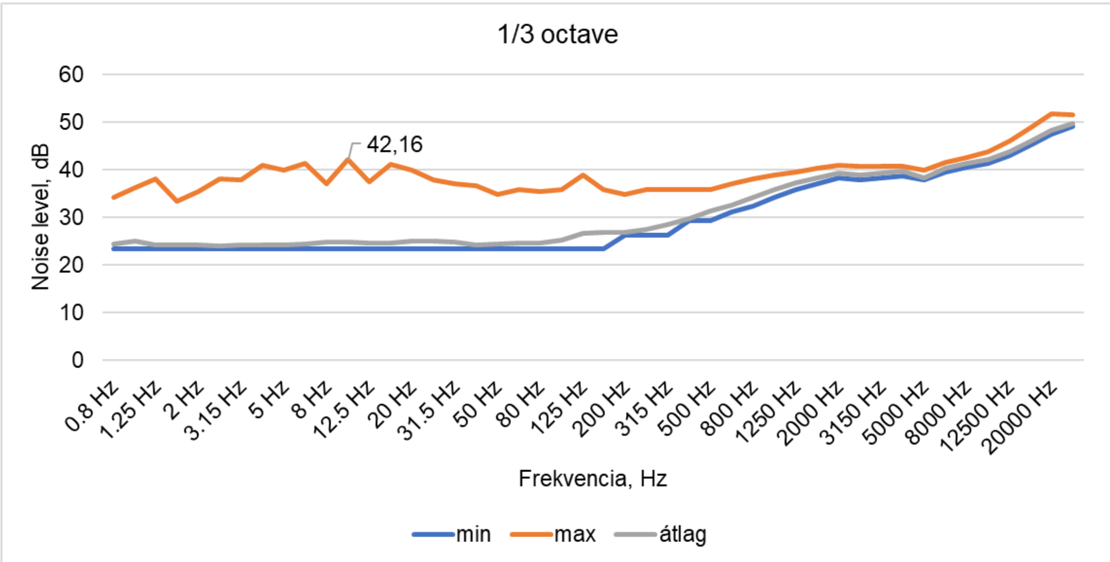
| S.N. | Ship type | DÖMÖS | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **74,4** | **51,9** | **48,74** | **50,01** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 4 cargo barges | | 6 | up | noise level (measured) | 97,18 | 83,41 | 49,6 | 49,2 |
| 4. | Motor freighter | | 18 | down | noise level (measured) | 90,93 | 80,66 | 50,6 | 49,1 |
| 5. | Motor freighter | | 13 | up | noise level (measured) | 100,6 | 72,0 | 49,8 | 49,3 |
| 6. | Passanger ship, Cruise ship | | 18 | down | noise level (measured) | 97,51 | 87,7 | 50,1 | 49,6 |
| 7. | Passanger ship, Cruise ship | | 12 | up | noise level (measured) | 99,12 | 87,7 | 50,1 | 49,3 |

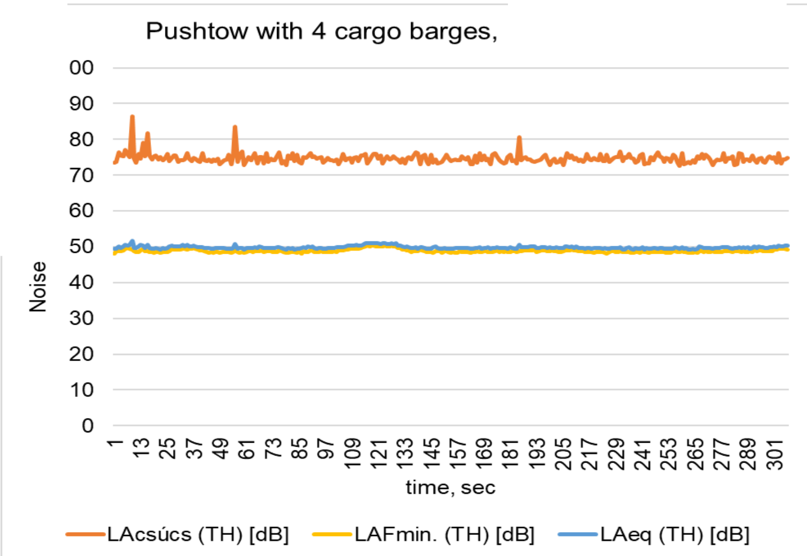


## 5. VÁC

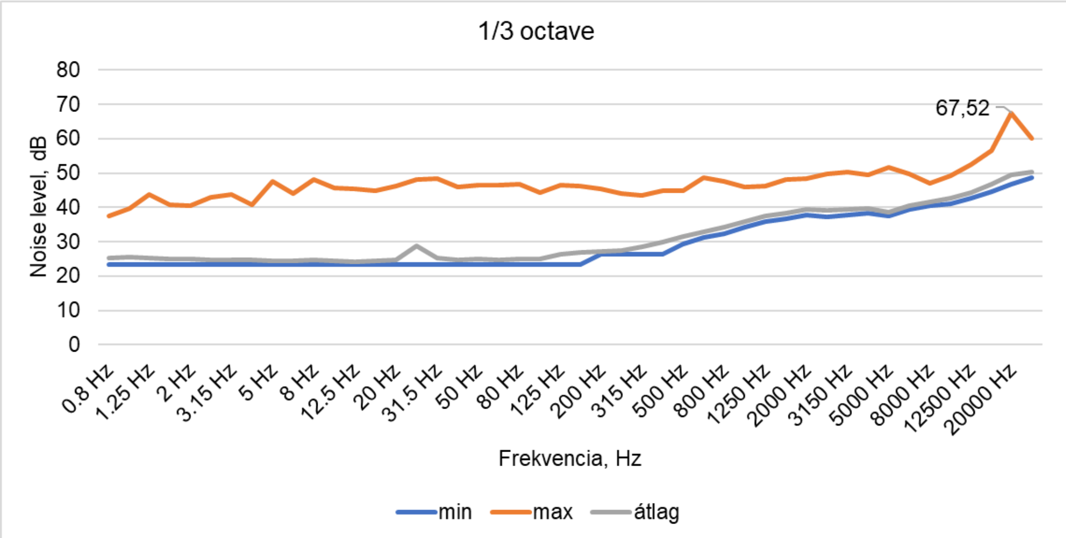
| S.N. | Ship type | Vác, Kompkötősziget | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **77,1** | **60,1** | **49,70** | **49,00** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 4 cargo barges | | 10 | up | noise level (measured) | 86,42 | 55,51 | 50,3 | 49,2 |
| 4. | Motor freighter | | 18 | down | noise level (measured) | 90,93 | 80,66 | 50,6 | 49,1 |
| 5. | Motor freighter | | 13 | up | noise level (measured) | 100,6 | 72,0 | 49,8 | 49,3 |
| 6. | Passanger ship, Cruise ship | | 18 | down | noise level (measured) | 97,51 | 87,7 | 50,1 | 48,6 |
| 7. | Passanger ship, Cruise ship | | 12 | up | noise level (measured) | 99,12 | 87,7 | 50,1 | 49,3 |

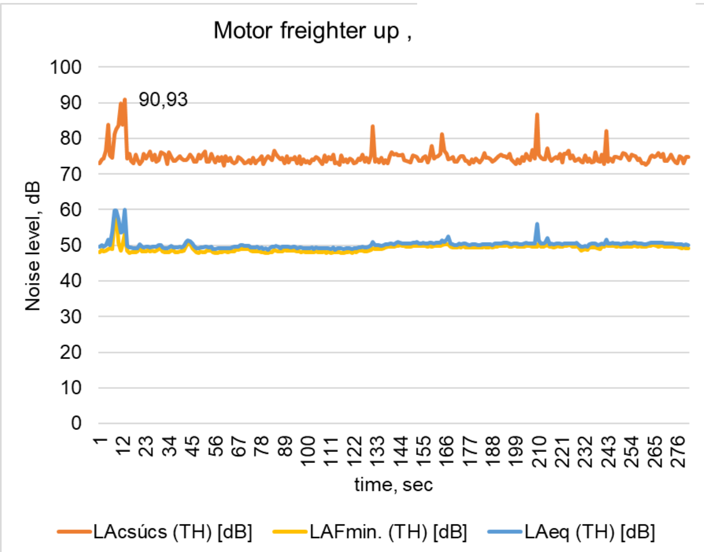


## 6. DUNAKESZI

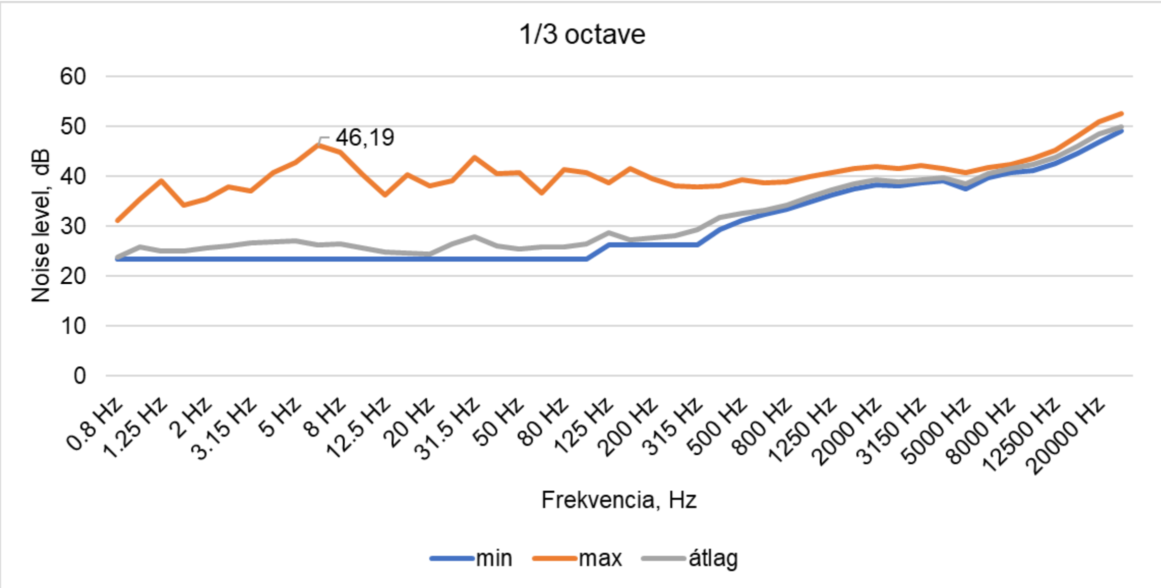
| S.N. | Ship type | Dunakeszi, Szűrkősziget | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **72,9** | **50,5** | **48,13** | **49,32** |
| 2. | Pushtow with 2 cargo barges | | 26 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 4 cargo barges | | 6 | up | noise level (measured) | 97,18 | 83,41 | 49,6 | 49,2 |
| 4. | Motor freighter | | 18 | down | noise level (measured) | 90,93 | 80,66 | 50,6 | 49,1 |
| 5. | Motor freighter | | 13 | up | noise level (measured) | 100,2 | 72,5 | 50,1 | 49,6 |
| 6. | Passanger ship, Cruise ship | | 18 | down | noise level (measured) | 98,31 | 86,7 | 51,1 | 49,6 |
| 7. | Passanger ship, Cruise ship | | 12 | up | noise level (measured) | 100,1 | 88,4 | 50,8 | 49,9 |

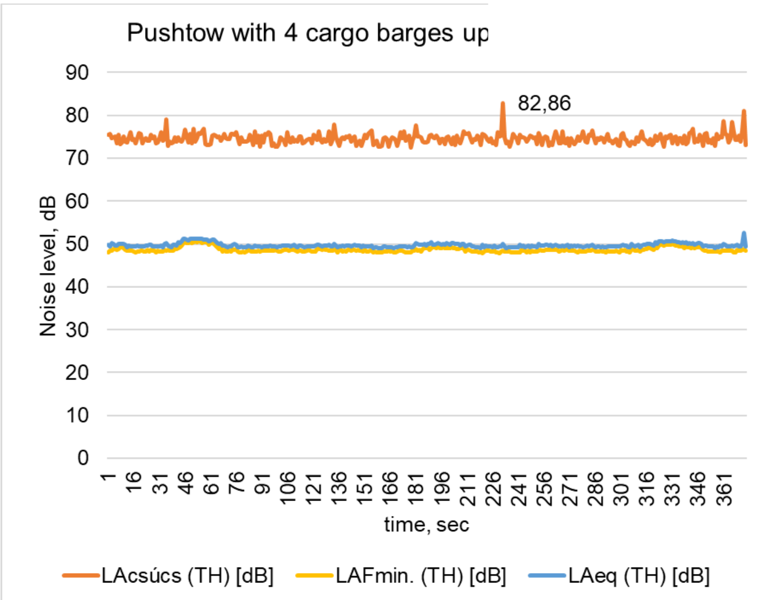


## 7. SZIGETÚJFALU

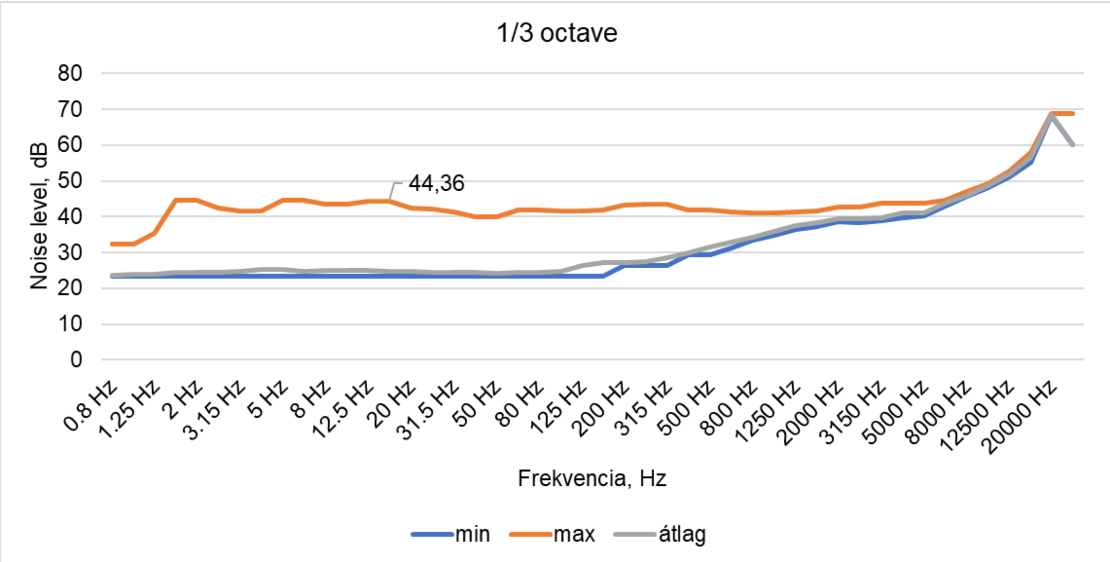
| S.N. | Ship type | Ercsi | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **77,1** | **60,2** | **50,82** | **48,82** |
| 2. | Pushtow with 2 cargo barges | | 13,5 | down | noise level (measured) | 81,32 | 75,65 | 50,31 | 49,25 |
| 3. | Pushtow with 4 cargo barges | | 5 | up | noise level (measured) | 82,86 | 56,63 | 47,81 | 49,7 |
| 4. | Motor freighter | | 17 | down | noise level (measured) | 91,25 | 81,41 | 50,6 | 49,2 |
| 5. | Motor freighter | | 3 | up | noise level (measured) | 98,1 | 76,5 | 49,7 | 48,9 |
| 6. | Passanger ship, Cruise ship | | 23,5 | down | noise level (measured) | 76,97 | 52,25 | 47,9 | 49,4 |
| 7. | Passanger ship, Cruise ship | | 11,5 | up | noise level (measured) | 105,5 | 79,48 | 59,4 | 56,8 |

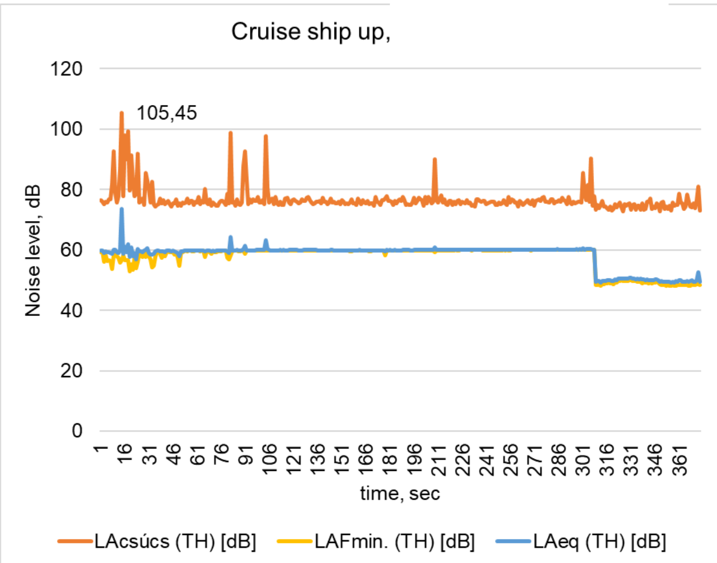


## 8. USZÓD

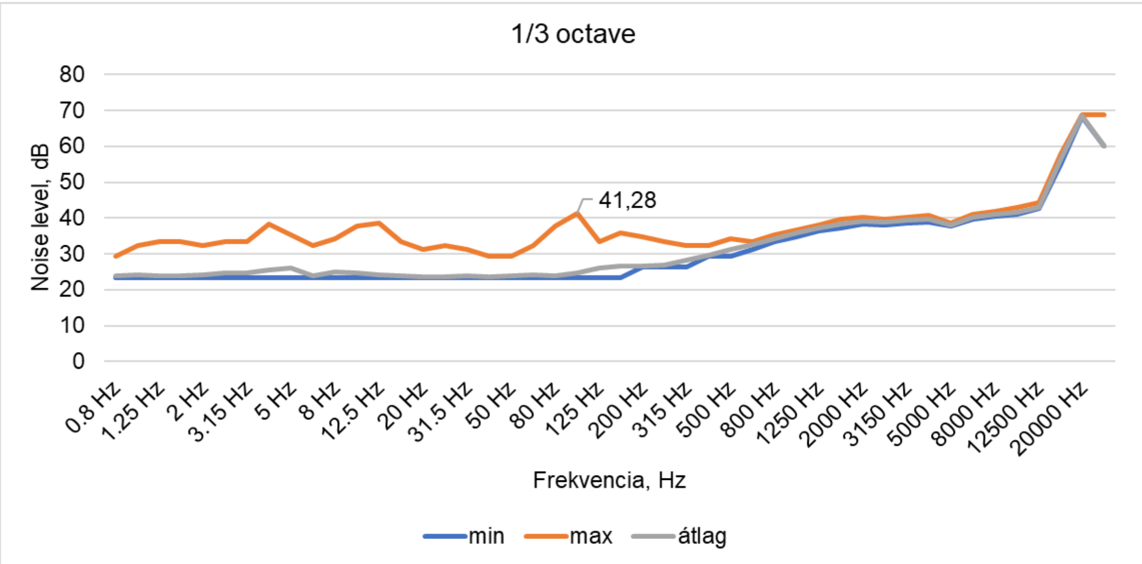
| S.N. | Ship type | Uszod neat 1524 RKM | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **74,7** | **51,8** | **50,16** | **49,14** |
| 2. | Pushtow with 2 cargo barges | | 13,5 | down | noise level (measured) | 81,32 | 75,65 | 50,31 | 49,25 |
| 3. | Pushtow with 4 cargo barges | | 5 | up | noise level (measured) | 82,86 | 56,63 | 47,81 | 49,7 |
| 4. | Motor freighter | | 17 | down | noise level (measured) | 89,34 | 80,56 | 51,6 | 50,2 |
| 5. | Motor freighter | | 3 | up | noise level (measured) | 98,1 | 76,5 | 49,7 | 48,9 |
| 6. | Passanger ship, Cruise ship | | 23,5 | down | noise level (measured) | 76,97 | 52,25 | 47,9 | 49,4 |
| 7. | Passanger ship, Cruise ship | | 11,5 | up | noise level (measured) | 105,5 | 79,48 | 59,4 | 56,8 |

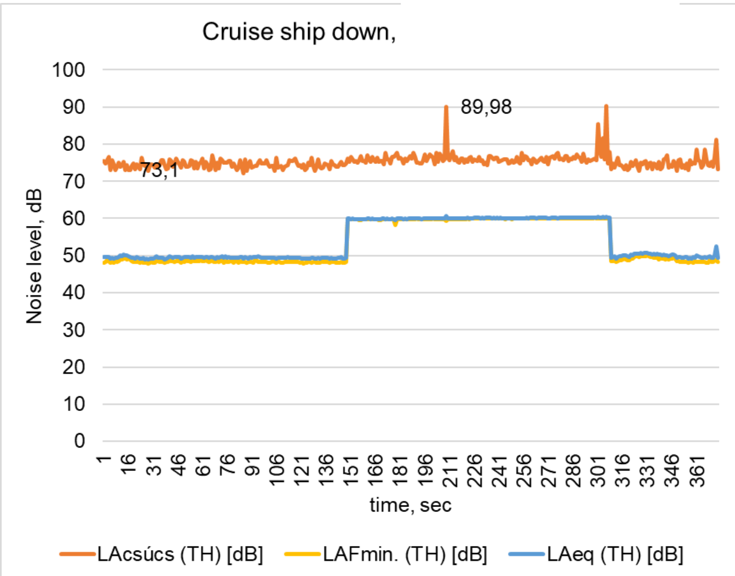


## 9. BAJA

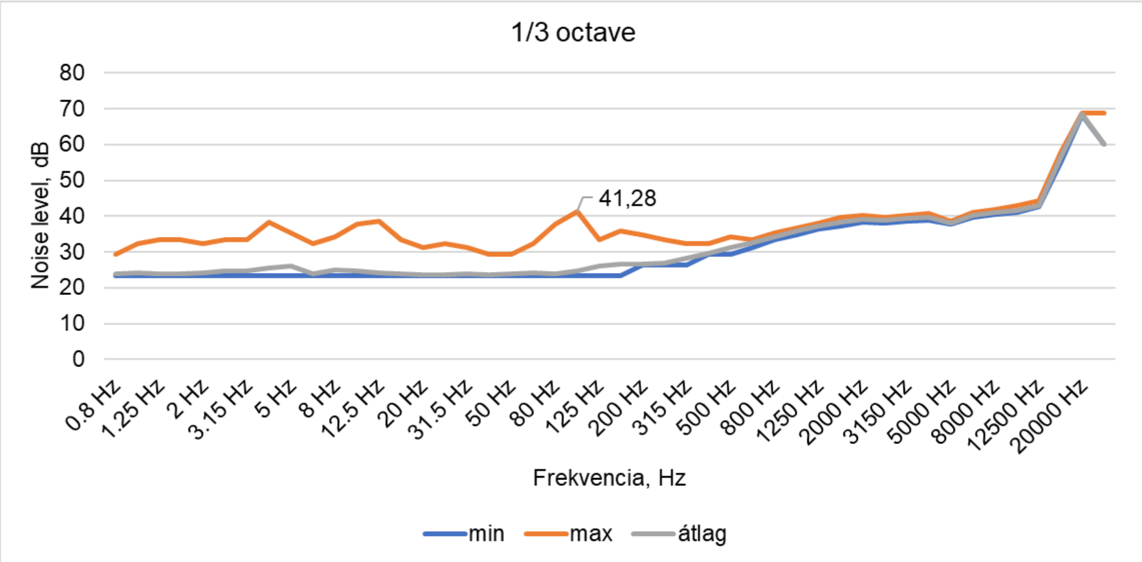
| S.N. | Ship type | Érsekcsanád, Grébec (river) mouth | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **96,0** | **66,8** | **49,80** | **48,40** |
| 2. | Pushtow with 2 cargo barges | | 13,5 | down | noise level (measured) | 81,32 | 75,65 | 50,31 | 49,25 |
| 3. | Pushtow with 4 cargo barges | | 5 | up | noise level (measured) | 82,86 | 56,63 | 47,81 | 49,7 |
| 4. | Motor freighter | | 16 | down | noise level (measured) | 91,25 | 82.35. | 52,6 | 51,2 |
| 5. | Motor freighter | | 8 | up | noise level (measured) | 99,2 | 78,4 | 50,5 | 49,9 |
| 6. | Passanger ship, Cruise ship | | 23,5 | down | noise level (measured) | 76,97 | 52,25 | 47,9 | 49,4 |
| 7. | Passanger ship, Cruise ship | | 11,5 | up | noise level (measured) | 105,5 | 79,48 | 59,4 | 56,8 |

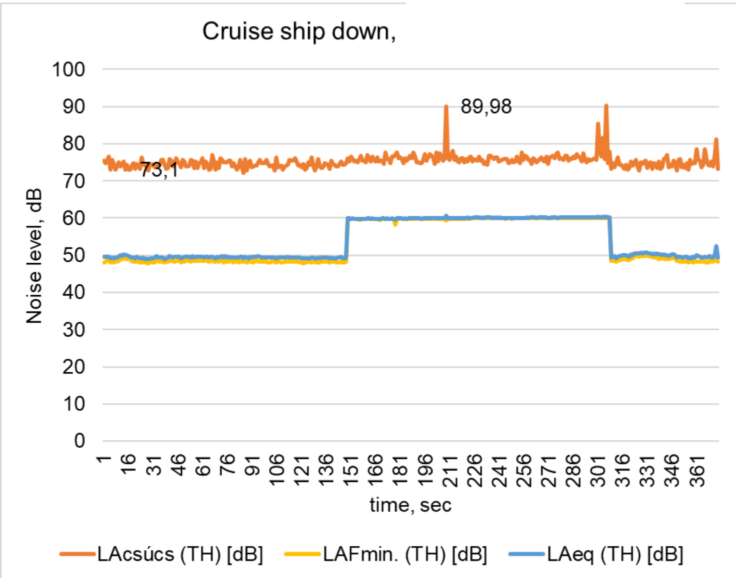


## 10. SZEREMLE

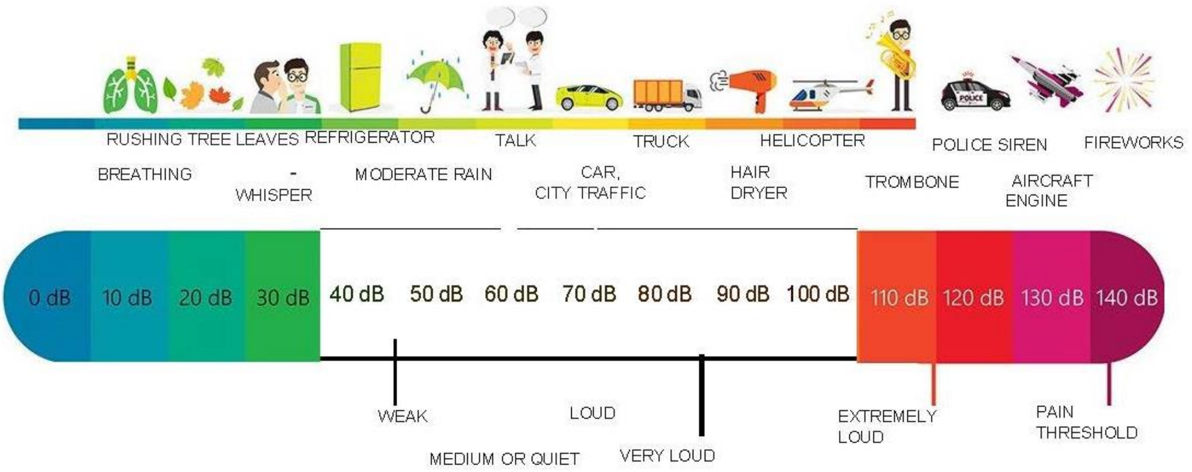
| S.N. | Ship type | Baja, zone Szeremle | speed km/h | direction | | MAX PEAK [dB] | LEQ PEAK [dB] | Laeq [dB] | Laeq MIN [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **Background noise level** | | | | | **72,4** | **50,2** | **48,83** | **47,95** |
| 2. | Pushtow with 3 cargo barges | | 8 | down | noise level (measured) | 80,59 | 74,66 | 49,60 | 48,37 |
| 3. | Pushtow with 1 cargo barges | | 11,5 | up | noise level (measured) | 80,76 | 55,46 | 46,73 | 48,6 |
| 4. | Motor freighter | | 16 | down | noise level (measured) | 91,25 | 82.35 | 52,6 | 51,2 |
| 5. | Motor freighter | | 8 | up | noise level (measured) | 99,2 | 78,4 | 50,5 | 49,9 |
| 6. | Passanger ship, Cruise ship | | 23,5 | down | noise level (measured) | 76,97 | 52,25 | 47,9 | 49,4 |
| 7. | Passanger ship, Cruise ship | | 11,5 | up | noise level (measured) | 105,5 | 79,48 | 59,4 | 56,8 |



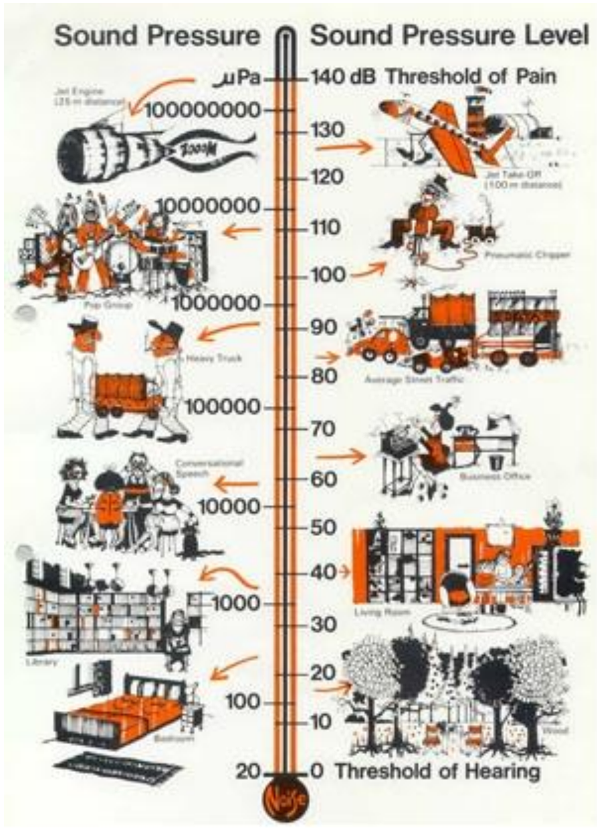



## 8. Conclusions - at what level, who could do what (preparation of proposals for future tasks for shipping and fishing users)

In the case of humans and fish, changes in sound pressure level are perceived in a similar way. The two figures below help you understand the measurement results. The first figure illustrates the physiological effect of the change in sound pressure level,




and the second figure shows how many times a decibel value increases on the logarithmic scale



It can be established that between 60 and 140 dB there is a 10,000-fold increase in the sound pressure level.

The calculated sound pressure level of different types of ships varied between 133 and 152 dB.

In the case of pushtow ships, this value is 133-150 dB

In the case of motor freighter ships, this value is 144-148 dB

In the case of cruise ships, this value is 150-152 dB.

A similar value of the sound pressure level caused by the edge of the given ship at different measurement sites. This suggests that the profile and structure of the riverbed have no effect on the sound pressure level. The sound pressure is not primarily caused by the ship propeller or screw, but the engine noise is amplified by the hull like a loudspeaker

Based on the first figure, it can be concluded that these levels exceed the pain threshold for fish. It can be assumed that this causes the fish to escape from the area of the fairway.

This primarily affects the Invertivores fish, which look for their food in these places. Invertivores fishes are they represent a link between aquatic invertebrates and piscivorous species.

From the fish stock of the examined districts, this may affect the following fish species the most: ide, europen perach, pigo, barbus, sterlet, tench, vimba bream.

This is almost a third of the economically important fish species found in the Danube.

It can be concluded that the sound pressure level of the ships chases the invertivorous fish away from the area of potential spawning and nursing sites.

Due to the continuous effect, this habitat loss leads to a decrease in the population of the given fish species. This has a negative impact on angling/fishing tourism.

The difference in the intensity of waves in both directions was not significant. Down it ranged from 6÷16%, up 5÷10%. While the difference in the height of the waves in both directions was significant. Up and down the difference between pushtow with x cargo barges and motor freighter was not significant (40-46%). However, in the case of passenger ship / cruise ship, it was very significant (255-280%).

## 9. Proposals for further measurements/inspections, measures (e.g. residential, institutional, legislative)

- Based on the calculated sound press values, it is highly likely that the high level of noise generated by the vessels has an impact on the behaviour of the fish. Effects can range from minor and insignificant changes in behaviour to long-term effects on reproduction or feeding.
- Those species of fish that live at the bottom of the river, such as sturgeon, barbel, catfish, escape their natural habitat and feeding place. In the case of sturgeons, the abandoned habitat affects the natural reproduction, because their spawning place is a rocky river bed. for these species natural beds must be provided to allow passage to a tributary of the river.
- The cyprinides, such as carp, roach, and tench, have their ears firmly attached to their swim bladder by a series of bones from their spine. The air in the swim bladder will be more susceptible to pressure changes than the body surrounding the fish. The connection to the ears transmits these vibrations so that the fish can feel the sound. This combination greatly extends their hearing range as the sound is produced by sudden pressure changes.
- Sturgeons do not have a skeleton and are therefore more exposed to high sound pressure.
- A solution must be found to lower the noise of the ship. The noise of the ship's propeller is not significant, while the engine noise increased by the ship's hull in low frequencies causes such a high level of sound press which is already damaging to fish.
- These measurement results are not sufficient to make appropriate recommendations. In the case of the affected fish species, the magnitude and nature of the stress caused by the ship's noise must be determined through laboratory tests.
- The necessary instruments and research staff can only be provided through the joint research work of Hungarian and foreign universities along the Danube.