CONSIDERATIONS TO REDUCE ENVIRONMENTAL IMPACTS OF VESSELS

Wolter, Christian [1] *& Söhngen, Bernhard* [2]

[1] Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Dept Biology and Ecology of Fishes, Mueggelseedamm 310, 12587 Berlin, Germany, email: wolter@igb-berlin.de
[2] Federal Waterways Engineering and Research Institute, Dept Hydraulic Engineering in Inland Areas, Kussmaulstrasse 17, 76157 Karlsruhe, Germany

Abstract: PIANC InCom Working Group 27 has been established to identify, quantify and predict operation-related impacts of inland navigation to minimize and mitigate potential impacts and to provide an environmental sustainable waterway system. The study followed two approaches. The technical "top down" approach covered direct vessel effects such as stranding of fish larvae or detachment of invertebrates due to ship induced water level fluctuation, as well as indirect effects like ship induced turbidity. An impact cascade has been developed providing tolerance thresholds for relevant impacts. The ecological "bottom up" approach covered major properties and requirements of aquatic communities of characteristic water body types. Characteristic groups of aquatic and semi-aquatic organisms have been reviewed to taxa-specifically derive most relevant impacts. This allowed identifying which kind of impact should be addressed and to which level in a specific waterway. Both approaches together served as "Ecological Relevance Check" (ERC) to assess ecological risks caused by shipping. ECR helped to identify the most important impacts and their possible mitigation. Detailed knowledge about operation-related physical impacts of inland navigation and how they might affect aquatic biota are substantial prerequisites to assess whether environmental related impacts are significant and which mitigation measures will be appropriate. A check list of adequate mitigation measures is given in the full report. Proper adoption of the mitigation measures suggested will sustain existing uses and improve the ecological quality of the waterways. Thus, the study is a major contribution to maintain and support an environmentally sound inland water transport.

Keywords: running waters, waterways, inland navigation, identifying appropriate conservation and restoration objectives, change of natural dynamics

Objectives

In the European Community, the Water Framework Directive legislation will require more accountability with respect to the ecosystem by various users including inland operators. Furthermore, as inland waterways systems are developing internationally it is fundamentally critical that designs fully integrate and balance engineering, economics and environmental objectives. Better understanding of the physical and ecological effects will result in sustainable waterway transport compatible with societal and political requirements. Therefore, a working group has been established by the Inland Commission (InCom) of the International Navigation Association (PIANC) to identify, quantify and predict operation-related impacts of inland navigation to minimize and mitigate potential impacts and to provide an environmental sustainable waterway system. The working group focused on state-of-the-art methods for describing, quantifying and managing physical effects produced by vessels to assess ecological impacts of vessel traffic as well as effects resulting from proposed future changes in inland navigation, like a different fleet, changed cargo type, larger vessels, and higher ship's speeds and draughts. In contrast, impacts resulting from waterway construction and maintenance, chemical pollution and air emissions were beyond the scope of the study.
This paper very briefly introduces the ecological impacts induced by moving vessels, impact cascades and relevant impacts identified, a relevance check to assess ecological risks caused by shipping, and suggested mitigation measures to inform about and raise interests in the full PIANC report by Söhngen et al. (2008).

Impact cascades

Moving and manoeuvring ships induce a variety of hydrodynamic changes and physical forces having different impacts on banks, flow and sediments, and accordingly, different ecological impacts based on significance, affected species groups, prevention, and mitigation. Impact cascades were compiled to illustrate the most significant navigation-induced pressures, their effects on aquatic life, and the correlations between various effects. These impact cascades considered primary and secondary vessel-induced impacts and resulting environmental stress factors as well as direct and indirect impacts on biota. For example, conventional propulsion systems may kill or injure aquatic mammals by direct hits, pelagic fish larvae and eggs by shear forces and pressure changes during entrainment through the propeller zone, and may also induce propeller washes and scouring on banks and bottom impacting on plants and invertebrates.

Based on the impact cascade the most important impacts and their causes have been described in detail in fact files by following two approaches, “top down” and “bottom up” considerations. The first, technical approach covered all direct and indirect vessel effects such as stranding of fish larvae due to water level drawdown respectively ship-induced sediment transport that might lower plant growth. The report reviewed typical peak values for each impact in different waterway types, from small navigation canals up to very large rivers, caused by typically sized modern motor vessels, single lane push tow units, passenger ships, and recreational boats. Average impact values are usually less than 50% of the peak values. The second, ecological approach covered major properties and requirements of aquatic communities of characteristic water body types. Characteristic groups of aquatic and semi-aquatic organisms have been reviewed to taxa-specifically derive most relevant impacts and critical threshold values. Tolerable impact thresholds are species-specific within all taxa groups and also vary within each species between age groups, ontogenetic stages and individuals.

The magnitude of peak values induced compared to the corresponding threshold values tolerated, served to identify major impacts from vessel movements as well as to determine efficient measures and sufficient mitigation levels. The so-called “Ecological Relevance Check” enables to waterway-specifically identify which kind of impact is significant, has to be addressed, to which level, and what are appropriate mitigations.

Impact ranking

Flowing rivers and stagnant lakes fundamentally differ in their hydrodynamics and related morphology, and in between there is a wide variety of differently flowing and sized rivers and canals. Species assemblages will vary according to the physical factors of the environment, and similarly, operation-related environmental impacts of inland navigation vary between waterways according to their size, depth, cross-section, hydrodynamics, flow velocity as well as species assemblages present and the conditions they are more adapted to, whether riverine or lake-like.

In wide- and depth-restricted waterways, the dynamic changes of the flow field around a moving vessel are the most significant impacts comprising return currents, drawdown, transversal stern waves, and slope supply flow. If the channel width is comparable to or smaller than the length of commercial vessels – which is typically the case in most riverine waterways – the ship-induced disturbances occupy the whole water column and reach the banks so quickly that the maximum of return velocities is observed in a cross section while a ship is still passing by. Under such conditions, return current and slope supply flow are the overwhelming impacts on littoral habitats. In contrast, if the width substantially exceeds the vessel length – which is typically the case in lake-like waterways, but also in very large rivers – breaking secondary waves are the main hydraulic impact on littoral habitats, whilst return and slope supply currents can be neglected.

In the open water column, entrainment mortality becomes the most severe impact induced by moving vessels. Pelagic fish, fish larvae and larger invertebrates will be killed or seriously injured by shear forces or pressure changes when passing the propulsion system. This impact is locally restricted to the entrained water volume around a vessel. In depth-restricted waterways benthic organisms and plants are additionally affected by propulsion-initiated flow and the resulting increase of turbidity. Navigation-induced turbidity is negligible in faster flowing waterways but becomes increasingly important in slow flowing and stagnant water bodies.

These general considerations resulted in the following ranking of waterways according to the significance of operation-related impacts of inland navigation: 1) stagnant or slow flowing, narrow, waterways with navigation draught being the full channel depth where all impacts act at maximum, 2) faster flowing, narrow, waterways with navigation draught being the full channel depth where all impacts act, except turbidity increase, 3) stagnant or slow flowing, wide, waterways with navigation draught being full channel depth, where all impacts act at lower magnitude of hydraulic forces along the banks, 4) faster flowing, wide waterways with navigation draught is the full channel depth, where all impacts, except turbidity increase act at lower magnitude, and 5) wide waterways with a depth much greater than that required for navigation, where only the secondary wave field may act along the banks and entrainment forces in the near field around the vessel.

Aquatic organisms differ in their anatomy, physiology, habitat requirements, preferences, life cycles, and mobility. Therefore, physical stressors induced by moving vessels vary in their impact on species, and they are neither affected by all impacts nor by the same amount. These general ecological differences resulted in the following considerations according to the significance of operation-related impacts of inland navigation on various taxa: 1) Permanently aquatic species are per se more affected than semi aquatic, facultative aquatic or wetland species, because they potentially share their permanent habitat with moving vessels, 2) Species with higher mobility and escape performance should be less impacted, but in contrast 3) highly flighty species intolerant to disturbances are significantly more affected, because frequent escapes are energy-costly and prevent them from feeding, 4) Impact thresholds vary between taxa depending on their habitat requirements and life histories, e.g. riverine species are typically more impacted than lacustrine, shore line species more than pelagic, 5) Impact thresholds vary seasonally within species, may decrease or increase during spawning or overwintering, respectively, and 6) Operation-related impacts decrease for all taxa with increasing size of the water body and distance to the moving vessel.

Mitigation

Operation-related impacts of inland navigation were evaluated to support the decision-making process related to a proper environmental assessment of possible impacts and whether or not mitigation measures are reasonable and which one seems the most efficient. However, the thorough evaluation of the impact cascade revealed that, principally: 1) navigation-induced impacts acting along the entire waterway were more significant and harmful to aquatic organisms; 2) obligate aquatic organisms were significantly more impacted by inland navigation than semi aquatic or water preferring organisms. Accordingly, mitigation should primarily focus on the large scale, higher ranked impacts, typically affecting larger numbers of taxa. In addition, cascading or indirect environmental impacts have to be expected due to complex biotic interactions between species and taxa, e.g. a loss of macrophyte cover due to navigation-induced waves secondarily results in decreasing densities of invertebrates and juvenile fish, because both depend on macrophytes for settling, feeding and shelter.

In many cases impacts from shipping can be reduced by very simple, low cost measures with low associated socio-economic losses. For example, fairway optimisation and speed limits are the best choices in most cases. Both are typical win-win situations, because they effectively lower vessel induced physical forces along the banks and thus, ecological impacts on one hand, and on the other they save cost for fairway maintenance and fuel. Mitigation measures have been classified and the most important briefly described by Söhngen et al. (2008). The proper adoption of the mitigation measures suggested will sustain existing uses and improve the ecological quality of waterways.

Conclusions

This study provides referenced information and deeper insight in the most important impacts related to inland vessel operation and their ecological endpoints. It also provides additional ideas about possible and most effective mitigation measures and finally shows a structured way how to find solutions for a special impact problem under consideration.

The report is the most extensive single review of relevant knowledge and experience on operation-related impacts of inland navigation, and therefore, a major contribution to maintain and support inland water transport.

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References

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