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# Aquaculture in the Baltic Sea area – A concept for joint research of Baltic Sea abutters *)

## Aquakultur im Ostseeraum – Ein Konzept zur gemeinsamen Forschung der Ostseeanrainerstaaten *)

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**Abstract**

A concept for joint research on aquaculture in the Baltic Sea area is presented. It consists of three major parts, the promotion of an aquaculture-based-fisheries, the development of low-output land-based aquaculture systems, and the search for sustainably produced substances from aquatic organisms to be used for different processes. They include substitutes for feeding stuffs or products of importance for medical, biotechnological and industrial applications.

**(Erweiterte Zusammenfassung s. S. 75)**

### The Baltic Sea – an inland sea with model character in the European Union area

The Baltic Sea is a brackish water sea. As an inland sea, it has a special status which requires considerable environmental protection efforts. It covers an area of 413 000 km$^2$ and its watershed area comprises 1 671 000 km$^2$.

The Baltic Sea – an enlosed brackish water sea of special interest

Four of all inland seas lie within the sphere of interest of the EU – Mediterranean, Baltic, Black and Caspian Sea. Three of them – Baltic Sea, Black Sea and Caspian Sea – are brackish water bodies and have comparable problems and options in fisheries and aquaculture. A programme designed for the Baltic Sea therefore serves as an exemplary model.

The economic and research policy environment in Baltic sea coastal states varies widely. A research support programme which specifically focuses on the region needs to consider these initial differences and should help to overcome the different aims and interests in the area.

Presently, aquaculture in the Baltic Sea area mainly produces trouts, rainbow trout and carp as well as a few other species (to a lesser extent); the number of species is very limited. The total volume of output accounts for about 36 000 tonnes per year in fresh and sea water. Catches have been declining for many years and presently amount to about 0.7 to 0.8 million tonnes annually (Kattegat and Skagerrak excluded). The per-capita consumption of fish varies – depending on country – between 13 and 60 kg live fish weight per year. Fish is very important as a source of protein in some regions.

Due to diffuse and point source of nutrient inputs, the Baltic Sea has been transformed into an eutrophic sea within a few decades.

The development of sustainable aquaculture in the Baltic Sea area has to consider the special situation of an inland sea especially when modern approaches are

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## Zusammenfassung

### Die Ostsee – ein Binnenmeer mit Modellcharakter im EU-Raum

Die Ostsee ist ein Brackwassermeer und genießt als „Binnenmeer" einen besonderen Status. Drei der vier Binnenmeere (Ostsee, Schwarzes Meer, Kaspisches Meer), die in der Interessensphäre der EU liegen, sind Brackwassermeere mit vergleichbaren Problemen und Optionen in Fischerei und Aquakultur. Daher hat das vorliegende Programm für die Ostsee Modellcharakter.

Die Entwicklung von Fischerei und Aquakultur und der Übergangsbereiche zwischen ihnen wie eine „Aquakultur-gestütze Fischerei" sind Bestandteil von Strategien für die gegenwärtige und zukünftige gemeinschaftliche Fischereipolitik (GFP). Dies gilt insbesondere für den strategischen Plan für die Aquakultur. Neue Strategien zur Fischerei und Aquakultur in Binnenmeeren müssen eine Reihe verschiedener Aspekte umfassen, wie z. B. Rechtsfragen zum „Ranching". Die Entwicklung gesetzlicher Rahmenbedingungen für ein Ranching-Programm im Binnenmeer Ostsee ist unabdingbar und vorrangig. Weitere Forschungsbereiche sind nachfolgend genannt.

Neue Konzepte nachhaltigen Fischereimanagements: Zwischen Fischerei und Aquakultur gibt es zahllose Übergänge. Hier sind Institutionen und Forschungseinrichtungen gefragt, die sich mit der Bestandskunde und dem Bestandsmanagement befassen und die an der Entwicklung einer „Aquakultur-gestützten Fischerei" interessiert sind.

Kreislauftechnologie für vorgegebene Wasserqualitätsziele („Fitness for Ranching"): Die Kriterien für einen „optimalen Betrieb" von Kreislaufsystemen, die die Brutaufzucht für Besatz im Rahmen von „Ranching" erzeugen sollen, sind andere als in der Produktion von Speisefischen im geschlossenen System. Ernährungs- und verhaltensphysiologische Studien (z. B. Form der Futtergabe; „Imprinting" und Umstellung auf Naturnahrung vor dem Aussetzen in Küstengewässer) sind Bestandteil der begleitenden Forschung.

Aquakultur-gestützte Fischerei: Ermittlung geeigneter Aussetzungsstrategien und Habitatanforderungen. Untersuchungen zur Habitatstruktur und zu den Habitatanforderungen für Jungfische. Modellhafte Studien (in experimentellen Anlagen und in situ) zu Fragen der Restaurierung von Habitaten und deren Akzeptanz für den Besatz mit Jungfischen.

Aussetzungsstrategien: („time-size-release window"): Die für den Besatz natürlicher Gewässer vorgesehenen Jungfische müssen über eine gute Konstitution verfügen, um in ihrem neuen Lebensraum bestehen zu können. Während der Aufzucht sind diese Jungfische vor dem Besatz nur teilweise an die Belastung mit Umweltnoxen adaptiert.

Monitoring und Bewertung von Aussetzungsprogrammen: Ökosystem-relevante Forschung wird erforderlich, um die systemaren Auswirkungen von Besatz- und Ranchingmaßnahmen auf verschiedenen trophischen Ebenen abzuschätzen und negative Auswirkungen zu vermeiden. Ziel ist es Besatzverfahren zu optimieren. Größenabhängige Verschiebungen im Trophiegrad der Tiere müssen in einem Monitoring qualitativ und quantitativ ermittelt werden. Die Stützung eines natürlichen Bestandes durch Besatzmaßnahmen erfordert ein Management des Elterntierbestandes, um die genetische Äquivalenz zwischen Wild- und Kulturbestand sicherzustellen. Es handelt sich vor allem darum, die genetische Variabilität erhalten und Inzuchtdepression zu verhindern. Moderne molekulargenetische Methoden spielen dabei eine bedeutende Rolle.

Marine Schutzgebiete, künstliche Riffe, Restaurierung von Vegetationsgürteln im Flachwasser und ihre Bedeutung für die Aquakultur-gestützte Fischerei: Der Ausbau von Schutzgebieten geht auch in der Ostsee weiter voran. Die HELCOM-Empfehlungen beinhalten verschiedene Managementpläne, die ein sinnvolles Instrumentarium darstellen, um einer Aquakultur-gestützten Fischerei zuzuarbeiten.

### Neue Strategien zur Aquakultur in offenen und geschlossenen Systemen mit geringer Umweltbelastung.

Produktion in land-gestützten Anlagen: Schwerpunkte liegen auf einer nachhaltigen Erzeugung von Produkten in landgestützten offenen und geschlossenen Anlagen für den menschlichen Konsum, die den steigenden Ansprüchen nach Lebensmittelsicherheit und Umweltverträglichkeit gerecht werden. In einem Aquakulturkonzept für den Ostseeraum ist wegen der hohen Empfindlichkeit dieses Gewässers auf eine möglichst geringe Belastung der Umwelt durch die Aquakultur zu achten.

Aquakultur im Systemverbund mit anderen aquatischen Ressourcennutzern: Die Entwicklung spezieller Aquakultur-Technologien zur Sekundärnutzung von Infrastruktur anderer mariner Anwender wie z. B. Betreiber von Windparks sind auch in der Ostsee notwendig.

Nachhaltig erzeugte Natur- und Rohstoffe aus aquatischen Organismen: Ersatzstoffe für Futtermittelkomponenten (Fischmehle und -öle) werden in der tierischen Produktion (einschließlich der Aquakultur) dringend gesucht. Hier ergibt sich ein weiterer Forschungsbedarf, der durchaus innovative Ziele für globale Märkte beinhaltet.

Naturstoffe in Medizin, Pharmazie, und Kosmetik: Die Herstellung von Naturstoffen durch Aquakultur (auch Nebenprodukte konventioneller Aquakultur) gewinnt zunehmend an Bedeutung. Polykulturverfahren, die nicht nur Konsumenten (Fische), sondern auch Produzenten (z. B. Algen) und Destruenten (z. B. Polychaeten) einbeziehen und dabei einen Mehrwert durch Weiterverarbeitung zu hochwertigen Produkten (z. B. Fettsäuren, Aminosäuren, Kollagen, biologische Antifoulingmittel) führen, haben Zukunftschancen.

Die Kultivierung von aquatischen Pflanzen führt nicht zu Einträgen, aber entnimmt Nährstoffe aus eutrophen Gewässern. Algen bilden den als Phytal bezeichneten Lebensraum. Das Expertengremium des Europäischen Parlaments für technologische Entwicklungen STOA (Scientific Technological Options Assessment) bewertet das Potential für die Nutzung von Meeresalgen als sehr hoch und empfiehlt die Ausweitung der Aquakulturentwicklung auf die aquatische Pflanzenwelt.

Zu Querschnittsthemen gehören z. B. funktionale Genomanalyse. Sie bieten die Möglichkeit einer schnelleren Selektion auf Wachstum, Futterverwertung, Krankheitsresistenz, Stressresistenz und Fitness bei der Aufzucht in modernen Kultursystemen.

Produktqualität und Vermarktung: Neue Verfahren zur Erhaltung und Verbesserung der Produktqualität. Steigende Anforderungen von Seiten des Verbrauchers verlangen neue schonendere Ernte- und Schlachtbedingungen, sowie die Entwicklung einer verbesserten Verarbeitungs- und Verpackungstechnologie im Einklang mit den Qualitätsvorschriften der EU-Hygienevorschriften für Lebensmittel tierischen Ursprungs.

Vermarktung nachhaltig erzeugter aquatischer Produkte: Die Kennzeichnungspflicht für Erzeugnisse aus Fischerei und Aquakultur und die Rückverfolgbarkeit haben Konsequenzen auf die Vermarktung aquatischer Organismen auch im Ostseeraum. Die Weiterentwicklung von Kontrollmechanismen benötigt eine Verifikation ihrer Effizienz durch begleitende Forschung, die die Themen Umweltverträglichkeit, Nachhaltigkeit, Tierschutz, Therapeutikaeinsatz u. a. in Produktion und Verarbeitung berücksichtigt

required to restore dwindling fish stocks subject to fishing, whilst using aquaculture to serve species protection.

In addition, drastic changes are underway in the Baltic ecosystem (a) due to climate change and (b) via the unintentional introduction and spread of foreign species that considerably affect the biocenose and food webs.

### Aims of the concept

The development of fishery and aquaculture as well as of the transitional fields of activity between the two such as an "aquaculture-based fishery" form part of strategies for the present and future common fishery policy (CFP). This holds true, in particular, for a strategic plan for aquaculture. We should call for close cooperation between science, industry and producers so that the requirements for sustainability, eco-friendliness, conservation of species diversity, animal health and human food safety (safe, healthy and high-quality food) are met.

## New strategies for fisheries and aquaculture in enclosed seas

The measures proposed below require an in-depth analysis of existing and potentially necessary regulatory frameworks for the regional aquaculture development as well as for the fishery use of fish stocks in the Baltic Sea.

### Questions of law with regard to "ranching"

The development of a legal framework for a ranching programme in the enclosed sea "Baltic" is indispensable and a priority task. All nations involved have to agree on uniform regulatory frameworks within their territories. Besides taking stock of the case-law in the Baltic Sea coastal states, there is a need to define common legal norms. This should include habitat definitions and a protection for all claims to use under the Water Framework Directive (WFD) (including the needs of aquaculture). The bilateral German-Polish project on integrated coastal zone management in the Oder estuary provides key reference points for this.

### New concepts for sustainable fisheries management

There are many transitional areas between fishery and aquaculture practices. The concept to be adapted to the Baltic is targeted at close cooperation between Baltic states. Institutions and research centres who deal with stock assessment and stock management are needed here as well as those institutions who are interested in developing an "aquaculture-based fishery".

Within the Baltic Sea area, we certainly can draw on traditional knowledge for the management of salmonid stocks (e. g. Sweden for almost 100 years). Furthermore, some other Baltic sea coastal states have drawn up support (stocking) programmes for various fish species.

### Recirculation technology for pre-determined water quality targets ("Fitness for Ranching")

The criteria for an "optimal operation" of recirculation systems in which fish fry is raised for stocking under a "ranching" programme are definitely different from those required for the production of edible fish in recycle systems. What matters is to modify the water quality criteria during the rearing period in such a way that they correspond to the natural conditions of the waters into which the fish are released. The animals have to be acclimatized in the long term to these natural conditions.

Such a conceptual approach requires new research concepts which allow us to adjust environmental conditions in line with predicted target levels in one and the same system for parameters such as a wide temperature range, varying salinities and different pH levels. Studies that ensure the required operational conditions are necessary. Besides acquiring empirical data on system performance, there is a need to develop appropriate simulation models to understand the processes involved and to secure process control. Research projects that target these issues (inclusive the development of expert systems for a "predictive modelling" of performance data) should be initiated.

Physiological studies on nutrition and behaviour (e. g. form of feeding; "imprinting" and transfer from prepared diets to natural food prior to release into coastal waters) should form an integral part of an accompanying research programme.

### Aquaculture-based fishery

#### *Field studies 1: Identification of useful release strategies and habitat requirements*

The success of any concept for an "aquaculture-based fishery" can only be realised when intelligent strategies for the release of cultured juveniles are developed. The success needs to be verified through appropriate new accompanying testing methods. Besides cod as a fishery-relevant species (central focus), salmonids, perciforms and several cyprinoid species are primarily of practical relevance, especially for the tourism-associated recreational fisheries. Studies with the following objectives are required:

- Investigations on the **habitat structure and habitat requirements** for juvenile fish. These studies should focus on the status of the fish nurseries, also on the littoral vegetational zones, and need to eva-

luate there the importance for the stocks of juvenile fish (seasonally and age-related).

- **Model studies** (in experimental units and in-situ) on aspects of habitat restoration and their acceptance (effectiveness) for stocking with released juvenile fishes ("assessment of habitat restoration and development of restoration methods")

- **Release strategies** ("time-size release window"). It can be assumed that only early life cycle stages will be available during the initial phase of an aquaculture programme to support fish stocks that are utilized by the commercial fishery. This holds true, in particular, for the Baltic cod because the start-feeding and rearing to juvenile fish still faces considerable biotechnological problems that need to be solved.
  The juvenile fish to be released into natural water bodies need to be in good condition to withstand the harsh conditions in their new environment. During the rearing period these juveniles will only be partly adapted to the environmental noxious load in the sea. The required fitness, which the juveniles will have to acquire in the culture units, will be expressed in the robustness of their immune status.

- **Monitoring and assessing release programmes**
  Ecosystem-relevant research will be necessary to estimate the system effects of release- and ranching measures at various trophic levels in order to avoid a negative impact of such measures. Research projects in this area should be closely linked with the new strategies developed for European fisheries management. The aim is to optimize release methods. Size-related shifts in trophic levels of the animals are to be qualitatively and quantitatively determined in a monitoring programme**.**

### *Field studies 2: Interactions between natural and cultured fish*

Supporting natural stocks through release measures requires a good management of brood stocks in order to secure the genetic equivalence between wild and cultured stocks. The primary aim is to maintain the genetic variability and prevent inbreeding depression. Modern molecular genetic methods will play an important role such as the use of micro-satellites and DNA-supported markers. Similar research topics are also valid for natural stocks. Finally one has to take into account that an exchange of genetic information will occur between wild and cultured specimens. Therefore, it has to be investigated which measures would be suitable to counteract a potentially reduced genetic variability.

### Marine protected areas, artificial reefs, restoration of vegetation belts in shallow water areas and their importance for an aquaculture-based fishery

The expansion of protected habitats also continues in the Baltic Sea area. HELCOM recommendations include various management plans which can be considered as useful instruments to foster aquaculture-based fishery (see also recommendations of NATURA 2000; Balzer and Ssymank 2005).

Interest in employing artificial reefs is increasing within the EU area (for example in environmental practices such as compensatory measures for harbour or other marine constructions or as objects for the diving tourist industry). Studies on materials, structures, extent and site and time of installations are necessary to determine the success of settlement on such structures with habitat-typical communities. Within the framework of an "aquaculture-based fishery" such protected areas and artificial reefs are gaining new and additional importance, requiring also substantially expanded and new research aims and thus also new and adapted research methodologies. Here are also regional and EU-relevant research needs with special model character for inland seas.

### Socio-economic benefits

Besides considering the technical and biological research aspects, there is a need to describe the socio-economic benefits of such release measures. Conceptionally, aspects on the economics of the proposed research projects will have to be included. It is indispensible to demonstrate the reachable added value of projects in this focal area. This added value relates to the increased attractiveness for tourism (e. g. recreational fishery) as well as the support for the availability of aquatic products on local markets (also across country borders)

## New strategies for aquaculture in open and closed systems causing minimal environmental loads

### Production in land-based systems

Expansion of our knowledge base as well as the support for innovations are primary aims of a programme that wishes to develop aquaculture in the Baltic Sea area. The focus is placed on a sustainable production of products for human consumption in land-based open as well as closed systems. These products need to meet the increasing requirements for product safety and eco-friendliness. This requires a reduction of effluents into rivers and the Baltic Sea also in light of the implementation of the Water Framework Directive. An aquaculture concept for the Baltic Sea area has to aim at minimum environmental loading because of the high fragility of this sea.

The development of new technologies and systems has consequences for the performance and well-being of the cultured organisms. The development of such systems must yield benefits for animal health. This has to be documented through respective physiological and ethological studies. In this context, consumer protection is directly affected.

### Expansion of the species spectrum in modern aquaculture

The number of cultivated species – plants and animals – is relatively low in the Baltic Sea area. Indigenous species should be tested as to their suitability as aquaculture candidates in order to diversify the product range. This would generally allow this industry to become less vulnerable, whilst enhancing the competitiveness at the same time.

### Aquaculture in combination with systems of other users of the aquatic resource

Support should be given to the development of special aquaculture technologies in conjunction with secondary uses of infrastructure provided by or available from other marine users such as the operators of offshore windparks and platforms. It can be assumed that wind parks in coastal waters will considerably expand. Based on existing experience, synergy effects can be expected. Research into biotechnological solutions of adapted production systems has not only to consider the biotechnological requirement, but also the operational and technological safety requirements and these have to be included into the design considerations.

### Business economics and sustainability

A key challenge for the success of modern, land-based systems for aquatic production lies in pooling the aspects of business economics and sustainability. Studies on business economics should also aim at cutting costs.

## Sustainably produced natural substances/ raw materials from aquatic organisms

### Substitutes for feeding stuffs

Substitute substances for feed components (fish meal and oils) are urgently sought after in livestock production (including aquaculture). This gives rise to a further need for research that will definitely include innovative goals for global markets. As livestock production expands worldwide and aquaculture production of chiefly carnivorous species increases, the availability of fish oil will reach its limits far sooner in the foreseeable future than is expected for fish meals. If aquatic organisms are to be primarily used to achieve a research target in the natural substance - raw materials sector, we should promote every promising approach. In doing so, we should deepen and develop the approaches already pursued under FP 6 (FP6 2003). The process development on the use of polluted resources in the Baltic Sea area also serves as a model case for other contaminated oceans of the northern hemisphere.

### Natural substances in medicine, the pharmaceutical industry and cosmetics

The production of natural substances through aquaculture (also by-products of conventional aquaculture), that can be used for physiological, pharmaceutical, nutritional and cosmetic products, is increasingly gaining in importance. We already know properties of some enzymes or enzyme agents that could be considered for biotechnological, industrial or also medical applications (e. g. medication to fight forms of cancer, dermatologically active substances). Substitutes for heparin are also urgently sought after. Easily renewable adsorbents can be obtained from cultivated macro-algae that can be used in the cleaning up of rivers and lakes, but also generally to accumulate heavy metals. Polyculture methods that not only involve consumers (fish), but also producers (e. g. algae) and destruents (e. g. polychaeta) and have an added value through further processing into high-quality products (e. g. fatty acids, amino acids, collagen, biological anti-fouling agents) have assured future prospects.

The cultivation of aquatic plants does not only result in inputs, but removes nutrients from eutrophic waters. Algae are efficient $CO_2$ assimilators and form the habitat called phytal zone that morphogenetically serves as a basis for the existence of many other marine life forms. Hence, the expert body of the European Parliament for technological developments STOA (Scientific Technological Options Assessment) assesses the potential of the use of marine algae as very high and recommends the expansion of aquaculture development to include aquatic flora.

## Cross-cutting issues

The subject areas set out below are interdisciplinary issues and will be vital for the research and development goals described above, but will differ in their importance depending on the topic.

## Functional genomics

Research in this and related areas, inter alia, gives us the opportunity to reach results much more quickly on selective growth, feed conversion, resistance against diseases, resistance against stress and overall fitness for cultivating species in modern systems. This research field aims at selection and performance criteria which increasingly deviate from survival criteria needed in natural habitats. In the long term, this process reduces the risk of effective interactions between wild (natu-

ral) and cultivated stocks of the same species, however, there is a need for intensified quarantine measures as long as the domestication has not made enough headway to sufficiently separate the cultivated from the natural stocks.

Genomics allow us to develop breeding lines faster as has so far been possible through traditional selection programmes (also for species protection aims). For some species there already exists a fairly detailed information base on the entire genome. The already acquired insights should be considered when dealing with other species.

## Product quality and marketing

### New methods to maintain or improve product quality

Increasing consumer demands with regard to product quality require new and gentle harvesting and slaughtering conditions as well as the development of improved processing and packaging technologies and these have to be in line with the quality requirements of the EU such as the EU hygiene rules governing food of animal origin. There is a clear research need to scientifically monitor the development of high-quality products.

Feeding and husbandry conditions exert a decisive influence on the quality of the product "fish". The composition of animal feed and the water quality also determine the nutritional value of the products (contents of essential elements, unsaturated fatty acids, residues) and also determine taste, texture and processing options for the final products. The presently ongoing development of modern fish processing methods provides new ways to prepare new and healthy products. This development relies on substantiation by accompanying research (from harvesting to the end product).

### Marketing of sustainably produced aquatic goods

The labelling requirement for products from fisheries and aquaculture and the traceability within the entire production line have implications for the marketing of aquatic organisms also in the Baltic Sea area. The legitimate consumer demand for transparency must be satisfied. The further development of control mechanisms (e. g. **HACCP (Hazard Analysis and Critical Control Points), tracebility**) and its efficiency needs to be verified through accompanying research, focusing on subjects such as environmental compatibility, sustainability, animal welfare and use of therapeutic agents during production and processing. These control mechanisms will enhance the transparency throughout the entire production process, processing methods and distribution chains as usually expressed by the slogan "*from farm to fork*".

## Conclusion

The concept presented here aims at improving the **competence and competitiveness of the Baltic Sea coastal states in the field of aquaculture**. At the same time it is intended to strengthen cooperation in the Baltic Sea area in order to improve the supply with aquatic products, to strengthen the economic capacity in the region and contribute to the protection of this inland sea.

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