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Local management of Baltic fish stocks – significance of migrations

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Innehåll

Sammanfattning: Lokal förvaltning av fiskbestånd i Östersjön – betydelsen av vandringar

Förvaltningen av många fiskbestånd har misslyckats med överfiske som följd. En delegering av befogenheter från central till lokal nivå föreslås allt oftare som en väg att förbättra förvaltningen. I idealfallet bör ett förvaltningsområde omfatta ett bestånds hela utbredningsområde. Lokal förvaltning måste alltså i första hand inriktas på tämligen stationära arter. Syftet med denna uppsats är att identifiera arter lämpliga att förvalta lokalt vid Sveriges och Finlands Östersjökust. Analysen baseras på tidigare rapporterade vandringsstudier.

Ett lokalt förvaltningsområde bör inte vara större än en kommun, vilken representerar den största administrativa enheten på den lokala nivån. Svenska och finska skärgårdskommuner har normalt en utsträckning understigande 100 km, som alltså kan sättas som övre gräns för ett lokalt förvaltningsområde. Gädda, abborre, gös, havslekande sik och piggvar företar sällan vandringar längre än 100 km och bör alltså vara möjliga att förvalta lokalt. Gädda, abborre och gös studerades närmare. För alla tre arterna var vandringarna kortare vid öppna kuster än i skärgårdar. Stora skärgårdar visar en stor variation i vandringssträckor; där det finns stora och speciellt gynnsamma lekplatser, är de förhållandevis långa. Kustens morfometri och förekomsten av goda lekplatser bör alltså beaktas vid avgränsningen av lokala förvaltningsområden.

English summary: Local management of Baltic fish stocks – the significance of migrations

Management of many economically important fish stocks has failed. Excessively high fishing pressure has typically caused stock collapses. Delegation of decision making from central to local level has been regarded as a way of creating more responsible and sustainable fisheries. Ideally, a management area should cover the whole dispersal area of a stock. Thus, local management is most effective for more or less sedentary species . The aim of this paper is to identify species suitable to be managed locally at the Baltic coasts of Sweden and Finland. The analyses are based on previously reported migration studies.

The size of a local management area should not exceed that of a municipality, which is the largest administrative unit at the local level. The extent of a municipality in the Swedish and Finnish archipelagos is typically less than 100 km, which can be defined as a maximum size for a local management area. Pike, perch, pikeperch, sea spawning whitefish and turbot seldom migrate further than 100 km and are thus suitable to be managed at the local level. Pike, perch and pikeperch were studied more in detail. They all migrated shorter distances at open coasts than in archipelagos. The migrations were longest in archipelagos with especially important spawning areas. The morphometry of the coast as well the location of spawning areas should therefore be considered when defining the boundaries for local management areas.

Introduction

There is a growing need for improvement of fisheries management. There are numerous examples of collapses of many economically important fish stocks (Hilborn & Walters 1992, Ward 2000) caused by excessively high fishing pressure and inefficient fisheries management (Begg & Waldman 1999). Management failures have often been seen as a result of insufficient knowledge of the ecology of the species to be managed, or ignoring this knowledge (Hilborn & Walters 1992). Ignorance of social aspects of fisheries, basing management only on biology or economy together with centralized management arrangements, has also been seen as a reason for the failures (Pinkerton 1989, Pearse & Wilson 1999, Brown 2001).

Broader participation of stakeholders in the management process has been regarded as a solution in creating more responsible and sustainable fisheries (Pinkerton 1994). Different forms of co-operative management, where fishermen and local people have more influence in decision-making processes, have been found useful in improving the status of fish stocks and reducing distrust between fishermen and policy-makers (Pinkerton 1989). The concept of co-operative management is not new. Many traditional, pre-industrial fisheries were managed with some kind of co-operation between local actors (Brown 2001). However, the co-operative strategies have not always succeeded (Pinkerton 1989); managing fisheries at local level is not suitable in all fisheries or in all cases (Brown 2001). It is most effective for species with local behaviour (FAO 1996) and less so for migratory fishes, where competition between management units/areas would be inevitable.

In coastal zones, the number of actors is high and uses of the coastal zone with effects on fish stocks are, e.g., land-use, agriculture, transports, industry and recreation. So, in order to be effective and sustainable, management has to take into account not only biological but also socio-economical and cultural factors. Integrated Coastal Zone Management (ICZM) is a process that is based on a wide participation of different actors and integration of decision-making. In order to find and to accomplish integrated solutions to concrete problems it is necessary to work on a local/regional level (EU 2000).

Fisheries management, as part of the ICZM process, has to take place also at the local/regional level. This requires knowledge of local stock structures, including genetics and geographic distribution, and nowadays estimating the dispersal area of a stock is recommended as the first step in assessment work (Deriso & Quinn 1998). In a biological sense, management would be most effective if each individual stock could be managed separately (Hilborn & Walters 1992) and a management area covered the whole life cycle, i.e. spawning, feeding and wintering areas. This would minimise the risk of stock depletion and also the risk of losing genetic variability.

When creating sustainable fisheries, it is crucial to understand that resource owners are legitimate stakeholders (Charles 2001). In the Baltic archipelagos of Finland and Sweden, there are local management systems based on private ownership of the fishing rights. The owners are organised in associations mostly corresponding to old administrative units, i.e. villages and municipalities. The aim of this paper is to identify the species suitable to be managed locally, taking into account the existing administrative units. Ideally, the whole life cycle should take place within the management area, and therefore we define local management as a process taking place within the boundaries of an area not larger than a municipality. When considering larger administrative units i.e. county, the term regional management would be appropriate. The size (diameter) of a municipality in the Finnish and Swedish archipelagos is typically less than 100 km and consequently we define “species suitable for local management” as species having dispersal areas smaller than 100 km. For some key species, the influence of the morphometry of the coast on the migrations, and hence the size of the management areas, is discussed. The analyses are based on previously reported migration studies, performed in the Baltic Sea.

Migration patterns

Fish migrations and hydrography in the Baltic Sea

In order to maximise survival and reproductive success, fishes balance their physiological needs and needs for reproduction, food and shelter by finding areas with an optimal combination of environmental factors (Wootton 1998). This optimum differs between species and, for a given species, generally also from day to night, summer to winter and time from hatching to adulthood (Wootton 1998). Migrations are the response to these changes and to the patchiness in time and space of the environment, e.g. regarding hydrographic conditions, food and predators.

Hydrographic conditions play an important role in fish migrations. These conditions vary remarkably in the Baltic Sea. Temperature is perhaps the most important factor, as fish seek temperatures optimal for growth, swimming activity and gonadal development (Fry 1971). Seasonal variations in temperature are large compared with those in oceans. The difference between summer and winter surface temperature in the Baltic is typically 14 °C, and in the archipelagos more than 20 °C. In the northern parts and in the archipelagos, winter temperature is normally around 0 °C, and the Bothnian Bay is normally completely covered by ice as are the coastal zones in the Bothnian Sea and the Gulf of Finland (Kullenberg 1981). In the central parts of the Baltic Proper, the probability of occurrence of ice is 25% (Kullenberg 1981). The ice is important not only for the temperature regime but also for the light conditions.

The salinity decrease from south to north is an important factor affecting the composition of the fish community in the Baltic Sea. In the southern parts, the surface salinity is 10–13‰, in the Gulf of Finland 5–9‰ and in the Gulf of Bothnia 3–7‰ (Kullenberg 1981). The number of marine species decreases from south to north, whereas the number of fresh water fishes increases from south to north. The yearly variations in salinity are largest in the southernmost part of the Baltic Sea, where currents transport saline water from the Kattegat and the Skagerrak. However, in most of the Baltic Sea, the salinity is fairly constant.

Even though the fish species in the Baltic can tolerate differences in hydrographic conditions, e.g. salinity, quite well as adults, the fertilization, egg development and larval phase of fishes are usually more sensitive and have much narrower tolerance limits (Wootton 1998, Urho 2002). Thus, the environmental conditions needed for reproduction are usually the most limiting for the geographic distribution of the Baltic fishes.

Species communities in the Baltic Sea

On the basis of life cycles and environmental preferences, it is possible to group the Baltic fish species in different communities. Aro (1989) identified three communities based on similarities in ecology: pelagic, benthic and coastal communities. A grouping made by Neuman and Piriz (2000) is based more on fisheries, and consequently is more suitable for an analysis of the relation between migrations and management (Table 1). It consists of coastal, sea migrating and river spawning species, together with eel, with its extreme migration pattern, in a group of its own. Neuman & Piriz also separate between "warm

Table 1. *The distribution of commercially important species between different Baltic fish communities (after Neuman & Piriz 2000)*

	cold water species	*warm water species*
coastal species		
	sea-spawning whitefish	perch
	turbot[1]	pike
		pikeperch
sea migrating species		
	vendace	
	herring	
	flounder[1]	
	cod	
	sprat	
Anadromous species (river spawning species)		
	salmon	
	sea trout	
	river-spawning whitefish	
Catadromous species		
		eel

[1)] *According to Neuman (1979a), turbot and flounder take an intermediate position between cold and warm water species.*

water species" with a temperature preference above 20 °C and "cold water species" with a preferred temperature below 15 °C (Neuman 1974).

Coastal species

Coastal species are typically quite sedentary and stay in the coastal zone, avoiding the open sea (Neuman 1974). Pike (*Esox lucius*), perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*) are spring-spawning warm water species. High and stable temperatures are important especially for the reproduction and the juvenile phase for these species; e.g. the temperature during the first year of life is the main factor determining year-class strength of perch and pikeperch (Karås 1996, Colby & Lehtonen 1994, Lappalainen & Lehtonen 1995). The spawning areas of pike, perch and pikeperch are shallow bays and inlets, where the water warms up fastest in spring, but spawning occurs also in river mouths and brooks, especially for pike and perch. The temperature not only determines where and when the spawning takes place but also governs the activity level (Neuman 1979b) and the migratory pattern. After spawning, the fish move to feeding areas, often close to the spawning areas. A movement to deeper water and more exposed areas takes place when the temperature increases (Neuman 1974, 1982, Berglund 1978, Lehtonen 1983, Segerstråle 1983). The thermocline acts as an outer border until it disintegrates in autumn. In the winter, rather deep and sheltered areas are preferred.

The migration pattern described above is most accentuated for perch and pikeperch; pike is more sedentary due to its territorial behaviour. It is an ambush hunter, hiding in the vegetation and behind stones. Perch hunts more actively but lives also mostly close to the bottom (Neuman 1982), whereas pikeperch prefers to live in more open water spaces (Deelder & Willemsen 1960).

The differences in behaviour between the species are reflected in the migration distances as they have been registered by mark-recapture experiments. Pike has the shortest migrations with more than 90% of the recaptures usually made within 5 km from the tagging place (Ekman 1915, Gottberg 1923, Hessle 1934, Kaukoranta & Lind 1975, Lehtonen *et al.* 1983, Karås & Lehtonen 1993) (Figure 1). The corresponding figures for perch are 80% within 10 km (Böhling & Lehtonen 1984) whereas for pikeperch (Lehtonen & Toivonen 1987) they are 75% within 9 km (Figure 1). Even though typically quite sedentary, these species can sometimes also migrate considerable distances. The longest distance observed for pikeperch is 300 km, and migrations over 100 km are not unusual (Lehtonen 1979).

There are only a few reported studies on the migration behaviour of turbot (*Scophthalmus maximus*) in the Baltic Sea. It moves from deeper to shallow water in the spring to eat and spawn, and back to deeper water in autumn (Ojaveer 1981). The spawning mostly takes place in June (Ojaveer 1981). Turbot is quite local in behaviour; 79% of the recaptures reported by Anéer & Westin (1990) were made within 10 km from the place where the fishes were released. In this study, however, fishes were caught and released in different places (the distance between places was about 4 km), which also may affect the results. As the biology of the early life-stages is poorly known, there is no information on the migration distances for the whole life cycle.

The whitefish (*Coregonus lavaretus*) is an autumn spawning cold water species. There are two sympatric forms in the Baltic Sea: the anadromous (*Coregonus lavaretus lavaretus*) and the sea spawning (*Coregonus lavaretus widegreni*) (Himberg & Lehtonen 1995). Even though these two forms often coexist, they differ remarkably in migration behaviour. The sea spawning one, more local in behaviour, seldom migrates more than 100–200 km (Lehtonen & Himberg 1991) and most fishes are caught much closer to the tagging place. Dahr (1947) reported average distances between 7 and 16 km in the southwestern Bothnian Sea, and Lehtonen *et al.* (1986) noted that 75% of the recaptures in the Quark were made within 20 km from the tagging place. In the Bothnian Bay, 87% of the recaptures were within 40 km (Lehtonen 1981).

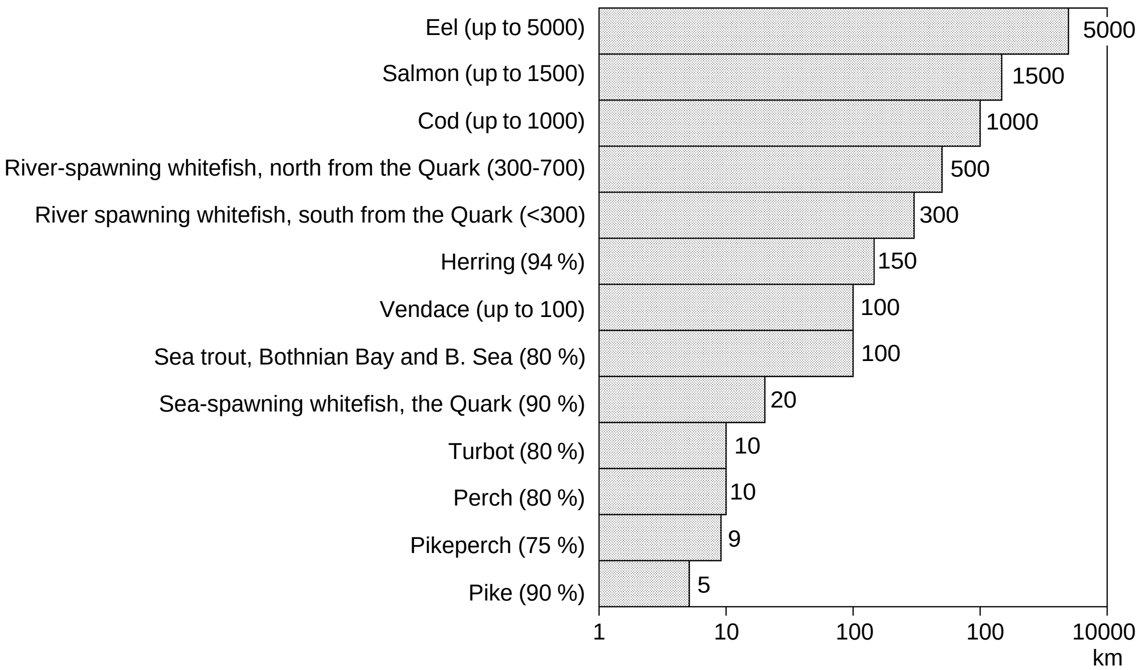


Figure 1. *Migration distances of fish species in the Baltic Sea based on tagging experiments. The numbers refer to distances within most (%) fishes were recaptured. See text for references.*

The seasonal migrations of the sea-spawning whitefish are directed mainly towards the coastline (Lehtonen 1981).

The migrations of the coastal species are typically rather short and thus these species should be possible to manage at the local level. As mentioned above, the sea spawning whitefish is often fished in the same area as the river spawning form, thus making it difficult to manage them separately without limiting the fisheries to the spawning place. The available information indicates that turbot can be managed locally, but the movements of the early life-stages are still unknown.

Sea migrating species

The sea migrating fishes move between the open sea and the coastal zone. Herring (*Clupea harengus membras*) and sprat (*Sprattus sprattus balthicus*) are the most abundant and most important species in the pelagic fish community in the Baltic (Aro 1989). Spawning of the herring takes place in coastal waters. The herring has sinking eggs and typically spawns on hard bottoms with rich vegetation, often close to deep areas (Kääriä *et al.* 1997). Most of the Baltic herring spawn in spring and early summer but there are also autumn spawners. According to Ojaveer (1981) there are two different forms of the Baltic herring: coastal and pelagic form with different biology and morphology. However, the stock structure of the Baltic herring is still poorly known (ICES 1999). Tagging experiments made in the Bothnian Sea gave most of the recaptures (95%) within 150 km from the tagging place (Parmanne & Sjöblom 1986). In the Archipelago Sea all recaptures were made within 140 km from the tagging place (Kääriä *et al.* 2001).

The sprat spawns both in deep waters and on the coastal slopes to the deeps (Ojaveer 1981). It has pelagic eggs. Its main distribution area is the main basin of the Baltic, and there are three different stocks (Aro 1989). Migrations pattern are not clearified. There are observations of both more local beq!viour as well as those that indicate a more migratory behaviour (Aro 1989).

In the Baltic, vendace (*Coregonus albula*) is mainly restricted to the Bothnian Bay and the northern Bothnian Sea. It is economically important for both Finnish and Swedish coastal fisheries. In summertime, during feeding migration, the vendace population is spread over the Bothnian Bay and in the autumn it migrates to nearshore spawning areas mainly situated at the Swedish side of the northern Bothnian Bay, where the fisheries also are most extensive. According to Lehtonen & Enderlein (1984), there are many local vendace stocks in the Bothnian Bay with strong homing to the spawning areas. The migration distances are typically less than 90 km (Lehtonen & Enderlein 1984).

Together with herring and sprat, cod (*Gadus morhua*) is the economically most important species in the Baltic fisheries (Anon 2001). There are two stocks in the Baltic Sea: the eastern (*Gadus morhua callaris*, the Baltic Sea cod), which is found frequently east of the Bornholm Island and up to the northern parts of the Bothnian Sea and to the Gulf of Finland, and the western (*Gadus morhua morhua*, the transition area cod) distributed west of the Bornholm Island (Aro 2000). The border between these two stocks is diffuse and mixing of stocks occurs (Bagge *et al.* 1994). Salinity limits successful spawning for the cod and the spawning areas are located in the southern and central parts of the Baltic Proper. The cod migrates to the spawning areas in the winter and early spring (Aro 2000). The most intensive spawning period for the western stock is usually March (Aro 2000). Earlier the peak spawning of the eastern stock took place in May–June (Grauman 1974), but now it has shifted to late July–August (Jarre-Teichmann *et al.* 2000, Wieland *et al.* 2000).

After spawning, the feeding migration takes place. The cod staying in the southern parts of the Baltic typically migrate some 100–300 km (Otterlind 1984, Netzel 1990), whereas those tagged in the Åland Islands were caught mostly 200–800 km from the tagging place (Sjöblom *et al.* 1980). Those migrating to the Bothnian Sea have migration routes about 1000 km. Dispersal area and migrations are related to the stock size. When abundance is high, it is found all over the Baltic Sea and its coasts except the northernmost Bothnian Bay, whereas in periods of low abundance, as today, cod is found only in the southern and central parts of the main basin (Sjöblom *et al.* 1980, Aro & Sjöblom 1981, Suuronen 1981, Neuman 1984).

The flounder (*Platichthys flesus*) lives in all parts of the Baltic Sea except in the deeper parts of the Gotland Deep, the easternmost part of the Gulf of Finland and the Bothnian Bay (Ojaveer 1981). There are two forms in the Baltic Sea with a rather distinct boundary between mature fishes. According to Otterlind (1967), this can be drawn from the southern part of Öland to Rosewie in Poland. The northern form spawns on shallow grounds and has sinking eggs (Sandman 1906, Solemdal 1967), while the southern spawns in the pelagial and its floating eggs and the larvae drift with currents. The flounder in the northern Baltic is confined to the coastal areas and performs rather short migrations (Aro & Sjöblom 1983) from shallow to deeper waters and along the coast (Ojaveer 1981, Aro & Sjöblom 1983). In the southern parts of the Baltic Sea, there is a more local and coast-bound type spawning in the coastal zones and another type spawning offshore and migrating long distances, up to 200 km (Cieglewitz 1947, Otterlind 1967).

The distribution areas of different stocks of sea migrating species are generally much larger than local administrative units, and as the fisheries are carried out mostly offshore, local management is not suitable for these species. However, it might be possible to manage the northern form of flounder locally, as it is typically quite sedentary in coastal areas.

Anadromous species

Species like salmon (*Salmo salar*), sea trout (*Salmo trutta*) and river-spawning whitefish have their spawning and nursery grounds in the rivers and feeding grounds in the sea. These species have suffered a lot from human activities, especially building of hydroelectric power plants. The number of rivers with naturally reproducing salmon populations has decreased from 80–120 to 37 (Rappe 1999), and in most of the rivers, the salmon production today is well under the potential. Most of the spawning rivers which have natural stocks left are located in the Bothnian Bay and the Baltic States (Rappe 1999). The salmon fisheries are now based mostly on stockings. The main feeding grounds are in the main basin and thus the migration distances for the stocks spawning in the rivers at the Bothnian Bay reach an order of magnitude around 1000 km. On the other hand, salmon spawning in rivers at the southern Baltic, seldom migrate longer than some hundreds of kilometres.

Whereas salmon lives pelagically in the open sea, sea trout and river-spawning whitefish are typically more coastal in their behaviour. For example, Aro (1989) described sea trout as having an intermediate position between the pelagic and coastal community with both long-migrating and more local stocks. Sea trout from the Gulf of Bothnia seldom migrate to the main basin and neither are migrations between the Bothnian Bay and the Bothnian Sea very common. Sea trout in the Gulf of Bothnia seldom move longer than 100 km (80% of recaptures closer than 100 km according to Toivonen & Tuhkunen 1975). In the main basin, migrations are more extensive (Aro 1989).

The migratory behaviour of river-spawning whitefish varies greatly in the Baltic Sea. In the Bothnian Sea, migrations are up to 700 km (Lind *et al.* 1972, Lehtonen & Himberg 1992).

The main feeding area in this basin is located in the south, near the Åland Islands. When tagged there, the range of the recaptures is wide; there are several stocks with spawning rivers both rather close to the area as well as stocks from the northernmost part of the Bothnian Bay. For example, Wikgren (1962) reported the longest migration to be 670 km from taggings made in the Åland Islands. The averages in his study were 113 km (tagging year 1956) and 92 km (tagging year 1957). Whitefishes tagged near the spawning areas in the Sundsvallsbukten Bay at the central part of the Bothnian Sea, were caught mainly within 50–100 km from the tagging place, the longest migration being about 200 km (Lindroth 1957). Recaptures were mainly south from the tagging place, i.e. towards the feeding areas.

Lehtonen & Himberg (1992) suggested that food resources in the northern part of the Gulf of Bothnia are scarce in relation to the size of the stocks, which might explain the long migrations of northern stocks. In the Baltic Proper and the Gulf of Finland, the stocks are smaller and the food conditions probably more favourable and hence the migrations seldom exceed 100 km (Ikonen 1982). In his study, Ikonen (1982) found that 70% of the whitefishes were caught within a radius of 10 km and most fishes were caught within 70 km.

As the sea migrating species, the river spawners make long migrations rendering local management difficult. Some short-migrating sea trout stocks might, however, be possible to handle locally.

Catadromous species

The migratory behaviour of the European eel (*Anguilla anguilla*) is extreme. The spawning areas are located in the Sargasso Sea, which leads to spawning migrations about five thousand kilometres (Berry *et al.* 1973). The rather sedentary juvenile eels and the eels performing spawning migrations are often fished in the same area. Due to the special life history of eel, fisheries management needs international co-operation and is beyond the scope of this paper.

Migrations and local management

Summing up, coastal species are most suitable to be managed at the local level as they spend all their life within limited areas. Pike, perch and pikeperch can be seen as key species in the discussion on local management in Baltic archipelagos as they are important to all types of fishermen and often subject to management-related conflicts. It is a reasonable assumption that most problems concerning local management, e.g. delimiting management areas and creating fishing rules, will focus on these species. Moreover, their biology is comparatively well known. Thus, we will analyse their migration behaviour in greater detail, especially with regard to the critical question of defining boundaries of management areas.

Defining boundaries of the management area – the effect of coastal morphometry on migration of pike, perch and pikeperch

The movements of pike, perch and pikeperch are affected by the morphometry of the coast. Where it is open, waters close to the shoreline are frequently deeper and colder limiting movements in the summer season, when feeding migrations take place. Where the archipelago is wide, and where there are large shallow areas with high summer temperatures, the conditions are more favourable for migrations. The chart is thus an important instrument in defining boundaries of management areas. This is illustrated by comparing the results of tagging experiments made at open coasts or in quite narrow archipelagos with those from wide archipelagos with large areas of shallow water. Information on the effects of other environmental factors on the migrations can be found in the original references, especially Böhling & Lehtonen (1984).

Pike

Results of tagging experiments made at different types of coasts vary very little (Figure 2). Generally, the portion migrating further than 5 km is less than 10%. The clear dominance for short migrations is not surprising because pike do not perform regular feeding migrations. Its main migrations are towards the spawning area in springtime and back to its territory thereafter. So migrations of pike are mainly defined by the location of the spawning areas, typically small and numerous, and the territory of the individual pike. Maalahti in the Vaasa archipelago is an exception since about 60% of the recaptures were made at distances longer than 5 km. Here, the estuary of a small river is very favourable for spawning and the archipelago is also wide with large areas of shallow water. It is supposed that there are fairly long feeding migrations from the outer parts of the archipelago to shallow areas near the mainland, where prey species are very abundant (Hudd *et al.* 1984).

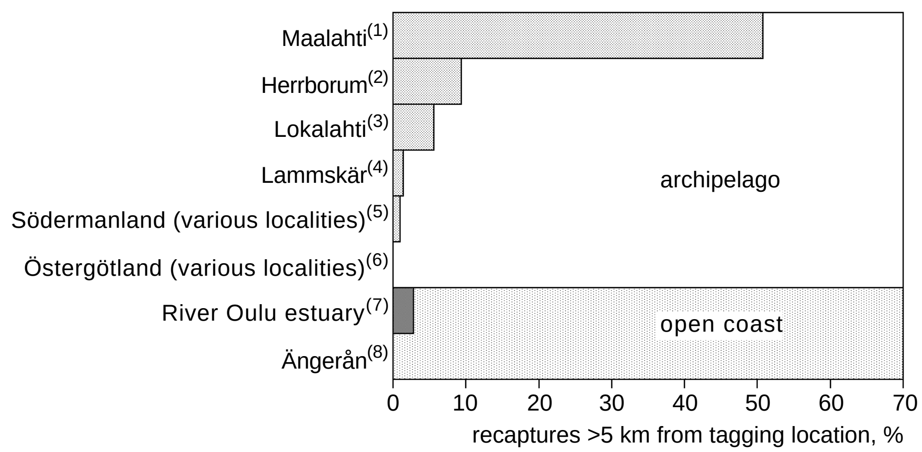


Figure 2a*. Pike recaptures in different coastal areas presented as percent of fishes which have migrated further than 5 km from the tagging place. References: 1. Hudd et al. (1989); 2. Hessle (1934); 3. Lehtonen et al. (1983); 4. Hessle (1934); 5,6. Ekman (1915); 7. Kaukoranta & Lind (1975); 8. Müller (1984).*

Figure 2b. Tagging places for pike presented in figure 2a.

Perch

According to Böhling & Lehtonen (1984) some 80% of the recaptured perches were caught within a radius of 10 km from the tagging place and this distance is used here as a typical maximum migration distance. The proportion of perch migrating longer than 10 km differs widely between different coasts (Figure 3). Migrations were short in all "open coast" areas, whereas there are remarkably large differences in migration patterns between areas classified as "wide archipelago". At Föglö and Korsholm only about 10% of the perches migrated further than 10 km, whereas at Lumparn there were more than 60% and at Taivassalo more than 80%. The Taivassalo experiment is not comparable with the others, as recaptures made in the tagging year are excluded. However, it probably gives the best description of migrations because fishes caught shortly after tagging and near the tagging place are excluded.

The long migrations at Taivassalo and Lumparn might be connected with the existence of large bays, and at Maxmo an estuary known by the local people for extensive spawning of perch. Their quality as recruitment areas is probably due to their size and sheltered location causing a fast warming in spring and high and stable temperatures in summer. Obviously, these areas attract perch from a wide area even though there are places suitable for spawning closer to feeding and wintering areas.

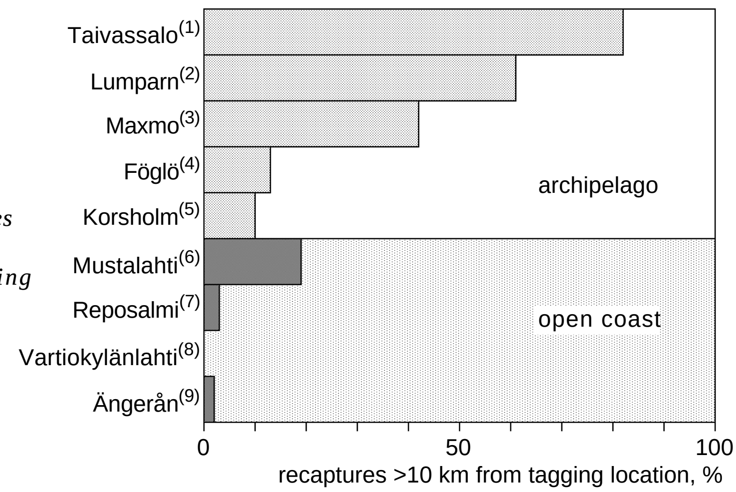


***Figure 3a.** Perch recaptures in different coastal areas presented as percent of fishes which have migrated further than 10 km from tagging place. References: 1–8. Böhling & Lehtonen (1984); 9. Müller (1984).*

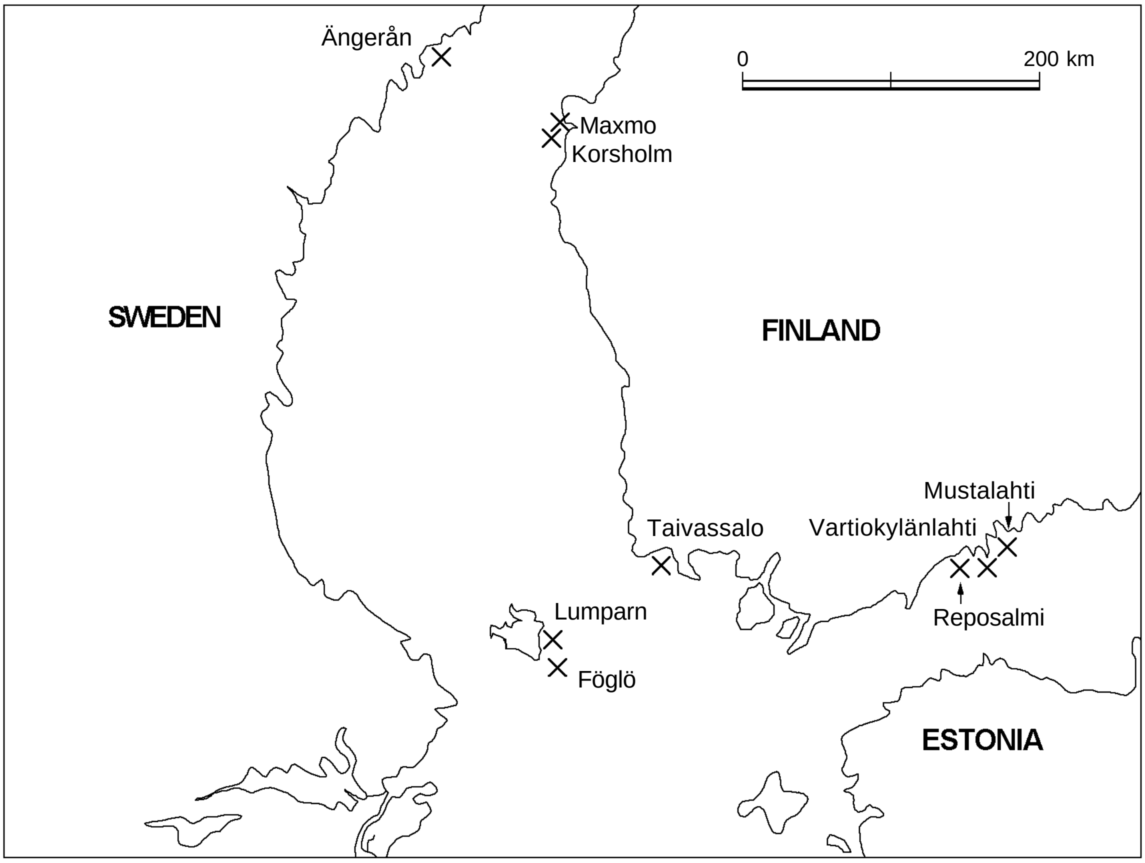
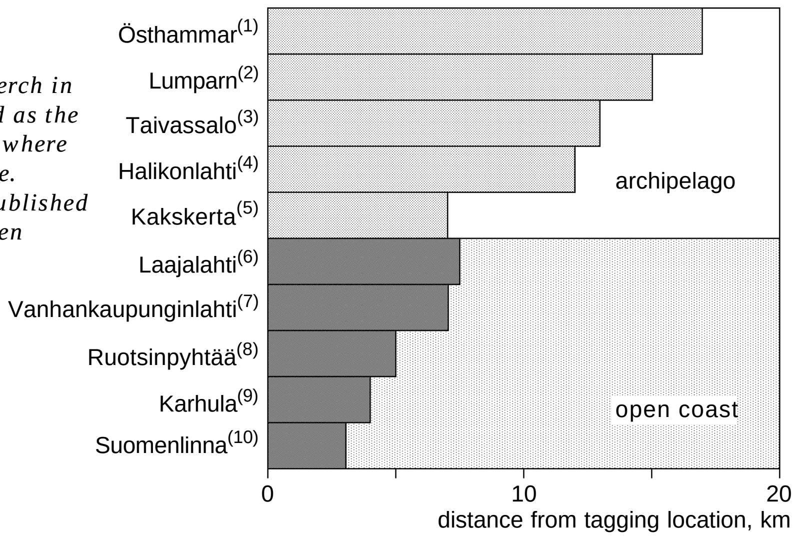


Figure 3b. *Tagging places for perch presented in figure 3a.*

Pikeperch

As for perch, the typical migration distances were short in all "open coast" areas and longer but varying in the wide archipelagos (Figure 4). The areas (Östhammar, Lumparn, Taivassalo and Halikonlahti), where migrations were longest, have favourable spawning areas well protected from open waters. An interesting example is provided by the Östhammar area, which is an archipelago surrounded by open coasts. Most of the recaptures were either made in this archipelago or north of the tagging location (K. Saulamo, unpublished data). In that direction, the water is shallow even if the coastline is open. On the southern side the waters are much deeper, even very close to the shoreline. Similar to perch, the morphometry of the coast is important for the movement of pikeperch, as suggested by Lehtonen & Toivonen (1987). As the species prefers turbid water, not only the presence of warm water but also turbidity might affect the migrations (Lehtonen & Toivonen 1987).

***Figure 4a**. Migrations of pikeperch in different coastal areas presented as the distance from the tagging place where 75% of the recaptures were made. References 1. (K. Saulamo, unpublished data); 2–10. Lehtonen & Toivonen (1987).*



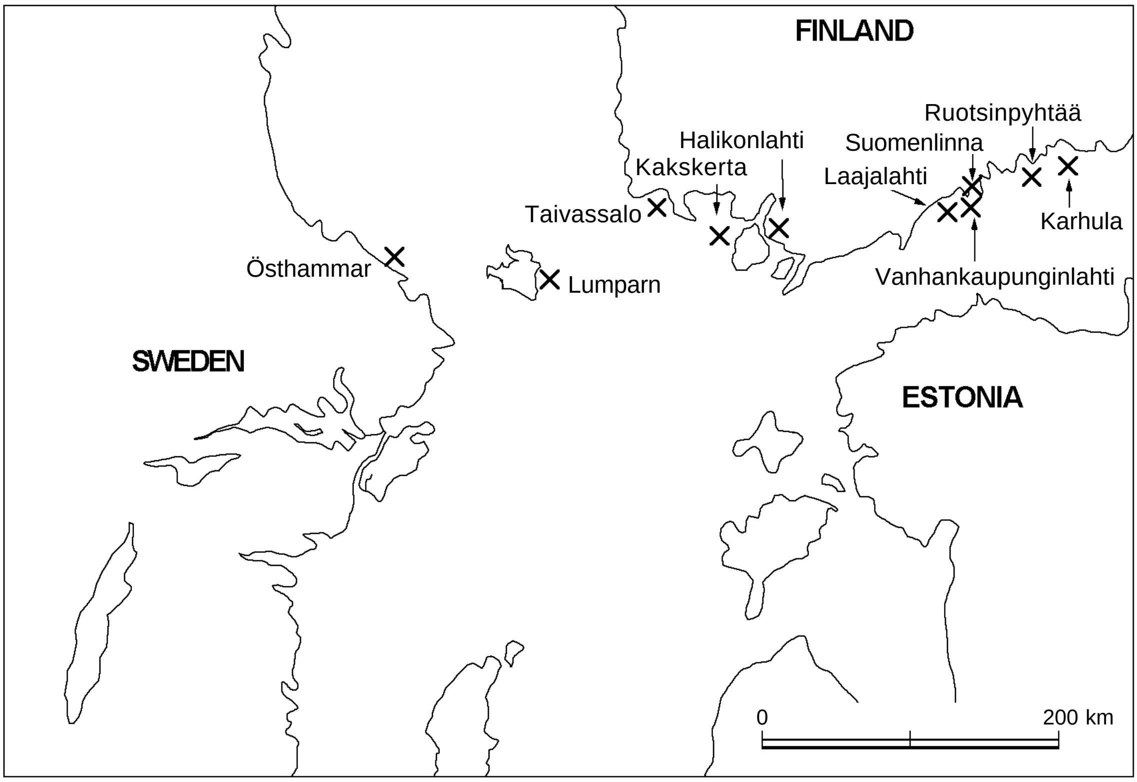


***Figure 4b**. Tagging places for pikeperch presented in figure 4a.*

Discussion

The possibility to manage economically important fish species in the Baltic Sea at a local level was analysed on the basis of migration studies. True coastal species, typically quite sedentary, were found to be most appropriate to manage locally with the criterion used here, i.e. that the whole life cycle could take place within the management unit. It is, however, also conceivable to manage species migrating over long distances (e.g. salmon) locally. Actually, pre-industrial salmon fishery was a good example of local management. Offshore fisheries did not exist; the fishing took place close to the spawning places, in rivers and river mouths, thus avoiding the problem of mixed stock fisheries. The situation is similar for sea-migrating species spawning at the coast, like herring, which earlier was fished mainly in connection with spawning. A return to this type of local, near-shore harvesting has been advocated by, e.g., Iles & Sinclair (1982), in order to avoid the risks with mixed stock fishing.

For planning local fisheries management in the Baltic archipelagos under the prevailing fishing conditions, pike, perch and pikeperch were defined as key species. Pike is most stationary and seldom migrates longer than 5 km. Perch and pikeperch typically donot migrate more than 10 km. The migrations of these species are dependent on the general morphometry of the coast and especially the location and quality of spawning areas. At open coasts and in narrow archipelagos, the dispersal areas are small. Wide archipelagos show a variety of migration distances; where there are large sheltered bays and inlets favourable for spawning, the migrations are typically long.

When interpreting results of mark-recapture experiments, one should bear in mind that the migrations are affected by the interannual variations in environmental conditions, and especially temperature for the warm-water fishes. Migration routes most favourable during the study period may not be so in other years. An obvious problem with the method is that fishing effort is not evenly distributed in space. Tagging is usually done at places where fishing is comparably intensive, and some of the fishes tagged are caught close to the tagging places, sometimes after some hours. Even when the time between tagging and recapture is long, it is more likely that the fish will be caught near the tagging place than at some other place. Thus, there is a risk that the method underestimates migrations.

Even if the migration distances are longer than indicated by the available figures, possibly they are short enough for pike, perch and pikeperch to enable them to be managed locally.

This is undoubtedly so for the Finnish "fishery regions", which often have a width of a few dozen kilometres. Considering the much smaller Swedish "fishery management areas", the situation is less clear. Pike seldom poses a problem, but the other species might need larger areas or co-operation between areas, especially in wide archipelagos with an uneven distribution of spawning areas.

Discussions on the size of management areas must be based on the selection of species to be managed and the morphometry of the coast. Additional information needed is:

1. Genetic structure of key species in order to identify the stocks to be managed.
2. Distribution of spawning areas. In cases where they are unevenly distributed between neighbouring management areas, co-operation between areas or one larger management area might be necessary.
3. Effects of an uneven distribution of the fishing pressure on migrations. If fishes tend to move from areas higher in density to areas where the density is lower, the management areas with high effort and less abundant fish stocks could attract fish from other areas.

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