3.3.2 Conservation and management of aquatic genetic resources: a critical checklist of German freshwater fishes

Schutz und Management Aquatischer Genetischer Ressourcen: Kritische Checkliste deutscher Süßwasserfische

Key words: conservation units, management, phylogeography, taxonomy

Abstract

A current checklist of German freshwater fishes is presented, and recent results of phylogeographic, systematic and taxonomic studies are discussed under the objectives of the Convention on Biological Diversity: the conservation of biological diversity on all its levels from genes to ecosystems and its sustainable use.

Zusammenfassung

Aktuelle Ergebnisse phylogeographischer, systematischer und taxonomischer Studien werden unter den Gesichtspunkten der Konvention zur Biologischen Vielfalt diskutiert. Weiterhin wird eine aktuelle Checkliste der deutschen Süßwasserfische wird vorgestellt.

3.3.2.1 Introduction

The objectives of the Convention on Biological Diversity (CBD) are the conservation of biological diversity on all its levels from genes to ecosystems and its sustainable use. Fisheries and aquatic resources are economically and ecologically important to nations, yet many of these resources are in decline due to habitat alteration, degrading water quality, invasive species, and overharvest.

In accordance with the Charter of the United Nations, and the principles of international law, Germany has the sovereign right to use its own resources, and the responsibility to ensure that activities do not cause damage to the environment. To aid conservation and restoration efforts, Germany needs to identify components of biological diversity important for conservation and sustainable use. Also, there is a need to identify ecosystems containing high diversity, endemic, threatened species or populations; or, which are representative, unique or associated with key evolutionary or other biological processes, and monitor the components (see http://www.biodiv.org/convention/articles.asp for details).

The growing awareness of the decline in diversity of freshwater fish has lead to a remarkable increase in knowledge about their genetic structure and evolutionary units. While the conservation and management units of biological diversity are usually restricted to the species level (see Kottelat 1997), the CBD as well as the American concept of Evolutionary Significant Units (ESU) also include distinct populations. The ESU is a concept developed out of a legal need in the USA to identify threatened populations. An ESU is a "sub-portion" of a species that is defined by substantial reproductive isolation from other conspecific units, and represents an important component of the evolutionary legacy of the species (Waples 1991 Dimmick et al. 1999). The aim of CBD and ESU is the conservation of biological diversity also below the species level (see also Dimmick et al. 1999; Young 2001; Fraser & Bernatchetz 2001 for critical comments).

In recent years, numerous data about conservation and management units of German freshwater fishes were published. Also, new species have been described, and the consequent application of the Evolutionary Species Concept (ESC) (Mayden 2002) has lead to the recognition of a number of species ignored. There have also been nomenclatorial changes leaded to the renaming of several German fishes.

The last review about the diversity of German freshwater fish (Freyhof 2002) is now outdated, and was limited to the species level. The present paper addresses these limitations, present a new checklist of German freshwater fishes and summarises the current knowledge of the conservation and management units of selected groups of German freshwater fishes, recognised at or below the species level, as is the aim of the CBD.

3.3.2.2 Systematic accounts

Petromyzontidae

The systematics of Danubian lampreys is still unresolved, and the identity of populations identified as *Eudontomyzon vladykovi* need to be re-examined.

The anadromous, predatory *Lampetra fluviatilis* and the sedentary, non-predatory populations collectively called *Lampetra planeri* have a very similar general morphology. There are indications that, at least in central Europe, *L. planeri* of a given river system are usually more closely related to the sympatric or nearby *L. fluviatilis* populations than to *L. planeri* of other systems (Schreiber & Engelhorn 1998). This suggests that *L. planeri* might have evolved from *L. fluviatilis* several times in parallel. Due to their size-selected mating behaviour, *L. planeri* and *L. fluviatilis* are reproductively isolated at the spawning sites. To date, there is no evidence that the offspring of *L. planeri* can develop the anadromous, predatory life-style of *L. fluviatilis*, or that offspring of *L. fluviatilis* can remain in their natal stream and spawn without feeding, but it may be possible in some areas. As *L. fluviatilis* and *L. planeri* are able to keep their specific identity in sympatry, they are treated as two species. But clearly, the classifications of all brook lampreys as a single species *L. planeri* needs to be re-examined. Data provided by Engelhorn and Schreiber (1997) suggest, that at least in the Danube drainage more than one species might have been be grouped together under *L. planeri*.

In the view of the CBD and to be precautious, non-predatory lampreys should be monitored on the population (in Danube drainage) or at least river catchments level (northern drainages).

Acipenseridae

Archaeological records and genetic markers suggest that *A. oxyrinchus* colonised the Baltic Sea basin about 1,800 years ago from North America and replaced *A. sturio* about 800 years ago in Baltic Sea (Ludwig et al. 2002). Therefore, we recognise *A. oxyrinchus* as native to the Baltic Sea basin and *A. sturio* as native to the North Sea basin.

Cyprinidae

Since the publication of the last checklist (Freyhof 2002) several nomenclatural and systematic changes have been published or have been accepted by qualified authors.

***Abramis*, *Ballerus, Blicca*, *Vimba*.** Supported by molecular data (Durand et al. 2002) and morphological data (Bogutskaya & Naseka 2004), two species (*Abramis ballerus* and *Abramis sapa*) traditionally included in *Abramis,* are now placed in their own genus: *Ballerus* (Table 1). *Abramis* is now restricted to *Abramis brama*; *Blicca* is restricted to *Blicca bjoerkna* and *Vimba* to *Vimba vimba*.

The recognition of *Vimba elongata* from subalpine lakes as a distinct species, (see Kottelat 1997), is not supported by morphological studies (Uiblein & Winkler 1994) or by unpublished molecular studies (C. Dümpelmann pers. comm.). However, there are exceptionally early spawning *Vimba* (early April vs. late May-July in *V. vimba*) known from Lake Starnberger See (A. Hartl pers. comm.) suggesting, that not all *Vimba* populations are identical. The data provided by Uiblein and Winkler (1994) do not reject the possibility, that postglacial, allopatric speciation might have leaded to locally endemic *Vimba*, distinct from riverine *V. vimba* in some subalpine lakes.

Until better data are available, the stocking of *Vimba* should therefore be avoided, and lacustrine populations should be monitored as individual units in the view of the CBD.

***Leuciscus*.** Two of the four *Leuciscus*-species (*L. cephalus*, *L. souffia*) distributed now into the genera *Squalius* and *Telestes*. *Squalius* as a valid genus was re-established by Bogutskaya (2002) based on morphological data, but the name was earlier applied by Iberian authors based on molecular data (Zardoya & Doadrio 1999). *Telestes* was re-established by Ketmaier et al. (1998) based on enzyme electrophoretic data. The distinctness of *Squalius* and *Telestes* from *Leuciscus* is also strongly supported by mitochondrial DNA data (Gilles *et al.* 2001; Zardoya & Doadrio 1999; Durand et al. 2002; Freyhof et al. 2006) and nuclear DNA data (Freyhof et al. 2006). Therefore, the valid names of these two species are now *Squalius cephalus* und *Telestes souffia*. Data presented by Salzburger et al. (2003) support the view, that German populations of *T. souffia* are quite similar to each other and closely related to Danubian populations. Salzburger et al. (2003) divided *T. souffia* in two major groups (Danube and Rhine vs. Rhone and south France) and the name *Telestes rysela* is available (not *agassii* or *agassizii*) for the Danube and Rhine *Telestes*, if they are shown to be distinct species (see Kottelat 1997 for details).

Mitochondrial data by Durand et al. (2002) also suggest that *Aspius* might be included in *Leuciscus* and it might soon be transferred to that genus if nuclear markers support this view. Nuclear data are needed to exclude, that *Aspius* has only the mitochondrial bodies of *Leuciscus* due to hybridizations, even distantly related cyprinids might exchange mitochondrial bodies (Freyhof et al. 2005b)

Durand et al. (1999) demonstrated that *Squalius cephalus* is divided in several groups, two of them occurring in Germany (Rhine and Weser vs. Danube and part of upper Elbe).

In the view of the CBD, *Telestes* and *Squalius* should be monitored on the river catchments level. To be cautious, at least *Squalius* should not be translocated at all until nuclear data from a wider range of populations are available.

Chalcalburnus. The cyprinid known as "Mairenke" from three or four subalpine lakes in Bavaria was included into *Chalcalburnus*. Populations from Germany were usually considered as subspecies *C. mento* of the Caspian shemaja *Chalcalburnus chalcoides*. Supported by molecular data (Durand et al. 2002) and morphological data (Bogutskaya & Naseka 2004), the genus *Chalcalburnus* is currently again included into *Alburnus*. A recent review of former subspecies of *A. chalcoides* revealed, that *Alburnus mento* is a valid species endemic to lakes in Germany and Austria (Freyhof & Kottelat 2006). The valid scientific name of Mairenke is therefore *Alburnus mento*.

Gobio. Morphological and mitochondrial DNA data presented by Naseka (1996) and Yang et al. (2006) clarify that European gudgeons have to be divided into two genera, *Gobio* and *Romanogobio*, both occurring in Germany. The former subspecies of *R. albipinnatus* are re-diagnosed by Naseka (2001) and are treated as valid species by Naseka and Freyhof (2004), as well as by Bogutskaya & Naseka (2004) as they conform to the Evolutionary Species Concept (see Mayden 2002 for species definitions in Ichthyology). *Romanogobio albipinnatus* is restricted to the Caspian basin. "Steingressling", *R. uranoscopus*, and "Weissflossengründling", *R. vladykovi*, are restricted to the Danube, *R. belingi* is the valid name for the "Weissflossengründling" of the rivers Rhine, Elbe and Odra. The presence of *R. kesslerii* in the German part of the Danube is still not confirmed (see Freyhof 2002).

The type locality of *Gobio gobio* was recently restricted to the River Sieg in the German Rhine drainage (Kottelat and Persat, 2005). These authors also mentioned a massively underestimated diversity within the genus *Gobio* in Europe. Freyhof and Naseka (2005) re-examined *Gobio* from Central and Eastern Europe including Germany. While it is obvious that *Gobio* from the rivers Rhine, Elbe and Orda belong to *G. gobio*, the situation in the Danube seems to be quite complicated, and several species might be recognised there. Our own preliminary morphological data suggests that a hybrid zone between Danubian *Gobio obtusirostris* and northern *G. gobio* cannot be excluded in the upper Danube (and in upper Rhine which was not studied).

In the view of the CBD and to be cautious, *Gobio* should be monitored on the subdrainage level (in Danube), and on the river catchments level (northern drainages).

Rutilus. Two Danubian endemics known as "Frauennerfling" *Rutilus pigus virgo* and "Perlfisch" *Rutilus frisii meidingeri* have been transferred from subspecies to species status following the Evolutionary Species Concept (see Kottelat 1997). *Rutilus meidingeri* and *Rutilus virgo* are the valid names. *Rutilus meidingeri* is restricted to Austrian subalpine lakes Attersee, Mondsee and Wolfgangsee. A population also exist in the Austrian stretch of the Danube (Zauner and Ratschan 2005). It is extirpated in Lakes Traunsee (Austria) and Chiemsee (Germany).

Rhodeus. German bitterlings are known as *R. sericeus*, *R. sericeus amarus* or *R. amarus* depending on the author. Recent molecular studies by Bohlen et al. (in press) could demonstrate that *R. sericeus* is restricted to Siberia. *Rhodeus amarus* is divided into two main populations groups. Only *R. amarus* from the Western Population group is native to Germany. *Rhodeus amarus* from the Eastern Population group are locally introduced in Germany and thereby have to be classified as alien (for details see Bohlen et al. (in press)). In the view of the CBD, if stocking of bitterlings is urgently needed, *Rhodeus* should be stocked from source populations which are confirmed to represent native populations.

Cobitidae

Cobitis elongatoides and *Sabanejewia baltica* were recently discovered in Germany by Bohlen et al. (2005). In addition to these, only *Cobitis taenia* and hybridogenous lineages are known from German waters (Bohlen et al. 2002). Hybridogenous *Cobitis* are almost all females which reproduce by gynogenesis or hybridogenesis. In northern German drainages, hybridogenous *Cobitis* occur in sympatry with *C. taenia.* However, in upper Rivers Elbe and Rhine, it cannot be excluded, that *C. elongatoides* occurs, most likely together with hybridogenous lineages. In Swiss Rhine drainage, *Cobitis bilineata* has been introduced from the Adriatic basin. It cannot be excluded, that this species might expand its range to the German upper Rhine. Therefore, *Cobitis* from upper Rhine have to be examined carefully. *Cobitis taenia* is not known from River Danube until now, and Danubian populations in Germany should be carefully studies if available.

Within a hybrid complex, individuals belonging to hybridogenous lineages are not distinguishable by external characters from individuals of bisexual parent species. Chromosome studies are needed to identify *Cobitis* properly (Bohlen et al. 2002). Frequently, hybridogenous individuals are more abundant in a given hybrid complex than are the parent species. An unbalanced sex ratio with many more females than males is a good indicator that hybridogenous lineages are present.

Salmo. Most German populations of *S. trutta* belong to the so called Atlantic lineage, and only few populations of the Danube catchment belong to the so called Danubian lineage (see Weiss et al. 2001 and Schreiber & Diefenbach 2004 for details). Resident, anadromous and lacustrine trout are often classified as subspecies or as forma *fario*, *trutta* and *lacustris*. Under the International Code of Zoological Nomenclature names of varieties and forms such as *S. trutta* forma *trutta* are not correct. The use of a wording such as '*S. trutta* sea trout form' is correct. These different, not reproductively isolated, life history forms of trouts (see Schreiber & Diefenbach 2004 for Rhine population) are called ecotypes and are no distinct conservation units following the CBD.

Salvelinus. Lacustrine charrs of the genus *Salvelinus* are one of the treasures of the German fish fauna, representing several endemic species (see Freyhof & Brunken 2004). Due to the existence of charrs with different appearance in different lakes (Behnke 1980, 1984) as well as within individual lakes (Jonsson & Hinar 1982; Hartley et al. 1992; Vollestad & L' Abee-Lund 1994), the systematics of charrs is still poorly understood. Charrs from subalpine lakes are usually lumped under one species, *S. alpinus*. While it is plausible, that *S.alpinus* is the name of a fish which is called "Alpensaibling", this is not correct for Central Europe. Linnaeus (1758) described four *Salvelinus*, *S. alpinus* from Lappland, and *S. umbla*, *S. salvelinus* and *S. salmarinus* from subalpine lakes. If subalpine and northern European populations are considered conspecific as still asserted by numerous authors, then the name *S. alpinus* is not available for the present species, but has to be replaced by *S. umbla*, as required by the International Code of Zoological Nomenclature. In this case, *S. umbla* is the first name available for subalpine charrs. Brunner et al. (1998) surveyed several charr populations of subalpine lakes of the Rhine, Rhone and Danube drainages and support the view that relationship of charr populations within subalpine lakes parallels the hydrographic system. Englbrecht et al. (2002) demonstrate that native charr populations still exist at least in German Lakes Ammersee and Königssee. Deepwater charrs from Lakes Bodensee, *S. profundus*, and Ammersee, *S. evasus*, were recently diagnosed by Freyhof & Kottelat (2005). Fresh material of Lake Königssee charr, *S. monostichus*, examined in 2004 (authors own unpublished data) agree well with historic *S. monostichus* examined and described by Heckel (1851).

In the view of the CBD and to be cautious, all native charr populations known, or suspected, to have survived should be managed as endemic species. In Lake Bodensee, there are even indications, that more than one populations exist, and artificial propagation might be a thread to them. Therefore, artificial reproduction and stocking currently is, and should continue to be, restricted to spawners caught at individual spawning places. Spawners are not, and never should be, mixed between different spawning places.

Thymallidae

Molecular studies demonstrate that there is a remarkable diversity of graylings within Europe (Koskinen et al. 2002; Weiss et al. 2002) and Germany (Gum et al. 2005). Until morphological data are available, no taxonomic conclusion can be drawn from these results, but we also cannot exclude, that more than one species might be involved in German *Thymallus*.

In the view of the CBD, *Thymallus* should be monitored and conserved on the catchment level and only stocked from source populations which are confirmed to be native.

Coregonidae

Coregonids are one of the treasures of the German fish fauna, representing several endemic species (see Freyhof & Brunken 2004). Almost all populations of "whitefish" are usually grouped in a catch-all species named *Coregonus lavaretus*, which was stated to be extremely plastic, able to adapt quickly to new habitats, and which has evolved into a great number of ecological morphs. In fact the main problem is that coregonid systematics has been complicated by poor or outdated concepts, and the work of scientists who have been unfamiliar with the correct application of the principles of systematics (see Kottelat 1997 for overview). Many observations are flawed by *ad hoc* theories and concepts, and the idea that coregonid systematics has to be different from the systematics of other fishes.

In several lakes, coregonids (up to six species in Bodensee) are morphologically and genetically distinct, live in sympatry, and have different habitats, ecology, prey preference and spawning seasons. These coregonids fit the definition of species. It is well known, that Coregonids evolve fast, but they do not evolve faster than other fish groups (see Myers 1960 and Seehausen 2002 as two of many examples). There are widespread concerns that the diversity of Coregonids is just ecophenotypic, and would therefore completely depend on the current environmental situation. It is widely believed, that the number and structure of gill rakers change within only few generations depending on the trophic situation in a particular lake. However, it has been clearly demonstrated (see Svärdson 1979 for details) that the gill rakers characteristics are genetically determined, and change by evolution, and are not phenotypicically plastic.

To date, 18 species are recognized from Germany, but the published data indicate the existence of more species (Vogt & Hofer 1909).

In the view of the CBD, all native coregonid populations known, or suspected, to have survived should be managed as if they are endemic species. In Ammersee, Bodensee, Breiter Luzin, Chiemsee, Starnberger See, and Stechlinsee, two or more native species exist, or existed, and artificial propagation might be a thread to them.

Lotidae

The earlier family Gadidae is now divided into five families (Gadidae, Merlucciidae, Lotidae, Gaidropsaridae and Phycinae) (Markle 1989), three of which are considered to be subfamilies of Gadidae by Teletchea et al. (2006). Van Houdt (2003) studied the biogeography of *Lota lota* and distinguished a Western and a Central populations group, occurring in Germany. *Lota* from the lower River Elbe belong to the Western group, while *Lota* from Lake Bodensee and River Isar belong to the Central group.

While the diversity of *Lota* populations in Germany is not really explored, *Lota* should be managed at least on the river catchments level.

Gasterosteidae

Only one species of genus *Gasterosteus*, *G. aculeatus*, is traditionally recorded from Central Europe. Kottelat (1997) considered incompletely plated fish (*G. gymnurus*) and full plated fish (*G. aculeatus*) as two species. In fact, the taxonomic situation seems to be much more difficult (see also Mäkinen et al., 2006), and more species seem to be involved.

In the view of the CBD, *Gasterosteus* should not be translocated.

Cottidae

Freyhof et al. (2005a) distinguish 16 species of *Cottus* in European waters, five of them are recorded from Germany. *Cottus microstomus* is restricted to two small streams in Brandenburg, and *C. rhenanus* to the tributaries of the Meuse, Middle and Lower Rhine. *Cottus perifretum* is known from the Middle and lower Rhine, being most likely an invasive species in Germany (Nolte et al. 2005).

Due to the high morphological diversity within *Cottus gobio* (Freyhof et al. 2005a), several local populations with an unique evolutionary history may exist. In the view of the CBD and to be precautious, *Cottus* should not be translocated.

Percidae

While Nesbo et al. (1999) did not find major differences between populations of *Perca fluviatilis* in Germany, Behrmann-Godel et al. (2004) demonstrated the existence of two "sub"-populations of perch in Lake Bodensee.

In the view of the CBD, *Perca* should be monitored at least on the catchment level until better data are available.

Gobiidae

All freshwater *Proterorhinus* have long been confused under the name *P. marmoratus*. The real *P. marmoratus* does not enter pure freshwaters (Stepien & Tumeo 2006) and the name *P. semilunaris* is valid for the German species which is quickly invading the Rivers Danube and Rhine. Also coming from the Danube, the bighead goby, *Neogobius kessleri* has reached the Rhine drainage in 2005. The round goby, *Neogobius melanostomus*, another powerfull Pontocaspian invader (Charlebois et al., 1997) was recorded from the Dutch Rhine in 2004 (van Beek 2006) and is expected to spread into the German Rhine soon.

Table 1: Checklist of freshwater lampreys and fishes of Germany.

Petromyzontidae
Eudontomyzon vladykovi
Lampetra fluviatilis
Lampetra planeri
Petromyzon marinus

Acipenseridae
Acipenser gueldenstaedtii
Acipenser ruthenus
Acipenser stellatus
Acipenser sturio
Acipenser oxyrinchus
Huso huso

Anguillidae
Anguilla anguilla

Clupeidae
Alosa alosa
Alosa fallax

Cyprinidae
Abramis brama
Alburnoides bipunctatus
Alburnus alburnus
Alburnus mento
Ballerus ballerus
Ballerus sapa
Barbus barbus
Blicca bjoerkna
Carassius auratus
Carassius carassius
Carassius gibelio
Chondrostoma nasus
Ctenopharyngodon idella
Cyprinus carpio
Gobio gobio
Gobio obtusirostris
Hypophthalmichthys molitrix
Hypophthalmichthys nobilis
Leucaspius delineatus
Leuciscus aspius
Leuciscus idus
Leuciscus leuciscus
Pelecus cultratus
Phoxinus phoxinus
Pseudorasbora parva
Romanogobio belingi
Romanogobio uranoscopus
Romanogobio vladykovi
Rhodeus amarus
Rutilus meidingeri
Rutilus virgo
Rutilus rutilus
Scardinius erythrophthalmus
Squalius cephalus
Telestes souffia
Tinca tinca
Vimba vimba

Balitoridae
Barbatula barbatula

Cobitidae
Cobitis elongatoides
Cobitis taenia
Misgurnus angullicaudatus
Misgurnus fossilis
Sabanejewia baltica

Siluridae
Silurus glanis

Ictaluridae
Ameiurus nebulosus
Ameiurus melas

Salmonidae
Hucho hucho
Oncorhynchus mykiss
Salmo salar
Salmo trutta
Salvelinus evasus
Salvelinus fontinalis
Salvelinus monostichus
Salvelinus profundus
Salvelinus umbla

Thymallidae
Thymallus thymallus

Coregonidae
Coregonus albula
Coregonus arenicolus
Coregonus bavaricus
Coregonus fontanae
Coregonus gutturosus
Coregonus hoferi
Coregonus holsatus
Coregonus lucinensis
Coregonus macrophthalmus
Coregonus maraena
Coregonus maraenoides
Coregonus oxyrinchus
Coregonus renke
Coregonus wartmanni
Coregonus widegreni
Coregonus sp. „Chiemsee-Kilch“
Coregonus sp. „Rhine“
Coregonus sp. „Starnberger See“

Osmeridae
Osmerus eperlanus

Esocidae
Esox lucius

Umbridae
Umbra pygmaea

Lotidae
Lota lota

Gasterosteidae
Culaea inconstans
Gasterosteus aculeatus
Gasterosteus gymnurus
Pungitius pungitius

Cottidae
Cottus gobio
Cottus rhenanus
Cottus microstomus
Cottus perifretum
Cottus poecilopus

Percidae
Gymnocephalus cernuus
Gymnocephalus baloni
Gymnocephalus schraetser l
Perca fluviatilis
Sander lucioperca
Zingel streber
Zingel zingel

Centrachidae
Lepomis gibbosus

Gobiidae
Neogobius kessleri
Pomatoschistus microps
Proterorhinus semilunaris

Pleuronectidae
Platichthys flesus

3.3.2.3 Conclusion

The presented checklist of German freshwater fishes (Table 1) is the first attempt to address the objectives of the Convention on Biological Diversity. In contrast to previously checklist (Freyhof 2002), genetic distinct populations of species were considered as discrete conservation and management units. The biodiversity on the level of discrete populations ensures the adaptive potential of a species and the resilience against environmental changes (Nielsen et al. 2001) and exploitation (Hilborn et al. 2003). In spite of a remarkable increase of our knowledge about the phylogeographic structure of some German fish species during recent years, there is still a lack of knowledge about the genetic structure and evolutionary units of many other species. Not only subalpine *Coregonus* and *Salvelinus* should be studied carefully, it could also not be excluded, that many "common" fish species as *Rutilus rutilus*, *Leuciscus leuciscus*, *Alburnus alburnus* or *Abramis brama* might be divided into discrete management units.

Therefore, the success of future conservation and management strategies to prevent loss of fish diversity and to ensure the sustainable use of the aquatic resource will be depending on the consideration of the presented recommendations and the future improvement of our knowledge about the phylogeographic structure of all German fish species. According to the CBD and to be precautious, species with unknown phylogeographic structure should be monitored on the population or at least river catchment level. Generally, translocation of these species between watersheds should be avoided.

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