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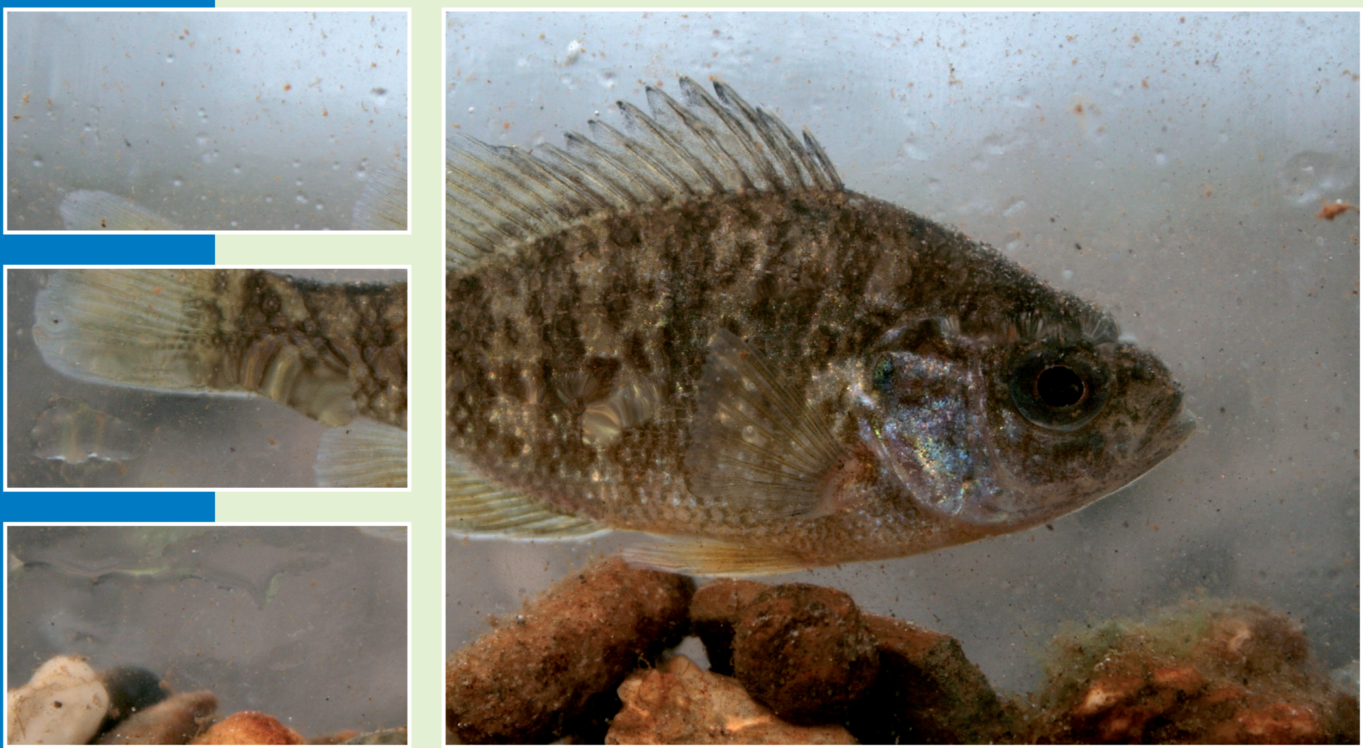

D.M. Soes
S.J. Cooke
H.H. van Kleef
P.B. Broeckx
P. Veenvliet

Bureau Waardenburg bv
Adviseurs voor ecologie & milieu

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D.M. Soes
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P. Veenvliet

**Bureau Waardenburg bv**
Consultants for environment & ecology
P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49
E-mail wbb@buwa.nl Website: www.buwa.nl

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| Author: | ir. D.M. Soes<br>prof. dr. S.J. Cooke<br>dr. H.H. van Kleef<br>ir. P.B. Broeckx<br>P. Veenvliet |
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| Name & address client: | Food and Consumer Product Safety Authority, Invasive Alien Species Team, P.O. Box 9102, 6700 HC, Wageningen |
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| Initials: | |

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**Bureau Waardenburg bv**
Consultants for environment & ecology

P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49

E-mail wbb@buwa.nl Website: www.buwa.nl

# Preface

Several species of Centrarchidae are known to be invasive species of special concern. The Elassomtidae have been mentioned to be an alternative for these species. To gain insight into the occurrence of exotic centrarchid and elassomatid species in the Netherlands, the possibility of them becoming invasive, the possible ecological, economical and social impacts, and the possibilities of risk management the Invasive Allien Species Team of the Food and Consumer Product Safety Authority have commissioned Bureau Waardenburg to carry out a risk analysis.

This risk analysis was carried out by Bureau Waardenburg:
ir. D.M. Soes (project leader and report)
prof. dr. S.J. Cooke (report & review)
dr. H.H. van Kleef (report)
ir. P.B. Broeckx (report)
P. Veenvliet (report)
L. Anema (GIS)

From the Team of Invasieve Exoten of the Food and Consumer Product Safety Authority the analysis was supervised by Mrs. dr. ir. José H. Vos and ir. J.W. Lammers.

We would like to thank the following people for their effort and contribution: J.L. Spier (Bureau Waardenburg), J. Klungers (specialist aquarology of subtropic fish species), S. Fenoglio (Università del Piemonte Orientale, Italy), P. Keith (Muséum national d¹Histoire Naturelle), J. Freyhof (Leibnitz Institute of Freshwater Ecology and Inland Fisheries), G.H. Copp (CEFAS), R. Gozlan (Bournemouth University), E. Tricarico (Università degli Studi di Firenze), E. Kruidenier (Naturalis), H. Verreycken (INBO), D. P.J. van Heugten (De Kreeften en Garnalen shop), J. Bohlen (Academy of the Sciences of the Czech Republic), RAVON, Sportvisserij Nederland, Waarneming.nl, A. Ploeg (Dibevo), T. Demol (Service public de Wallonie) & A. Lamboj (Fischartenatlas.de).

We acknowledge that much of the material of chapter 5 is from a recent book on centrarchid fish by Cooke & Philipp (2009) with particular reliance on the chapters that focused on natural history accounts (Warren, 2009), winter biology (Suski & Ridgway, 2009) and organismal physiology (Kieffer & Cooke, 2009). We thank the authors for giving permission for using these texts.

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# Summary

The family Centrarchidae includes about 34 species, which all have their native range in North America. In the Netherlands the most ill famous member is *Lepomis gibbosus*. This in the Netherlands invasive species is the only member of the family with established populations. These populations can be found all over the Netherlands and the species seems to be still expanding. Its negative image is caused by its presence in many isolated water bodies where it has a strong negative impact on the fauna, including rare amphibians such as the common spadefoot (*Pelobates fuscus*) and the European tree frog (*Hyla arborea*). Because of this impact a wholesaler has decided stop selling this species in 2010.

In this study it is shown that another nine species of Centrarchidae should be considered to be potentially invasive. They are all at least available for export in North America and have a high probability of establishment based on their thermal biology: *A. rupestris, P. annularis, P. nigromaculatus, L. cyanellus, L. macrochirus, L. megalotis s.l. (L. megalotis s.s.* & *L. peltastes), M. dolomieu* & *M. salmoides*. When considering possible climate change in the period 1990-2050 *L. auritus* should be included in this list. These species are all flexible in their habitat preferences and are likely to find suitable habitats in most regions in the Netherlands. With these centrarchids known to be good dispersers, it is likely that they will spread relatively easily after establishing reasonable populations. The family Elassomatidae, which is also reviewed as they might be a potential substitute for centrarchids in trade, is considered to be of no risk as they are unlikely to survive Dutch winters.

Like *L.gibbosus* also other Centrarchidae are likely to affect ecosystems mainly by predation (amphibians, smaller fish species, damselflies, etc.) and competition with other predatory fish. Especially ecosystems, lacking comparable native predatory fish species prior to the establishment of such an exotic centrarchid, are susceptible to significant ecological impact. Centrarchidae have not been reported to be vectors for parasites or diseases of special concern.

The establishment of larger centrarchid species will have a small, positive social and economic impact to commercial fisheries, the angling society and related business.

When established, centrarchid populations can in most instances only be eradicated with rigorous measures like dewatering or the use of piscicides. Obviously, the prevention of entries and further spread reduces the need for such actions. The major components of prevention are banning of potential invasive species from trade and educating the public about the impact of centrarchids.

# 1 Introduction

The pumpkinseed (*Lepomis gibbosus*) originates from North America. Since the late late 19th century this species has been introduced and proven to be invasive in many countries in Europe, including the Netherlands. Also the largemouth bass (*Micropterus salmoides*), another member of the Centrarchidae is invasive in Europe, but this species has not arrived in the Netherlands yet. Furthermore several other members of both the families Centrarchidae and Elassomatidae are also considered to be potential invasive species in Europe. As at least Centrarchidae have the potential to cause serious ecological, economic and social impacts, they therefore can interfere with the goals of various European Directives such as the Water Framework Directive (WFD) and the Habitat Directive (Nature 2000).

In this study, commissioned by the Invasive Alien Species Team of the Food and Consumer Product Safety Authority, a risk analysis was undertaken to provide more insight into the present distribution of Centrarchidae and Elassomatidae, their (potential) impacts, the probability of entry (introduction pathways), the probability of establishment, the probability of further spread and endangered areas. Subsequently, measures are identified to prevent further spread of these species and eradication and physical control methods are described that can be used to reduce the number of especially *L. gibbosus* in The Netherlands.

*Figure 1.1: Micropterus salmoides.*

# 2 Taxonomy and distribution

## 2.1 Centrarchidae

### 2.1.1 Taxonomy

The Centrarchidae is a family of fishes belonging to the order Perciformes, which is endemic to North America. In total 32-34 species are included in the Centrarchidae, depending on the bibliographic source. The differences between the lists of Fishbase.org with 32 species and the list of Near & Koppelman (2009) with 34 species are due to the two species which were formerly considered to be subspecies of respectively *L. megalotis* and *M. punctulatus*: *L. peltastes* and *M. henshalli* (Baker *et al*., 2008; Bailey *et al*., 2004). It is expected that several additional centrarchid species are likely to be identified after further research using molecular techniques (Near & Koppelman, 2009), especialy in polymorhic taxa like *L. megalotis* and *L. macrochirus*.

Hybridization is common among centrarchid fishes and is known from the genera *Lepomis* and *Micropterus*. This makes the task of identifying species that have already proven to be difficult to identify almost impossible. An example are the basses. Especially *M. salmoides* and *M. floridanus* are difficult to seperate without the aid of molecular methods. Because of this, it is actually unclear what species status should be assigned to European populations of these species. After molecular work it might become clear that some populations are actually *M. floridanus* or hybrids instead of pure *M. salmoides* populations as now commonly assumed.

*Figure 2.1: Spanish bass: M. salmoides, M. floridanus or a hybrid? Photo by pescaprofessional.*

*Table 2.1: List of known extant centrarchid species. Based on Fishbase, Near & Koppelman (2009) and several Dutch publications.*

| Scientific | English | Dutch |
|---|---|---|
| *Acantharchus pomotis* (Baird 1855) | Mud sunfish | |
| *Ambloplites ariommus* (Viosca 1936) | Shadow bass | |
| *Ambloplites cavifrons* Cope 1868 | Roanoke bass | |
| *Ambloplites constellatus* Cashner & Suttkus 1977 | Ozark bass | |
| *Ambloplites rupestris* (Rafinesque 1817) | Rock bass | rotsbaars/steenbaars |
| *Archoplites interruptus* (Girard 1854) | Sacramento perch | |
| *Centrarchus macropterus* (Lacepède 1801) | Flier | pauwoogzonnebaars |
| *Enneacanthus chaetodon* (Baird 1855) | Blackbanded sunfish | schijfbaars |
| *Enneacanthus gloriosus* (Holbrook 1855) | Bluespotted sunfish | diamantbaars |
| *Enneacanthus obesus* (Girard 1854) | Banded sunfish | diamantbaars |
| *Lepomis auritus* (L. 1785) | Redbreast sunfish | roodborstzonnebaars |
| *Lepomis cyanellus* Rafinesque 1819 | Green sunfish | groene zonnebaars |
| *Lepomis gibbosus* (L. 1785) | Pumpkinseed | zonnebaars |
| *Lepomis gulosus* (Cuvier 1829) | Warmouth | |
| *Lepomis humilis* (Girard 1858) | Orangespotted sunfish | |
| *Lepomis macrochirus* Rafinesque 1819 | Bluegill | |
| *Lepomis marginatus* (Holbrook 1855) | Dollar sunfish | |
| *Lepomis megalotis* (Rafinesque 1820) | Southern longear sunfish | grootoorzonnebaars/ langoorzonnebaars |
| *Lepomis microlophus* (Günther 1859) | Redear sunfish | |
| *Lepomis miniatus* Jordan 1877 | Redspotted sunfish | |
| *Lepomis peltastes* Cope 1870 | Northern longear sunfish | |
| *Lepomis punctatus* Valenciennes 1831 | Spotted sunfish | |
| *Lepomis symmetricus* Forbes 1883 | Bantam sunfish | |
| *Micropterus cataractae* Williams & Burgess 1999 | Shoal bass | |
| *Micropterus coosae* Hubbs & Bailey 1940 | Redeye bass | |
| *Micropterus dolomieu* Lacepède 1802 | Smallmouth bass | zwartbaars/ zwarte baars |
| *Micropterus floridanus* (LeSueur 1822) | Florida bass | |
| *Micropterus henshalli* Hubbs & Bailey 1940 | Alabama bass | |
| *Micropterus notius* Bailey & Hubbs 1949 | Suwannee bass | |
| *Micropterus punctulatus* (Rafinesque 1819) | Spotted bass | |
| *Micropterus salmoides* (Lacepède 1802) | Largemouth black bass | grootbekforelbaars |
| *Micropterus treculii* (Vaillant & Bocourt 1874) | Guadalupe bass | |
| *Pomoxis annularis* Rafinesque 1818 | White crappie | witte zilverbaars |
| *Pomoxis nigromaculatus* (Lesueur 1829) | Black crappie | zwarte zilverbaars |

### 2.1.2 Description

Centrarchidae are perch-like fish which are characterised by a double dorsal fin. The first part consists of strong spines while the second part has branched, soft fin rays. In a few species these parts are separate fins or only on the basis connected. Two main groups can be distinguished within Centrarchidae: relatively small species with a deep body shape and large, more streamlined species. The smaller species have a small mouth and predate on invertebrates, amphibian larvae and larval fish while the large species have a large mouth and actively pursue middle sized fishes.

*Figure 2.2: The deep bodied L. macrochirus and the elongated M. punctulatus.*

### 2.1.3 Native range

The Centrarchidae are native to the area east of the Rocky Mountains from southern Canada to northern Mexico. Only one species, *A. interruptus*, occurs west of the Rocky Mountains in California. The range of fossil centrarchids is more extensive, including Alaska and southern Mexico (Berra, 2007). Most species are subtropical in their range with only a few species having northern ranges up into Canada.

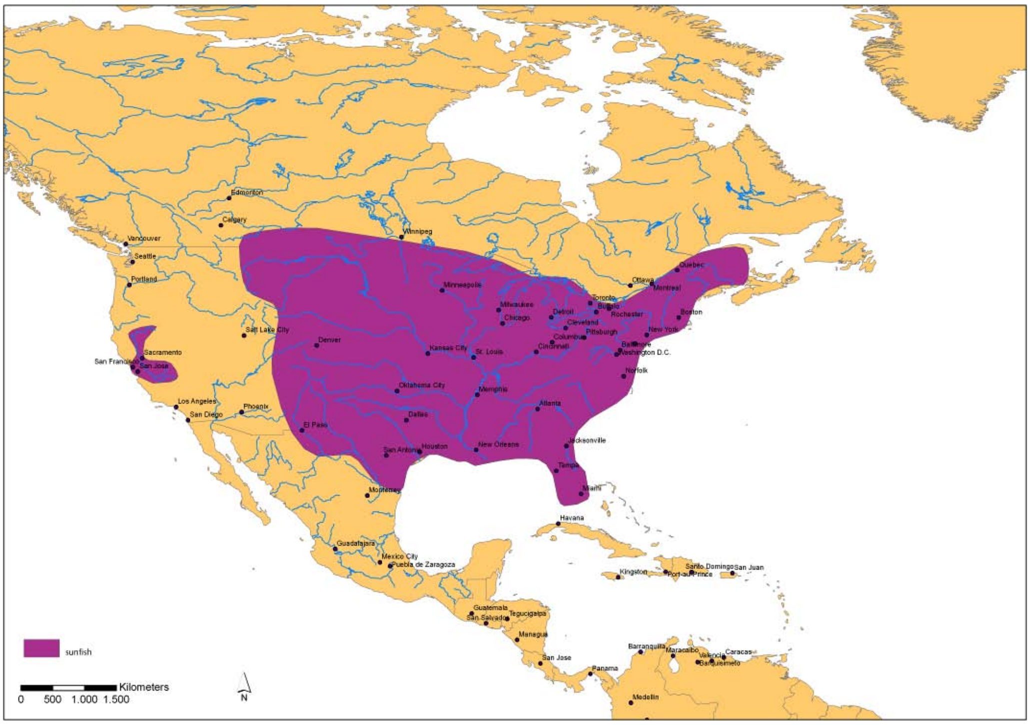



*Figure 2.3: Natural range of the family Centrarchidae in North America.*

### 2.1.4 Introductions

Within North America several centrarchid species have been introduced outside their natural range. *M. salmoides* and *L. macrochirus* have been widely and successfully translocated to many states in the USA, provinces in Canada and to numerous localities in Mexico. They also have been introduced to many other countries worldwide. Tabel 2.2 based on Lever (1996) gives an overview of successfully reported introductions that resulted in established populations. Although the data include erroneous records, e.g. *M. dolomieu* records in Europe, this overview gives an impression which species have been exported in what extent. Evidently one species stands out: *M. salmoides*. With more than fifty countries with reported successful introductions, this species is in the top five of most introduced fish species worldwide. Other species that have been repeatedly been introduced are *L. cyanellus, L. gibbosus, L. macrochirus* and *M. dolomieu*. Other Centrarchid species have been introduced outside their natural range only occasionally.

*Table 2.2: Naturalized populations of Centrarchidae worldwide. Based on Lever, 1996.*

| | Europe | North America | Central America | South America | Asia | Africa | Oceania | total |
|---|---|---|---|---|---|---|---|---|
| *Ambloplites rupestris* | 2 | 1 | | | | | | 3 |
| *Lepomis auritus* | 1 | 1 | 1 | | | | | 3 |
| *Lepomis cyanellus* | 1 | | | 1 | 2 | 4 | 1 | 9 |
| *Lepomis gibbosus* | 13 | | 1 | 1 | | 1 | | 16 |
| *Lepomis gulosus* | | 1 | 1 | | | | | 2 |
| *Lepomis macrochirus* | | | 2 | 2 | 3 | 4 | 2 | 13 |
| *Lepomis microlophus* | | 1 | 2 | | | 2 | 1 | 6 |
| *Micropterus coosae* | | | 1 | | | | | 1 |
| *Micropterus dolomieu* | 3 | 1 | 1 | | 2 | 2 | 2 | 11 |
| *Micropterus punctulatus* | | | | | | 2 | | 2 |
| *Micropterus salmoides* | 16 | | 9 | 3 | 4 | 14 | 6 | 52 |
| *Pomoxis annularis* | | 1 | | | | | | 1 |
| *Pomoxis nigromaculatus* | | 1 | 2 | | | | | 3 |

**Europe**

Six species of Centrarchidae are reported to have been introduced in European waters, of which probably only three have established populations that persist until now (Kottelat & Freyhof, 2007; J. Freyhof, pers. com.). The first imports for these introductions are early in date with the first trials already from 1877, and most species were already imported before 1900 (Table 2.3). Some of the stocked species, such as *L. gibbosus* and *A. rupestris,* are remarkable because of their small body size, which makes them uninteresting for human consumption or angling. In general the first introductions of exotic fish species around 1900 had the purpose to improve commercial fish stocks (Van Drimmelen, 1987). Most likely, the stocking of smaller species was more out of scientific interest and realising the possible drawbacks. In fish farms these smaller species were cultured for aquaristic purpossess only.

*Table 2.3: Some first imports of centrarchid species in Europe. Based on Stansch (1914), Nijssen & De Groot (1987). Per species the year of the first import, the person of the first import, the destination and the purpose of the import are given.*

| species | year | person | destinat | purpose |
|---|---|---|---|---|
| *Ambloplites rupestris** | 1877 | Von Begg | France | aquaculture/stocking |
| *Centrarchus macropterus* | 1906 | O. Preuße | Germany | aquaristics |
| *Enneacanthus gloriosus* | 1895 | P. Nitsche & P. Matte | Germany | aquaristics |
| *Lepomis auritus** | 1891 | Max von dem Borne | Germany | aquaculture/stocking/ aquaristics |
| *Lepomis cyanellus** | 1906 | H. Stüve | Germany | aquaristics |
| *Lepomis gibbosus** | 1866 | Max von dem Borne | Germany | aquaculture/stocking/ aquaristics |
| *Lepomis gibbosus** | 1877 | Von Begg | France | aquaculture/stocking/ aquaristics |
| *Lepomis gibbosus** | 1881 | Max von dem Borne | Germany | aquaculture/stocking/ aquaristics |
| *Lepomis megalotis* | 1895 | P. Matte | Germany | aquaristics |
| *Mesogonistius chaetodon* | 1897 | W. Geyer | Germany | aquaristics |
| *Micropterus dolomieu** | 1883 | Max von dem Borne | Germany | aquaculture/stocking |
| *Micropterus salmoides** | 1879 | Marquis of Exeter | Scotlans | stocking |
| *Micropterus salmoides** | 1883 | Max von dem Borne | Germany | aquaculture/stocking |
| *Pomoxis nigromaculatus* | 1887 | Berthoule | France | aquaculture/stocking |
| *Pomoxis sparoides* | 1891 | Max von dem Borne | Germany | aquaculture/stocking |

* Species reported to be introduced in European waters.

The six species reported to have been introduced in European waters are discussed per species in the following paragraphs.

_Ambloplites rupestris_

Currently the only existing population of *A. rupestris* known in Europe is located in France. This population is present in the Loire River, east of where the Allier River joins this river (fig. 2.4). It is a result of stocking between 1904-1910, so it has been in existence for around one hundred years (Keith & Allardi, 2001). In total this population exists throughout one hundred kilometres of river, but it is thought not to have actually expanded much in the period 2000-2010. Why its territoy has not expanded is not known (P. Keith, pers. com.).


*Figure 2.4: The distribution of Ambloplites rupestris in France with data upto 2010. Provided by P. Keith, Muséum national d¹Histoire Naturelle.*

In England a population of *A. rupestris* has been present for more then 25 years. This population was present in an artificial lake (said to be a former gravel pit) of about 1.2 hectares near Oxford. The first specimen was caught in July 1937 by an angler who subsequently collected a number of smaller specimens in the same water, proving that this was an established, breeding population at that date. The first specimen is in the British Museum (Natural History) together with further collected specimens in 1956. The 1956 specimens were received from Mr D. F. Leney who wrote that the pond was teeming with ‘bass’ but few exceeding 15 or 18 centimeters. Enquiries made at the time, produced no record of the history of this introduction. This population was still in existence in the 1960s (Wheeler & Maitland, 1973). Currently this population is thought to be extinct (Copp *et al.*, 2007; G.H. Copp, pers. com.; R. Gozlan, pers. com.).

*Lepomis auritus*

*L. auritus* has not become a great succes in aquaristics. With the exception of reports from Italy not much is heard from this species after the first imports. Maitland (1977) listed this species as occuring in Italy and describes the surroundings of Rome as its range. This is confusing as the only documented reports of this species are from Lago di Varano and Lago di Monate (Besana, 1908), both at considerable distance from Rome. Besana (1908) describes in his paper the result of his stockings of this species, which he calls 'sunfish – *Lepomis auritus*', in these two lakes. Especially from Lago di Varano he reports a success with a total catch in 1907 of almost 13,000 kilograms. Remarkably no subsequent reports of this species are known, which is suprising with the great success according to Besana (1908). A recent review of the exotic fishes in Italy does not list *L. auritus* (Gherardi *et al*., 2008) and Fenoglio *et al*. (2010) actually suggest that Besana (2008) misidentified the 'sunfish' and that he actually introduced *L. gibbosus*. More likely is confusion with an older name for *L. gibbosus*: *Eupomotus aureus*. The second part is a bit similar with *auritus*. Another illustration of the confusion about the Italian *Lepomis* are two samples in the collection of Naturalis (15001, Florence, 6-9-1934 & 15002, Rome, 8-9-1934) named *Apomotis punctatus*. This is an old, hardly used name for *L. punctatus*. Both samples are actually *L. gibbosus* (D.M. Soes, pers. observ.). Overall there has been a lot of confusion about the identity of the *Lepomis* introduced in Italy and it is highly uncertain that *L. auritus* has actually been established in the past in Italy and clearly there are no recent records (E. Tricarico, pers. com; S. Fenoglio, pers. com.).

*Figure 2.5: L. auritus (left) and L. gibbosus (right) probably confused in Italy.*

*Lepomis cyanellus*

Regulary this species is reported to have been introduced in the surroundings of Frankfurt (Germany). These stockings supposedly resulted in established populations in this area (Maitland 1977). This is contradicting the statement of Sterba (1959) that it had vanished from Europe. According to Lelek (in Arnold, 1990) no proof for the occurrence of *L. cyanellus* is present and he noted that *L. gibbosus* is very common around Frankfurt. For *L. auritus* and *L. cyanellus* there is no conclusive evidence for established populations in Europe and clearly no established populations are present in Germany nowadays (J. Freyhof, pers. com.).

*Lepomis gibbosus*

Often the import in 1881 by Max von dem Borne is considered the onset of the settlement of *L. gibbosus* in Europe, but actually there have been several shipments from North America that are likely to have been involved in the settlement of *L. gibbosus* in Europe. Such imports are e.g. known from France (1885), Germany (1881), Czechoslovakia (late 19th century), Italy (between 1880-1920) and Spain (between 1910-1913) (Lever, 1996). Other European countries, like the Netherlands, received first shipments from European countries.

After the first imports it became quickly established in e.g. France, South England and Italy, and has actually become one of the most successful exotic fish species with populations in almost every European country (Tomecek *et al*., 2007). Not only its biological characteristics have made this species so successful, also the diversity in vectors has probably played a role. Its first releases might have been for angling purposes, for serving as a food item for *M. salmoides* or just scientific curiosity. More recent releases are mainly associated with aquaristics, garden ponds and even its use as a bait-fish in especially the Iberian Peninsula (Tomecek *et al*., 2007).

*Micropterus dolomieu*

*M. dolomieu* is reported to be released in numerous countries, but in many instances its identification is doubtful. Introductions of young fish believed to be *M. dolomieu* were in fact *M. salmoides* (this is also the case in the US, where some *M. dolomieu* introductions mentioned in the literature were later believed to have been *M. salmoides)*, and similarly, some supposed *M. salmoides* introductions (from German suppliers) were probably pikeperch (*Sander lucioperca)*, because the former was never found but *S. lucioperca* was later found established in these waters. The problem with much of the old literature was that in general only the proper taxonomists were reliable sources and other persons were not very good in their identifications of *Micropterus*-species (G. Copp, pers. comm.). Some more reliable reports of releases in the beginning of the 19th century, like e.g. in several English lakes and lakes in Italy and Germany, never resulted in self sustaining populations (Vooren, 1972; Wheeler & Maitland, 1973; Arnold, 1990). Currently this species is thought to be absent from Europe (Kottelat & Freyhof, 2007).

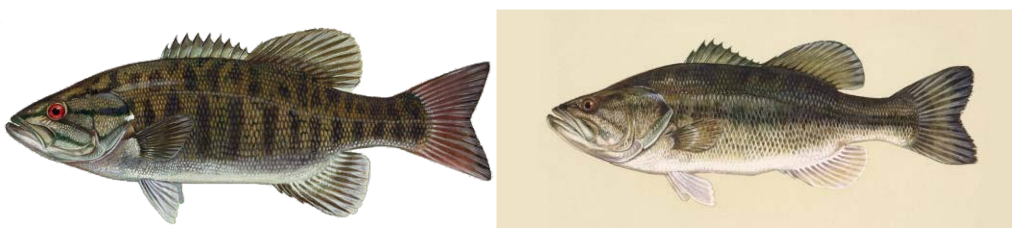


*Figure 2.6: M. dolomieu (left) and M. salmoides (right) probably often confused in Europe.*

*Micropterus salmoides*

The first import of *M. salmoides* in Europe is an attempt of the Marquis of Exeter in 1879. Several specimens obtained in the USA were unsuccesfully stocked in 1881 or 1882 in Loch Baa, Scotland. After the import of *M. salmoides* in 1883 by Max von dem Borne the species has been successfully cultured in Germany. The developed stock has been used to introduce this species in waters in several European countries (Lever, 1996). The first introductions of this species in England, Scotland, Germany and the Netherlands have been unsuccessful in producing selfsustaining populations in the long run (Kottelat & Freyhof, 2007). In England, populations have been present for some time in clay pits, gravel pits and similar watertypes, but all have failed to persist (Lever, 1996).

Introductions in Southern Europe have been much more successful. Nowadays this species is widely naturalized in the Mediterranean region: Portugal, Spain, southern France, Italy, Switzerland (Ticino) and the Adriatic basin from Slovenia to Albania. Naturalized populations are also known from the Slovenian Danube drainage and the lakes of Carynthia (Austria) (Kottelat & Freyhof, 2007).

**The Netherlands**

Centrarchids have been rare in Dutch aquaculture. *M. dolomieu* is reported to have been imported (Mulier, 1900), but this hasn't resulted in a successful culture or stocking program (Nijssen & De Groot, 1987). Reports of successful introductions of *M. dolomieu* (Vooren, 1972) are considered to be erroneous and a possible result of confusion with *M. salmoides* (Nijssen & De Groot, 1987). This latter species, which is not listed for the Netherlands by Vooren (1972), has actually been present in Dutch aquaculture and has also been released in Dutch waters.

**"Zwarte baars"**

Probably some of the confusion about the presence M. dolomieu in the Netherlands originates from the use of the name "zwarte baars". This Dutch name is both used for M. dolomieu and stunted European perch (Perca fluviatilis) populations. Such populations are found in densely vegetated waters with high fish densities. In the Dutch peat district these "zwarte baarzen" are common (Looijen, 1948). Photo: Ron Offermans

*Micropterus salmoides*

The first trial to import *M. salmoides* from America already took place in 1884. But this order by Artis didn't survive the shipment across the ocean. A few years later another shipment was more successful and five specimens arrived in Artis Zoo. Successive attempts to breed them were not very successful and no introductions seem to have been attempted by Artis (Nijssen & De Groot, 1987). In the 1920s experimental stockings have been undertaken in a single small fishing lake. The location of this lake is not clear as it is not reported. The stocked *M. salmoides* were able to reproduce well, creating a well noticed high density (Anonymous, 1930). The fish farm in Gulpen seems to have been involved because in the collection of Naturalis a single *M. salmoides* specimen (RMNH.PISC.36087) is present labeled: Gulpen, 25-2-1927. This specimen was before part of a small RIVO collection.


*Figure 2.7: The fish farm of Gulpen in 1943 (photo: beeldbank.nationaalarchief.nl) and the Micropterus salmoides specimen present in the collection of Naturalis (photo: E. Kruidenier).*

The experiment in 1920s with *M. salmoides* was treated remarkably critical (Anonymous, 1930). Its quality as a game fish was questioned and it is thought to have reduced populations of much appreciated course fishes to an extent that it was needed to restock these course fishes. The article ends with a general warning about the introduction of exotic fish species: “Vóór alles dient men de zekerheid te hebben dat hetgeen men plant geen onkruid is, dat gelijk de forelbaars en meer dergelijke vraatzuchtige en waardeloze producten een ware plaag wordt voor degenen, die er mede wordt opgescheept”.

*M. salmoides* is known from a single recent record. This specimen, caught in 2005 by an angler in the River Waal near Nijmegen, was only published in ‘Beet’, a magazine for anglers (Ahlen, 2005). As this species is not stocked recently in the Netherlands this specimen probably originated from outside the Netherlands, see also chapter 4.

*Figure 2.8: The Micropterus salmoides specimen (≈ 60 cm) caught in the River Waal near Nijmegen, the Netherlands. Photo by R. Ahlen.*

*Lepomis gibbosus*

In 1902 *L. gibbosus* arrived for the first time in the Netherlands in the fish farm in Vaassen. It reproduced easily, but its qualities for consumption or angling were considered insufficient to start a stocking program. *L. gibbosus* has never been officially stocked and only kept in culture for ornamental purposes. From its first import it has been present continuously in Dutch fish farms until today (Looijen, 1948), see also chapter 4.

Its first releases or escapes have been badly recorded and the first establishments are rather speculative. In the 1920s *L. gibbosus* was present in the fish farm of Valkenswaard in the south of the Netherlands (Iven & Van Gerwen, 1974). The used ponds were not isolated well from the Tongelreep, a stream running through the fish farm. This is illustrated by the unwanted colonization of these ponds by European perch, which was abundant in the Tongelreep (Iven & Van Gerwen, 1974). Escapes from this farm might have resulted in the population in the Dommel drainage in the province Brabant which is mentioned by Ruting (1958).

*L. gibbosus* is nowadays a rather widespread species in the Netherlands (fig. 2.9). It is present in all provinces, including the province of Drenthe. Records from this province are lacking in fig. 2.9, but this species has actually been recorded from this province, although with hardly any established populations (Brouwer *et al.,* 2008). Also in the provinces of Friesland, Groningen, Overijssel, Flevoland and Zeeland *L. gibbosus* is not very common, occurring mostly in isolated locations. The species is more common around Amsterdam, in the provinces Brabant and Limburg and in the eastern parts of the province of Gelderland. Remarkable are the records on the Wadden Islands Terschelling (Meisterplak) and Schiermonnikoog. These records show clearly the extent of the introduction of this species by humans in the Netherlands.

*Figure 2.9: The distribution of Lepomis gibbosus in the Netherlands, Based on data provided by Waarneming.nl, RAVON and Limnodata.*

## 2.2 Elassomatidae

### 2.2.1 Taxonomy

*Fig 2.10: Elassoma okefenokee*

The Elassomatidae form a small family consisting of only seven species (table 2.4), which are all placed within one genus (*Elassoma*). The group has been thought to be closely related to Centrarchidae and was placed within this family for some time as a subfamily (Elassominae). Although they superficially resemble small individuals of the family Centrarchids the have been, particularly since 1962, regarded as a separate family (Gilbert, 2004). Increasing evidence has even suggested that they are not even closely related to the Centrarchidae and might even be a sister group of the Gasterosteiformes (Roe *et al*., 2002; Wiley *et al*., 2000; Gilbert, 2004). Currently they are placed in their own order (Elassomatiformes) which is still considered to be incertae sedis, meaning of uncertain taxonomy (Fishbase.org).

*Table 2.4: List of the species of Elassomatidae. Given are the scientific name, the English common name and the Dutch common name. Based on Gilbert (2004), Snelson et al. (2009) and Fishbase.org.*

| Scientific | English | Dutch |
|---|---|---|
| *Elassoma alabamae* Mayden 1993 | Spring pygmy sunfish | |
| *Elassoma boehlkei* Rohde & Arndt 1987 | Carolina pygmy sunfish | |
| *Elassoma evergladei* Jordan 1884 | Everglades pygmy sunfish | Everglades dwergzonnebaars |
| *Elassoma gilberti* Snelson Jr, Krabbenhoft & Quattro 2009 | Pygmy sunfish | |
| *Elassoma okatie* Rohde & Arndt 1987 | Bluebarred pygmy sunfish | |
| *Elassoma okefenokee* Böhlke 1956 | Okefenokee pygmy sunfish | Okefenokee dwergzonnebaars |
| *Elassoma zonatum* Jordan 1877 | Banded pygmy sunfish | |

### 2.2.2 Description

The *Elassoma*-species are small with maximum lengths up to 45 millimeters. The body is shallow and laterally compressed with a terminal mouth. The lateral line is absent. Males and females exhibit substantially different color patterns. This is especially explicit during the breeding season. The males of several species have the vivid colors which make them popular with specialized aquarists.

*Figure 2.11: Elassoma okefenokee male (left) and female (right). Photos by Jörg Bohlen.*

### 2.2.3 Native range

Elassomatidae are mainly subtropical family restricted to the south-eastern parts of the United States. Two of the species are relatively widespread, the other five have restricted ranges. *E. zonatum* is the most widespread species with a distribution basically equal to that of the genus as a whole. The, also relatively common, *E. evergladei* occurs on the Atlantic and Gulf coastal plain from North Carolina south to the northern edge of the Everglades. The other species are more localized, with *E. alabamae* the most confined, occurring only in Moss Spring and some adjacent springs in the middle Tennessee River drainage in Alabama (Berra, 2007).


*Figure 2.12: Natural range of the family Elassomatidae in North America.*

### 2.2.4 Introductions

None of the species belonging to the family Elassomatidae is known to be introduced outside its natural range (Welcomme, 1988; Fishbase.org), except for an introduction of *E. evergladei* in an artificial warm water stream in Germany. This introduction took place in the Ore Mountains (Erzgebirge) near Chemnitz (Karl-Marx-Stadt). The individuals released by aquarianists were able to maintain a small population for some years, but this population had gone extinct by 1988 (Arnold, 1990).

# 3 General ecology

## 3.1 Centrarchidae

### 3.1.1 Reproduction

The reproductive behavior of the Centrarchidae has been well studied and is similar in most species. Males excavate a shallow, bowl-shaped depression in the gravel or sand by fanning vigorously with the caudal tail from a near vertical position. Spawning occurs in mid-spring to early summer and involves a ritual courtship. A male and a female may circle over the nest with their heads and ventral surfaces touching, and eventually the female swoops down to the nest on her side and releases the eggs. The male follows and fertilizes the eggs. Several females might spawn in the same nest. The males will then proceed to guard the nests until the offspring leaves the nest (Berra, 2007).

In addition to the territorial, large males that builds and defends the nests, smaller males, called 'sneakers' may dart in and try to fertilize eggs as well, and intermediate-sized males in female colours may gain admission to a nest by posing as a receptive female (Neff *et al*., 2003).

### 3.1.2 Habitat

The members of the Centrarchidae occupy the shallows of warm, rocky, and vegetated lakes, ponds, slow moving streams, back waters, swamps and other standing or slowly flowing waters. Fast flowing streams and rivers are generally avoided, and when they are found within this habitat they are found in slow moving parts. Within this range of habitats most species are rather flexible and found in several types of habitats. *L. gibbosus* for instance can be found in small lakes, ponds, shallow, weedy bays of larger lakes, and in the quiet water of slow-moving streams (Scott & Crossman, 1973).

### 3.1.3 Diet

Centrarchids are predatory fish that do not include plant material and detritus in their diets. Four main types of predators can be recognized (Collar & Wainwright, 2009):

- Piscivores/crayfish predators: Typical examples are members of the genus *Micropterus* and *L. gulosus*. These species have relatively shallow bodies and large mouths. Most species forage in the open water, with some being specialized to hunt in densely vegetated areas (e.g. *L. gulosus*).
- Zooplanktivores: Rare amongst Centrarchids in the adult stage and best represented by *L. macrochirus*. This species is small-mouthed and has a deep body. In the day it can feed heavily on zooplankton in the open water or in vegetated areas.

• Molluscivores: *L. gibbosus* and *L. microlophus* are the two Centrarchid species which have specializations for predating mollusks. In body shape and the size of the mouth gape they resemble *L. macrochirus*, but their pharyngeal jaws have been strengthened to allow them to crush molluscs.
• Generalist invertivores: These species tend to have intermediate values for body depth, mouth size and robustness of the pharyngeal jaws. This is actual a rather variable group that feeds mainly on smaller invertebrates that can be amongst vegetation, on the bottom or at the water surface.

All Centrarchid species are opportunistic and rather flexible in their diet. This flexibility is well presented by *L. gibbosus*. The actual diet of this species varies seasonally and is highly associated with the abundance of local macroinvertebrates (Tomecek *et al*., 2007). Adult *L. gibbosus* are able to feed heavily on molluscs that they crush between their pharyngeal jaws (fig. 3.1) (Wainwright *et al*., 1991). This includes the in the Netherlands highly invasive *Dreissena*-species (Tomecek *et al*., 2007). The development of the muscles and bones of these pharyngeal jaws is depended on the mollusk density which is represented by the numbers of molluscs in diets of *L. gibbosus*. In mollusk rich habitats robust pharyngeal jaws will be build. In mollusk poor habitats they will happily feed on other invertebrate prey and develop less hypertrophied pharyngeal jaws (Wainwright *et al*., 1991; Almeida, 2009).

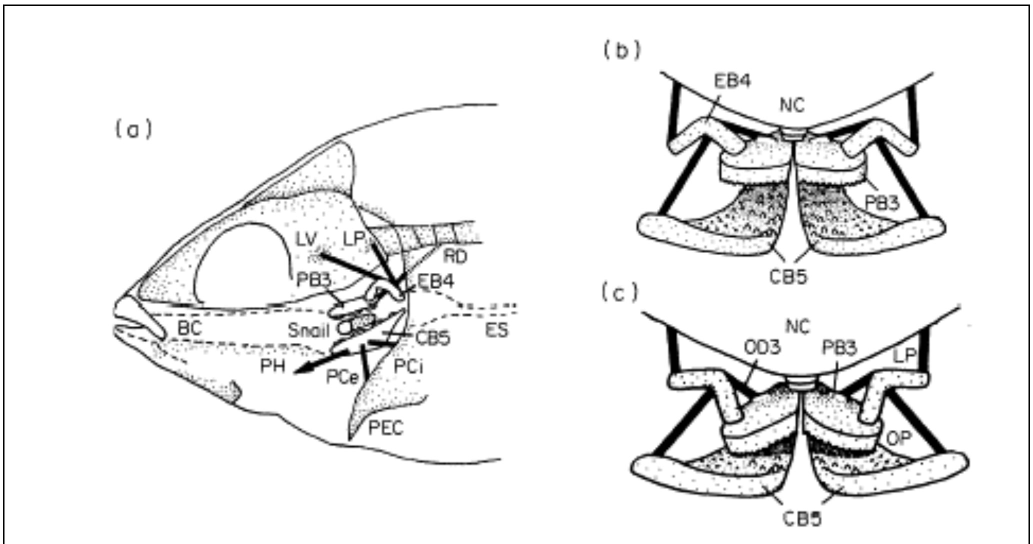



*Figure 3.1: Illustrations of the snail-crushing mechanism in the pumpkinseed sunfish. Taken from Wainwright et al. (1991).*

The diet of especially the larger Centrarchids changes during their development. In e.g. *M. salmoides* the small young of the year (YOY) feed first on zooplankton, typically shifting to insects and other smaller invertebrates as they grow and then to crayfish and fish. The shift to crayfish and fish usually begins at 50-70 millimeters standard length and in general bass are almost exclusively piscivores at 80-100 millimeters standard length. In some instances *M. salmoides* predates mainly on larger invertebrates at larger sizes, especially when crustaceans such as shrimps and crayfish are abundant (García-Berthou, 2002).

### 3.1.4 Predators

With the Centrarchids being variable in size and habitat use, they meet with a wide range of predators, ranging from predaceous water insects, piscivorous fishes, piscivorous waterbirds to aquatic mammals. In large piscivorous Centrarchids, such as *Micropterus*-species, cannibalism is also likely to play a role. In Europe pike (*Esox lucius*), zander (*Sander luciopercus*), European catfish (*Silurus glanis*) and several species of piscivorous waterbirds are probably the most important predators (Arnold, 1990)

*Figure 3.2: Pike (Esox lucius) and Perch (Perca fluviatilis) predate on L. gibbosus. Photos: Hans Waardenburg & Floris Brekelmans*

### 3.1.5 Parasites and diseases

Centrarchidae are known to harbor a great diversity of parasites. From well studied species like *M. salmoides* and *L. gibbosus* more than 150 species of parasites per species have been recorded. This includes the whole range of usual groups of fish parasites like e.g. protozoan’s, trematodes, cestods, acanthocephalans, leeches and crustaceans (Hoffman, 1999).

One of the most important diseases recorded from Centrarchidae is the largemouth bass virus (LMBV). This is the only virus to have been associated with large fish kills of *M. salmoides*. While LMBV has been isolated from a number of other species of warm-water fishes, the disease response has only been observed in largemouth bass (Cooke *et al*., 2009; research.myfwc.com).

## 3.2 Elassomatidae

### 3.2.1 Life cycle

In suitable conditions *Elassoma*-species mature quickly and can reproduce at an age of three to four months (Arnold, 1990). Based on experiences in aquaria they may reach an age of four to five years (Fischarten-Datenblätter Aqua4you, 2010), although for at least *E. okefenokee* it is thought that they usually live only up to one year (Tate & Walsh, 2005)

### 3.2.2 Reproduction

The starting and length of the breeding season seems to be rather variable amongst the different *Elassoma*-species. *E. alabamae* seems to breed almost throughout the year, with larvae being recorded from April to September (Center for biological diversity, 2009). Comparable data are known from *E. evergladei* (Fischarten-Datenblätter Aqua4you, 2010). A population of *E. okefenokee* in Florida, on the other hand, behaved like an annual species, with breeding adults only found from late January through mid-March. After mid-March adults were absent from conducted samplings (Tate & Walsh, 2005).

Males defend territories including suitable egg laying substrates, e.g. *Myriophyllum sp*. or aquatic mosses. When receptive females approach a territory a complicated ritual involving fin undulation, weaving, vertical bobbing, and dashing is performed. After this courtship, which is among the most complex behaviour described for fishes, the female will deposit her 30-120 eggs in dense, fine-leaved vegetation and cover it with a protective gelatinous mass. The eggs and earliest larvae stages will be guarded by the male (Center for biological diversity, 2009; Tate & Walsh, 2005; Bohlen & Nolte, 1993).

### 3.2.3 Habitat

All *Elassoma*-species are mainly found in slow flowing and stagnant waters with dense submersed vegetations. Typical habitats are heavily vegetated swamps, ditches, stream pools, and sluggish streams with a muddy bottom. Most species prefer soft, tannic waters and avoid hard-water streams (Center for biological diversity, 2009; Bohlen & Nolte, 1993).

### 3.2.4 Diet

The *Elassoma*-species are stalking predators of mainly invertebrates, using dense vegetation to conceal their activities. They are not cannibalistic and are not known to regularly predate on fish or amphibian larvae. Plant material is not an important food item, and might normally actually be ingested accidentally.
Typical prey items are cladocerans, copepods, amphipods, isopods, ostracods, dipteran larvae, and snails. Especially daphnids and other cladocerans are regular

prey items of all *Elassoma*-species and comprise usually 25-30% of the volumetric consumption (Center for biological diversity, 2009; Tate & Walsh, 2005).

### 3.2.5 Predators

The main predators of *Elassoma*-species are large predatory insects like giant water bugs (Belostomatidae), piscivorous fish species like pickerels (*Esox*) or larger Centrarchids, birds like herons and kingfishers, and aquatic mammals like otters (Center for biological diversity, 2009; Tate & Walsh, 2005).

### 3.2.6 Parasites and diseases

With Elassomatidae not being cultured or of importance in fisheries relatively little information on their parasites and diseases is present. Some parasites are reported including three species of monogeneans which are only known from *Elassoma*-species (*Urocleidus circumcirrus, U. udicola* and *Gyrodactylus heterodactylus*). Two species of nematods are known, both cosmopolitans. *E. zonatum* is reported as a final host for the trematod *Rhipidocotyle septpapillata*, a North American species with a wide range of hosts. Another four species have been reported from *Elassoma*-species in juvenile stages: *Caecincola latostoma, Cryptogonimus spinovum, Posthodiplostomum minimum* and *Textrema hopkinsi*. All four are mainly known from Centrarchidae (Hoffman, 1999).

# 4 Chances of entry

## 4.1 Presence in Dutch pet trade

### 4.1.1 Centrarchidae

Information on the presence of Centrarchidae in the Dutch pet trade has been collected by consulting three wholesalers in ornamental fish, visiting pet shops and checking numerous internet resources such as forums and websites associated with pet shops and hobbyists.

Only *L. gibbosus* is sold regularly and is available in most larger shops dealing in ornamental fish for garden ponds. According to wholesalers the numbers sold are rather low in comparison to other species such as goldfish and koi. Actual numbers could not be obtained. Other species encountered in pet shops are *E. gloriosus, E. chaetodon*, *C. macropterus, L. cyanellus* and *M. salmoides*. All these species are currently rare in trade and probably only imported incidentally.

In 2010 one wholesaler announced that they stop distributing *L. gibbosus* because of the reported impact of this species on native species, particularly amphibians, see also §10.1. It is not unlikely that other wholesalers may follow as this species is actually not considered to be of high economic value. To what extent wholesalers might search for alternatives (e.g. other Centrarchids) remains unclear.

### 4.1.2 Elassomatidae

So far all species of Elassomatidae have been very rare in the Dutch pet trade, but one wholesaler expressed intentions of increasing the import from the USA in 2011.

## 4.2 Presence in American trade

Recent introductions of virile crayfish (*Orconectus virilis*), white river crayfish (*Procambarus acutus/zonangulus*) and Chinese mystery snail (*Bellamya chinensis*) showed that presence in European trade is not a good predictor for the chances of entry of North-American species (Soes & Koese, 2011; Soes *et al*., 2011). All mentioned species have established populations in the Netherlands but could not be directly traced in the Dutch pet trade. These North American species have probably only been imported on an experimental basis. Knowledge on the availability of such species in American trade is likely to be a more reliable source of information. In addition to species available for aquaria or garden ponds, species cultured for consumption or angling (e.g. bait) should be included in risk assessments.

We present a list of all 34 species of centrarchid fishes using the Latin Binomial. Relative rarity is a subjective measure of the population size and distribution of each species in North America. “Rare” denotes a restricted range and relatively low population size. If present in Europe, distribution is also noted. North American export serves as an indication of the relative ease with which Dutch citizens could obtain centrarchids. Based on the relative rarity, distribution in Europe and availability for export from North America we have identified species that will be included in the report for further discussion related to the potential for introduction in the Netherlands.

*Table 4.1: Potential threat to introduction of the 34 species of Centrarchidae. The rarity in their natural range, their presence in Europe and their availability in American trade are given.*

| Latin Binomial | Relative Rarity in Natural range | Present in Europe | North American Export (for stock enhancement or ornamental trade) | Inclusion in Report as Potential Threat to Introduction |
|---|---|---|---|---|
| *Acantharchus pomotis* | rare | no | no | no |
| *Ambloplites ariommus* | rare | no | no | no |
| *Ambloplites cavifrons* | rare | no | no | no |
| *Ambloplites constellatus* | rare | no | no | no |
| *Ambloplites ruprestris* | common | yes | limited | yes |
| *Archoplites interruptus* | rare | no | no | no |
| *Centrarchus macropterus* | uncommon | trade only | yes | yes |
| *Enneacanthus chaetodon* | rare | trade only | yes | yes |
| *Enneacanthus gloriosus* | rare | trade only | yes | yes |
| *Enneacanthus obesus* | rare | trade only | yes | yes |
| *Pomoxis annularis* | common | no | yes | yes |
| *Pomoxis nigromaculatus* | common | no | yes | yes |
| *Lepomis auritus* | uncommon | no | yes | yes |
| *Lepomis cyanellus* | common | trade only | yes | yes |
| *Lepomis gibbosus* | common | yes | yes | yes |
| *Lepomis gulosus* | rare | no | no | no |
| *Lepomis humilis* | rare | no | no | no |
| *Lepomis macrochirus* | common | no | yes | yes |
| *Lepomis marginatus* | rare | no | no | no |
| *Lepomis megalotis* | common | trade only | yes | yes |
| *Lepomis microlophus* | uncommon | no | yes | no |
| *Lepomis miniatus* | rare | no | no | no |
| *Lepomis peltastes* | uncommon | no | yes | yes |
| *Lepomis punctatus* | rare | no | no | no |
| *Lepomis symmetricus* | rare | no | no | no |
| *Micropterus cataractae* | rare | no | no | no |
| *Micropterus coosae* | rare | no | no | no |
| *Micropterus dolomieu* | common | no | yes | yes |
| *Micropterus floridanus* | common | probably | yes | yes |
| *Micropterus henshalli* | uncommon | no | no | no |
| *Micropterus notius* | rare | no | no | no |
| *Micropterus punctulatus* | uncommon | no | yes | yes |
| *Micropterus salmoides* | common | yes | yes | yes |
| *Micropterus treculii* | rare | no | no | no |

## 4.3 Aquaria

### 4.3.1 Centrarchidae

In the first half of the last century aquarists concentrated on keeping coldwater and later subtropical species. Early books that made this hobby popular, such as those of Den Hollander (1900), Heimans (1912) and Portielje (1925), primarily discuss indigenous fish species like three-spined stickleback (*Gasterosteus aculeatus*), European bitterling (*Rhodeus amarus*) and Crucian Carp (*Carassius carassius*).

Coldwater species that were imported early such as goldfish (*Carassius auratus*) and eastern mudminnow (*Umbra pygmaea*), and some subtropical species such as paradise fish (*Macropodus opercularis*) and chameleon cichlid (*Cichlasoma facetum*), quickly became popular.

This interest in more exotic fish species also stimulated the import and keeping of several centrarchid species. A relatively large number of centrarchid species were kept in the early days of the aquarium trade. According to Den Hollander (1900), species such as *E. chaetodon*, *E. obesus*, *L. gibbosus* and *L. megalotis* s.l. were regularly available in the aquarium shops. Heimans (1912) and Portielje (1925) added *A. rupestris*, *P. nigromaculatus, C. macropterus, M. salmoides and M. dolomieu* to the list of kept species. The last species is probably erroneous, see also 2.1.3. The drawing in the book of Heimans (fig. 4.1) was made with a photo as an example and did not use specimens obtained from trade.

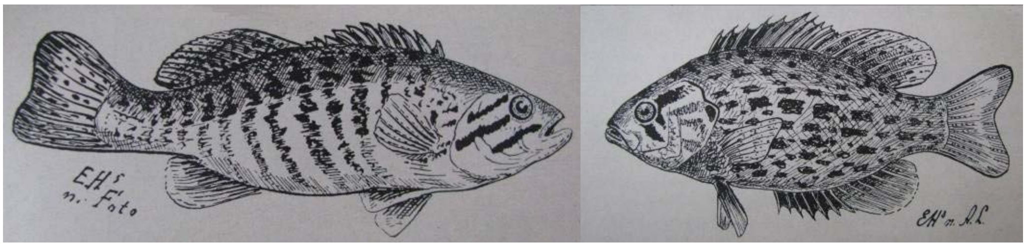


*Figure 4.1: Micropterus dolomieu and Ambloplites rupestris taken from Heimans (1912).*

*Figure 4.2: Ambloplites rupestris and Enneacanthus chaetodon taken from Portielje (1925).*

After the Second World War there were a number of technical developments (e.g., cheap heating systems; Frey, 1983) that enabled the general public to be able to keep a variety of tropical fish species. With a wider choice of fish species, the interest in Centrarchidae declined (Pinter, 1968). Nowadays, centrarchids are rarely kept in aquaria and most species that have been kept in the past are hardly available in aquaria shops.

There are several reasons for the decline in interest in centrarchids in the pet trade in The Netherlands. Several species have relatively large body sizes for normal sized aquaria, e.g. *A. rupestris* and *P. nigromaculatus*. Furthermore, some centrarchids such as *L. gibbosus* and *A. rupestris* are difficult to raise/house with other fish species because of their aggressive territorial behavior. These territorial species are also very aggressive towards conspecifics and need spacious aquaria with a lot of cover if one wants to keep several specimens in one aquaria. Too little space is likely to result in fatalities (Den Hollander, 1900).

Centrarchid species tend to be difficult to train to eat dry fish foods, and need live animal food if they are to survive and grow. It is also necessary to keep them at lower temperatures (8-12°C) in winter to maintain their health and make it possible to breed in the spring (Pinter, 1968). With hundreds of other species that are regarded as equally or more attractive than centrarchids, as well as a number of species that are easier to raise, the decline in interest is understandable.

*Chance of entry*
Centrarchid species are rarely available in pet shops in The Netherlands. They are not sought after as centrarchids are not particularly popular anymore in the aquarium trade. This makes most species relatively rare in aquaria. Only *L. gibbosus* is regularly sold.

From internet forums it is clear that inexperienced buyers of *L. gibbosus* are regularly disappointed as they have not been well informed about the aforementioned downsides of keeping centrarchids. These fish might end up being released in nature. This may also be the case in the few instances that people breed centrarchid species in aquaria. All species that are kept in aquaria nowadays are known to be possible to breed (www.akfs-online.de).

The chance of entry from aquaria (introductions from aquarium trade) is moderate for *L. gibbosus* and low for the other Centrarchid species.

### 4.3.2 Elassomatidae

At least three species of Elassomatidae have been imported to Europe for aquaria: *E. zonatum, E. okefenokee* and *E. evergladei*. *E. zonatum* has not become very popular and seems to have disappeared (Arnold, 1990). Only Bohlen & Nolte (1993) reported keeping and breeding *E. zonatum*, which they had caught and imported themselves from the USA. No Dutch papers on this species or discussions about this species in Dutch internet forums could be found. In a Belgian internet forum it was mentioned to be extremely difficult to obtain. According to J. Klungers (pers. comm.) this species is not available in the Netherlands.

*E. okefenokee* was imported to Europe in 1980 and ever since it has been irregularly available. The first imports of *E. evergladei* to Europe are probably from around 1925 and this species is still the most kept one of the *Ellasoma* species (Arnold, 1990). Also in the Netherlands both species are kept in aquaria, with *E. evergladei* being the most common one of the two (D.M. Soes, pers. observ.). Beside Dutch pet shops, sources for these species are aquarist, which are successful in breeding these species, and the German pet shop Zoo Zajac (J. Klungers, pers. comm.). This shop claims to be the largest in the world and did in October 2010 actually sell *E. evergladei* (13.50 euro per pair).

*Elassoma* species are only suitable for specialist and experienced aquarists. For common household aquaria they are unsuitable and are not likely to survive for a long time. Especially for breeding, which is hard to accomplish, it is best to keep them in tanks specifically arranged for their needs with no other species present. Further complicating factors for their keeping and breeding are their need for lower temperature during the winter and their need to be fed with small, live food (Anonymous, 1948; J. Klungers, pers. comm.; D.M. Soes, pers. observ.).

*Chance of entry*
All *Elassoma*-species are rarely available in pet shops and need to be purchased from specialist shops or other aquarists. This makes them relatively rare in aquaria. With breeding being difficult and never over-productive, surplus animals will easily be sold to other aquarists and are not likely to end up in nature. Instead of being aggressive fish that may be released because of damaging/killing other fish species, *Elassoma* species tend to be shy, non-aggressive species. Although deliberate stocking can never be excluded, the chance of entry by aquarist releasing animals in nature is considered to be quite low.

## 4.4 Garden ponds

### 4.4.1 Centrarchidae

*<u>L. gibbosus</u>*
In Dutch garden ponds *L. gibbosus* is by far the most commonly kept centrarchid. This species is regularly recommended as a controller of ‘vermin’ in garden ponds, such as fish parasites (e.g. fish lice (Argulidae) and leeches (Hirudinea)) and harmful insects (e.g. mosquito’s (Culicidae), predaceous diving beetles (Dytiscidae) and dragonfly larvae (Anisoptera)). It is also recommended for controlling the numbers of fish species which easily breed in garden ponds, such as goldfish (*Carassius auratus*), gudgeons (*Gobio gobio*) and fathead minnows (*Pimephales promelas*). In shops, this species is usually displayed in glass containers showing their colorful appearance.

True-life experiences in garden ponds are often less positive. When seen from above, the appearance of *L. gibbosus* is often a disappointment as its colorful flanks are not as striking. Furthermore they turn out to be aggressive fish which, especially when present in higher numbers, also attack and harm larger fish species such as koi and goldfish. Besides invertebrates they also predate on amphibian larvae, which is often regretted by pond owners. Some garden pond keepers report that *L. gibbosus* is able to adjust to dry fish pellets and start competing for this artificial food with other residents in their garden ponds.

When both male and female *L. gibbosus* are present, they are most likely to reproduce. Often garden ponds end up being populated with hundreds of *L. gibbosus*. Most fish species regularly spawn in garden ponds, but resulting eggs are quickly eaten by other fish. Only in densely planted ponds some species (e.g. goldfish, fathead minnow) are successfully reproducing, as part of the eggs can survive in the vegetation. In contrast, *L. gibbosus* can reproduce successfully also in "bare" ponds with a high density of egg-eating fish. Prior to the spawning act, male *L. gibbosus* clear a small area from debris. On the resulting bare stones, sand or pond bottom, the female deposits her eggs. After spawning the male chases away the female. The male then proceeds to care for eggs by regularly fanning water over them, which provides oxygen and prevents debris from settling on the eggs. Egg guarding male *L. gibbosus* are aggressively chasing all fish which come close to the eggs. The reported aggression of *L. gibbosus* likely originates from this nest guarding activity. The guarding of eggs continues until the eggs are hatched and young are able to swim. At this age, young *L. gibbosus* can successfully evade most other pond fish and have a high survival rate.

In small ponds it is possible to manipulate numbers by removing fish regularly. In larger ponds this is often not practical and the only possibility to remove *L. gibbosus*, is to drain the entire pond. It is not without reason that it is often advised just to keep only one *L. gibbosus* per garden pond.

When trying to dispose excess animals it is probably impossible to sell sufficient numbers. Killing fish is to many people an inhumane act they not want to commit. Releasing them in the wild is then the only option left. Pond owners then search for "nice living areas" for their surplus fish, as their fish should have a "good future when no longer cared for". As a consequence, they are frequently released in places with a high value for nature, like moorland pools and amphibian reproduction sites.

<u>Other species</u>

Other Centrarchidae are rarely kept in Dutch garden ponds as their availability through garden trade and pet shops is low. In books, magazines, internet forums, etc., hardly any information on Dutch experiences with e.g. *L. cyanellus* or *E. gloriosus* can be found.

At least five Centrarchidae species are sold in the Netherlands in recent years, which can be categorized in two groups: *M. salmoides* and *L. cyanellus* are relatively large species with aggressive predatory behavior. This makes them less suitable for ponds that offer too little space and cover. Like *L. gibbosus* they are likely to injure even species with larger body sizes. *E. gloriosus, E. chaetodon* and *C. macropterus* are smaller, timid species that will tend to stay amongst cover. These species will do especially well in densely vegetated garden ponds with non-aggressive inhabitants.

*Figure 4.3: L. cyanellus from a Dutch garden pond bought as 'diamantbaars'. Photos by Sander den Bleeker*

All mentioned species are likely to be able survive through the winter in larger ponds, although *Enneacanthus* in particular are reported to be sensitive. In smaller ponds with temperatures dropping below 4°C for a longer period they are less likely to survive the winter outdoors. As an alternative they can be kept in aquaria during the winter.

In Germany two further species are kept: *L. megalotis* and *E. obesus*. These species that also might turn up in the Dutch trade are also reported to be winter hardy in larger garden ponds, with *E. obesus* again being a bit more sensitive (www.sonnenbarsche.info).

*Chance of entry from garden ponds*
With *L. gibbosus* still being sold in large numbers the chance of entry due to releases of fish from garden ponds is high due to their high reproduction capabilities in garden ponds and their aggressive behavior towards other fish species. The chance of entry of other centrarchid species is low, mainly because of their low availability in shops.

### 4.4.2 Elassomatidae

With *Elasoma* species not being able to survive Dutch winters in garden ponds (see 5) they are not of interest to common garden pond keepers. Also they have never been found to be sold for garden ponds (P. Veenvliet, pers. comm.). The chance of entry from garden ponds is considered to be negligible.

## 4.5 Angling

### 4.5.1 Centrarchidae

*M. salmoides* and other *Micropterus*-species are the most popular freshwater game fishes of North America, supporting a multi-billion dollar industry (U.S. Department of the Interior *et al*., 2006). This popularity is not restricted to North America and black bass have been stocked in many parts of the world mainly for recreational fishing (www.issg.org). Also in Europe it has become a popular game fish in Spain en France (Maitland, 1977).

Although still absent, the popularity of *M. salmoides* has also reached the Netherlands. When questioned, several commercial fishing farms (Visdorado De Kool, De Ronde bleek and De Berenkuil) indicated to be interested in stocking ponds with *M. salmoides* and having studied the possibilities of doing so. The lack of nearby fish farms that breed *M. salmoides* resulting in high transportation costs of importing fish (e.g., from southern France) have apparently prevented the introduction of the species in fishing ponds. But, based on the uttered intentions of the fishing farms, the chance of this happening in the future is very realistic. Other large centrarchids have not been considered by the questioned farms.


*Figure 4.4: A big largemouth bass makes an angler happy. Photo by Pieter-Bas Broeckx.*

The interest in black basses extends to an increasing interest in stocking exotic fish species other then the traditional trout species in fishing farms. Recent examples are striped bass (*Morone* sp.), African sharptooth catfish (*Clarias gariepinus*), claresse (hybrid between *Heterobranchus longifilis* en *Clarias gariepinus*) and sturgeons like the Russian sturgeon (*Acipenser gueldenstaedtii*) (D.M. Soes. pers. observ.). One of the reasons to stock such species is to provide fishing opportunities in the summer season. In this season water temperature in many fishing ponds becomes too high for trout species because they lose their appetite in this period. In such conditions anglers have no opportunity to catch trout and business becomes low. Including species such as African sharptooth catfish or *M. salmoides* can increase and sustain business in the summer season, making fishing farms more profitable.

Trout are known to escape and be released from fishing farms. Ther is no reason to assume that this would be different for *M. salmoides* specimens if they are actually stocked in fishing ponds. Numbers that escape or are released from farms tend to be low (Soes & Broeckx, 2011).
During the project no intentions to stock centrachid species in waters other then fishing ponds were noted. Furthermore current legislation (Fisheries law & Flora- and fauna law) forbids stocking of any centrarchid species in nature.

The chance of entry from fishing farms or angling related stocking programs is low.

### 4.5.2 Elassomatidae

The Elassomatidae are because of their small size not of interest to the angling community. The chance of entry by activities associated with angling is considered to be negligible.

## 4.6 Aquaculture

### 4.6.1 Centrarchidae

In North America centrarchids are of some importance in aquaculture. *Lepomis sp.* and *M. salmoides* are both dominating this production (Morris & Clayton, 2009). *Lepomis sp.* sales in the USA had in 2005 a value of around 5 million dollar and *M. salmoides* over 10 million dollar (www.agmrc.org). The primary markets are sport-fish stocking and fee-fishing operations, but they are also sold for human consumption (Morris & Clayton, 2009).

On a worldwide scale, centrarchids are of minor importance in aquaculture (ww.fao.org). Extensive introductions of *M. salmoides* in Europe, Africa and Asia were primarily to improve fisheries stocks and centrarchids were mainly taken into culture for supporting these stocking programs (Liao, 1999; Jackson, 1988; Welcomme, 1988).

In the Netherlands none of the centrarchids can be legally cultured for human consumption as only species listed in the Animal Health and Welfare Act (Artikel 34 van de Gezondheids- en Welzijnswet voor dieren) are permitted. None of the centrarchids is included in this list (www.aquacultuur.wur.nl).

A review of possible new species for innovation of the Dutch aquaculture didnot list centrarchid species as being promising (Kals *et al.*, 2005). But with increasing interest in especially *M. salmoides* for stocking in fee-fishing operations some small scale (experimental) rearing might be possible, comparable with e.g. Atlantic trout (*Salmo trutta*) and 'Elsasser saibling' (hybrid *Salvelinus alpines* and *S. fontinalis*). The 'Elsasser saibling' has been reared for fee-fishing operations although it is not included in the list of the Animal Health and Welfare Act (Soes & Broeckx, 2011).

This legislation does not include ornamental fishes and at least two ornamental fish farms in the Netherlands did in 2010 actually culture and sell *L. gibbosus*. The risk of fishes escaping from these fish farms has not been assessed.
The chance of entry from fish farms is considered to be very low.

### 4.6.2 Elassomatidae

None of the *Elassoma*-species is commercially cultured. The chance of entry by activities associated with aquaculture is considered to be negligible.

## 4.7 Entry from neighboring countries

### 4.7.1 Centrarchidae

<u>Flanders</u>
In Flanders only *L. gibbosus* is established. Past introductions of *M. salmoides* and maybe *M. dolomieu* have not resulted in established populations (Vrielynck *et al*., 2003).

*L. gibbosus* is widespread in Flanders occurring in all but one basin (Yser), but being most abundant in the eastern part of Flanders (basins of Demer, Nete and Meuse), where where they locally have become abundant. The presence of these fishes in north-east Flanders is assumed to be due to the high concentration of pond fish farms in this area, where numerous abandoned peat diggings provided suitable conditions for pond farming (Verreycken *et al*., 2007).

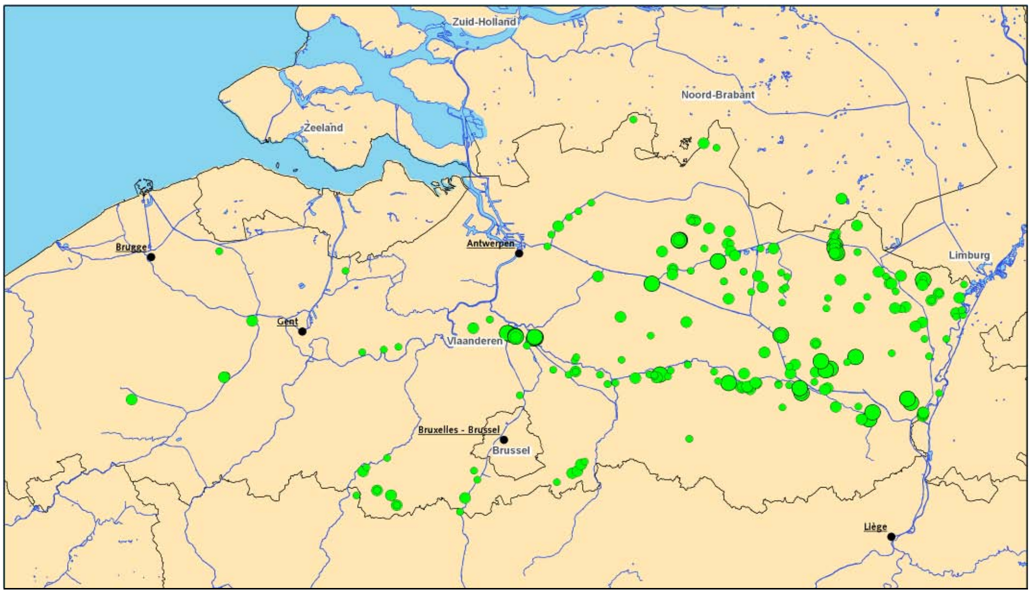


*Figure 4.5: The distribution of Lepomis gibbosus in Flanders, including Baarle-Nassau and Baarle-Hertog. Based on data from vis.milieuinfo.be*

Several Belgium streams, e.g. Mark, Dommel, Prinsenloop and Aa Beek, with populations of *L. gibbosus* are entering the Netherlands. Therefore, it is inevitable that this species enters the Netherlands from Flanders.

<u>Wallonia</u>

In Wallonia *M. dolomieu* has been stocked in the 1950s in the River Semois. This species was first thought to be established, but with no records after 1964 it should be considered extinct for already a long time.

*L. gibbosus* is widespread but much rarer compared to Flanders. This relative rarity is due to the absence of preferred habitats. The pools and other smaller standing waters that are the dominant habitat of *L. gibbosus* in Flanders are much less abundant in Wallonia. Furthermore is stocking of e.g. lakes with salmonids or other large predatory fish is more common in Wallonia, when compared to Flanders. Such large predators decrease the chance of establishment of *L. gibbosus*.

It is recorded the most in the Meuse Basin, making it likely that fish from Wallonia might enter the Netherlands.

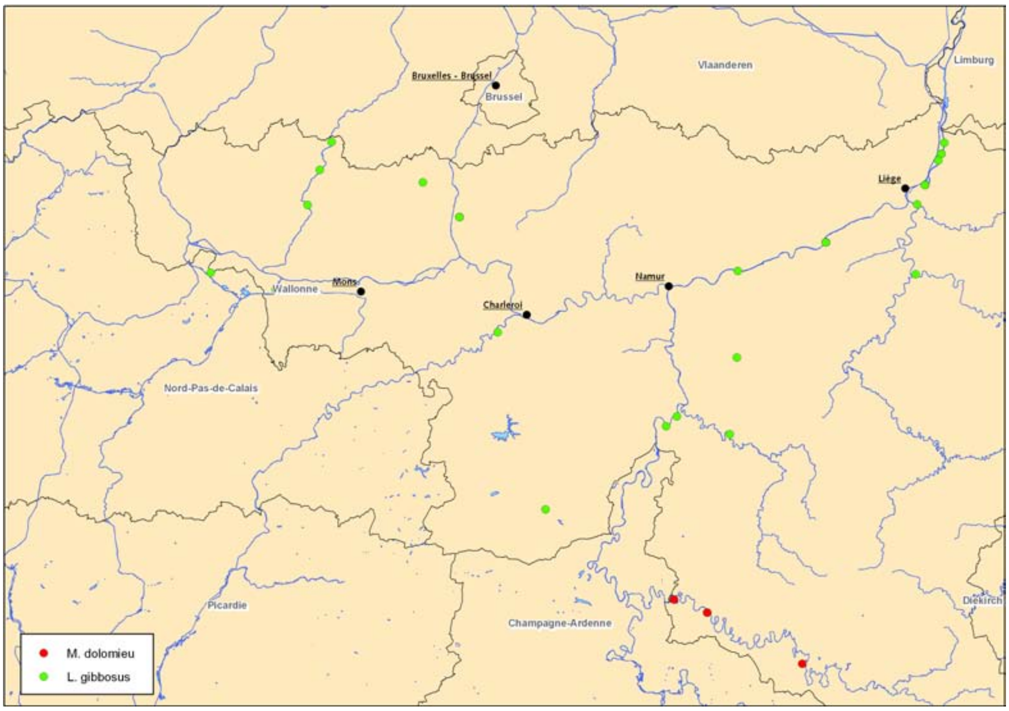



*Figure 4.6: The distribution of Lepomis gibbosus and Micropterus dolomieu in Wallonia. Data are from the period 1954-2009 and provided by Service public de Wallonie - Direction générale opérationnelle Agriculture, Ressources naturelles et Environnement - Département de l'Étude du Milieu naturel et agricole.*

<u>Germany</u>

In Germany only *L. gibbosus* is established. *M. salmoides* has not been officially stocked, but among anglers rumors about illegal stockings are circulating (J. Freyhof, pers. com.).

*L. gibbosus* is especially common in the Rhine river basin, but is also recorded from the Ruhr and the Swalm (fig. 4.7). Also during a recent visit to Karlsruhe it was noticed that *L. gibbosus* was abundant and widely distributed in most flood plain waters in the Rhine Valley near this city (D.M. Soes, pers. observ.). *L. gibbosus* is known to use smaller and larger rivers, such as the Ruhr and the Rhine, for dispersion and is likely to enter the Netherlands from Germany.

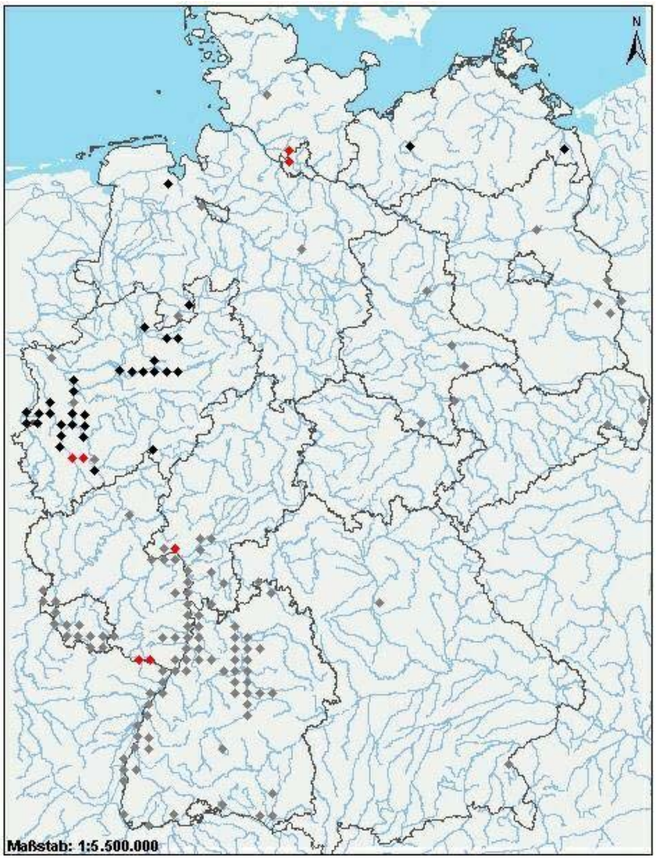


*Figure 4.7: Distribution of Lepomis gibbosus according to fischartenatlas.de, accessed 24 October 2010. Black = recent recordings, Grey = data from literature, Red = data from literature with exact locality uncertain.*

France

In France three species of Centrarchidae have established: *L. gibbosus, A. rupestris* and *M. salmoides*. *L. gibbosus* is widely distributed and also present in the Meuse basin. *A. rupestris* is limited to the Loire basin, making it unlikely that this species might enter from France. *M. salmoides* is widespread and also occurs in the northern part of the Seinne basin. Anglers are expecting specimens of this species, originating from stockings in France, to show up in the nearby future in the Dutch stretches of the Meuse. However, data confirming the presence of a significant population of *M. salmoides* in the Meuse basin are still lacking (fig. 4.8).

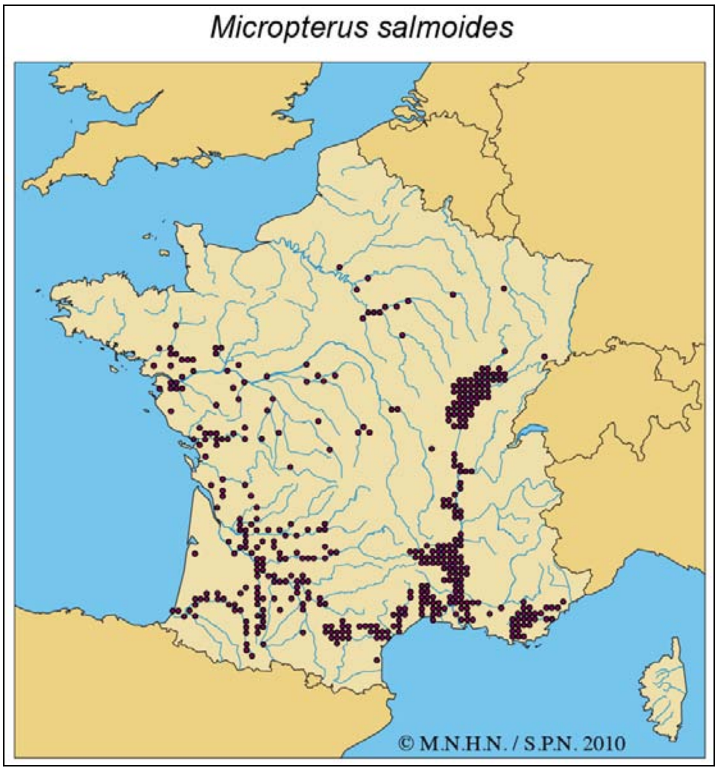



*Figure 4.8: The distribution of Micropterus salmoides in France with data upto 2010. Provided by P. Keith, Muséum national d'Histoire Naturelle.*

### 4.7.2 Elassomatidae

Introduced populations of *Elassoma*-species are not known from Europe. The chance of entry by dispersing from other countries is considered to be zero.

# 5 The probability of establishment

## 5.1 Centrarchidae

### 5.1.1 Thermal Biology of Centrarchids

Although there are a number of factors that influence the invasion potential for a given species, water temperature is certainly one of the most important in inland waters. Since fish are ectothermic, changes in ambient water temperatures are realized throughout the animal, and can have pronounced impacts on cellular function (Prosser, 1991), protein structure (Somero, 1995), enzyme activity, diffusion rates and metabolism (Fry, 1971; Brett & Groves, 1979; Farrell, 1996; Kieffer *et al*., 1998). Temperature is also an important determinant of many behavioral attributes (Fry, 1971; Ultsch, 1989) and overall organismal performance (Kieffer & Cooke, 2009). For centrarchids and other fishes, it also influences factors such as geographic range, spawning date, food consumption (Hathaway, 1927), digestion rates (Fänge & Grove, 1979), growth, swimming abilities and activity (Malizia *et al*., 1984; Demers *et al*., 1996), winter biology (Suski & Ridgway, 2009), and habitat selection and distribution (Neill & Magnuson, 1974; Neill, 1979; Armour, 1993). Moreover, temperature can also be lethal at both low and high extremes. In fact, temperature plays such an important role that it has been termed the abiotic “master factor” (Brett, 1971).

Water temperatures have been cited as regulating the distribution of warmwater fishes such as centrarchids. As air temperatures increase with climate change, the thermal habitat of most northern waterbodies lakes would become suitable for warmwater fish habitation (Magnusson *et al*., 1985; DeStasio *et al*., 1996). There is also the possibility that populations of centrarchid fishes would be able to expand their distributions farther north. It has been theorized that the northern limit of centrarchid distributions are regulated by the fact that during winter months, foraging is restricted and starvation occurs (Shuter & Post, 1990). As climate change warms North America, the duration of winter would decrease and starvation would not occur as often in northern waterbodies (Shuter & Post, 1990). This would then allow centrarchid populations to expand northward (MacCauley & Kilgour, 1990; Shuter & Post, 1990). As centrarchid distributions shifted farther north, local fish communities could suffer from shifts in community structure associated with the introduction of centrarchid fishes (Jackson, 2002).

As outlined by Coutant (1975a), the responses of fish to temperature vary across different life stages (e.g., eggs, larvae, adults), so no single temperature can be viewed as good or bad. Instead, the temperature must be viewed in the context of the life stage as well as the activities that the organism is trying to perform. Here, we focus on adult thermal tolerances given that it is the most relevant in the context of invasion potential. Fry classified physical and chemical aspects of fish habitat as 1) lethal, 2) controlling, or 3) directive, based on how they influence fish (Fry, 1947;

1971). In this context, extreme temperatures can kill fish and would be viewed as lethal. When not at extremes, temperature can control developmental and physiological rates and processes (i.e., metabolism) of fish. Temperature can also direct the position or habitat preference of an individual fish (i.e., orientation response). Fry's paradigm also included another group of factors commonly referred to as "limiting" such as those that are in short supply (e.g., oxygen) or others that are "masking" the influence of other environmental factors.

### 5.1.2 Lethal Temperatures

In general, survival in response to extreme temperatures (either high or low) depends on three primary factors 1) the initial acclimation or holding temperature, 2) the exact test temperature, and 3) the duration of exposure to the test temperature (Hart, 1952). Other factors such as individual variation in energy stores, parasite/disease burdens, reproductive state, etc., can also play a role in temperature related mortality but these effects are typically manifested over longer periods (See Suski & Ridgway, 2009). Obviously when acting as a lethal factor, temperature has the most dramatic effects (Fry, 1947).

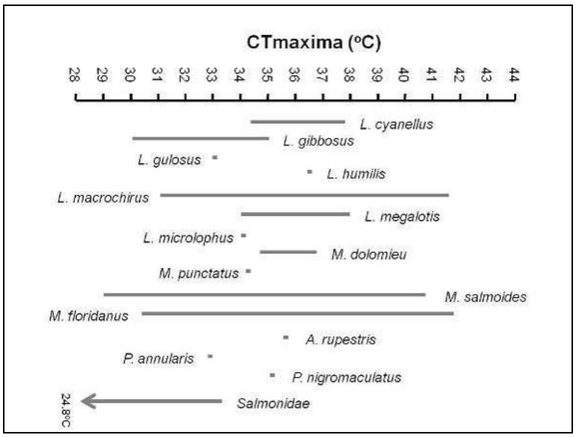



*Figure 5.1: Critical thermal maxima data for centrarchid fishes. Taken from Kieffer & Cooke (2009).*

Methods used to determine thermal tolerances are critically reviewed in Becker & Genoway (1979) and Beitinger *et al*. (2000). Critical Thermal Maxima (CTM) tests involves exposing fish that are usually acclimated to specific temperature(s) to a constant linear change in temperature until a near lethal endpoint is reached. The endpoint is determined when locomotory movements are impaired and represents the CTminima or CTmaxima. Overall, CTM measurements are generally regarded as the most realistic (Beitinger *et al*., 2000). For centrarchids studied to date, CTmaxima values range from a low of 29.2º C for largemouth bass to a high of 41.8º C for Florida largemouth bass (Kieffer & Cooke, 2009). CTminima has also been determined on an infrequent basis (only 2 species) relative to CTmaxima. In both cases, CTminima were varied extensively with acclimation temperature and were as low as 1.7º C for *L.*

*macrochirus* acclimated to 15º C (Beecher *et al*., 1977), and 3.2º C for largemouth bass acclimated to 20º C (Currie *et al*., 1998).

### 5.1.3 Preferred Temperatures

Centrarchid fishes have long been the focus of work on thermal preferences. Data on thermal preferenda are more common that quantitative data on lethal temperatures. In fact, even some of the less economically valuable species of centrarchid fishes have experimentally determined values (e.g. *E. gloriosus*; Casterlin & Reynolds, 1979; Stauffer, 1981). One of the few studies that provides comparative data for several centrarchid (and salmonid) species is Cherry *et al*. (1977). The authors exposed *A. rupestris*, *L. macrochirus*, *M. punctulatus*, and *M. dolomieu* to a range of standardized acclimation temperatures and thermal gradients. In general, thermal preferences increased with acclimation temperatures until acclimation temperatures reached 30ºC. As the fish approached lethal temperatures (i.e., > 30ºC), preferences decreased. For all the centrarchids the authors evaluated, final thermal preferenda were near 30ºC. Kieffer & Cooke (2009) generated a figure that illustrates the range of final thermal preferenda for all centrarchid fish for which they exist.

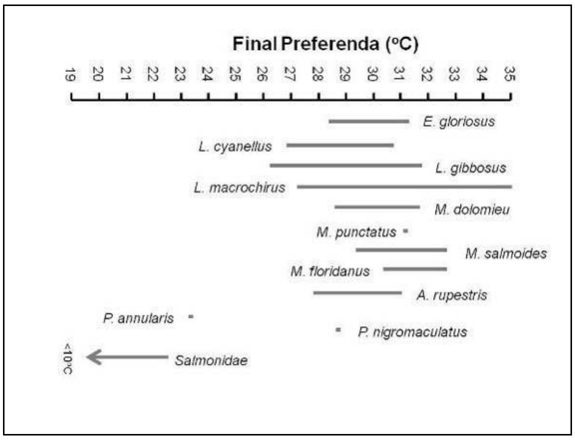



*Figure 5.2: Thermal preferenda data for centrarchid fishes. Taken from Kieffer & Cooke (2009).*

In general, the thermal preferenda are between 28 and 32º C with few exceptions. What is particularly interesting is the general conformity of all species to a rather narrow range of preferred temperatures. There are a number of clear ecological correlates of preferred temperature, which make it an important consideration for invasion biology (Magnuson *et al.,* 1979). The majority of physiological processes are optimized at the thermal preferenda (e.g. Coutant, 1975a). However, in the wild some species spend very little of their time at temperatures that fall within their preferred temperature ranges as a function of constraint from available temperatures. Magnuson & DeStasio (1996) illustrated this succinctly for *M. salmoides* across the United States. The authors concluded that *M. salmoides* occupy suboptimal thermal habitats for much of the year. In fact in some regions, fish may not ever experience preferred temperatures.

### 5.1.4 Winter as a Limiting Factor

As noted above, toward the northern edge of their range (or in areas such as Europe), it is believed that centrarchid distributions are regulated by the fact that during winter months, foraging is restricted and starvation occurs (Shuter & Post, 1990). Temperate latitudes in both North America and Europe experience a predictable annual cycle of alternating warm and cold periods that can result in below freezing conditions, ice cover, and alterations to aquatic habitats that persist for a substantial portion of a year. Winter represents a very challenging time of year that exerts a strong selective pressure on individual survival, community structure and year class strength for centrarchid fishes (Suski & Ridgway, 2009). Winter is typically defined as the period of the year between the autumnal equinox and prior to the onset of spawning in centrarchid fishes. Centrarchids can experience a broad range of climatic conditions during winter across their range. Pronounced latitudinal gradients in winter conditions exist with growing degree days and summer temperatures both declining with latitude, while winter severity (i.e., lower daily temperatures) and winter length both increase with latitude. The reality is that all centrarchids experience winter but there is certainly local adaptation such that fish that have co-adapted gene complexes tailored to a given suite of winter conditions typically survive, however, if fish from those populations are moved to areas where there experience harsher winters, chance of survival is reduced.

### 5.1.5 Species Accounts for those with Invasion Potential in The Netherlands

For those species identified in table 4.1 as being a potential threat to introduction we present a brief overview of their natural history with a focus on distribution in North America, thermal biology and winter ecology. For most species little is known about their thermal biology aside from inferences derived from the distribution of the species. The information is derived from a thorough review of peer reviewed literature. We acknowledge that much of the material of chapter 5 is from a recent book on centrarchid fish by Cooke & Philipp (2009) with particular reliance on the chapters that focused on natural history accounts (Warren, 2009), winter biology (Suski & Ridgway, 2009) and organismal physiology (Kieffer & Cooke, 2009). We thank the authors for giving permission for using these texts.

**Ambloplites rupestris – Rock Bass**

In North America *A. rupestris* occurs in the St. Lawrence River-Great Lakes, Hudson Bay (Red River), and Mississippi River basins. *A. rupestris* has been widely introduced and is established in Atlantic Slope drainages as far south as the Roanoke River, Virginia, and in the Missouri and Arkansas river drainages. The species is also established in several western states (Page & Burr, 1991; Fuller *et al*., 1999).

*A. rupestris* frequents cover in pools of creeks to small and medium rivers and the rocky and vegetated margins of lakes, being most common in silt-free rocky streams. Little is known about the winter biology of *A. rupestris*. Collections of fish through the ice in Ontario by Keast (1968) noted that *A. rupestris* collected at water temperatures between 6.5-8.5°C appeared to have not eaten for several weeks suggesting that this species is quiescent in the winter. Further support for this idea is that in laboratory experiments, *A. rupestris* preferred to remain solitary during winter simulations, and often migrated to non-flowing water (Breder & Nigrelli, 1935). Coble (1965) presented evidence that seasonal growth begins at temperatures of 10-14°C in *A. rupestris* whereas reproduction typically occurs at 16°C.

Both the growth and reproductive temperatures for *A. rupestris* fall within the range of temperatures commonly experienced in the Netherlands. There is no doubt that extreme winter conditions can impact overwinter survival of *A. rupestris*, but in Ontario and Quebec the species resides in regions with mean monthly minimum temperatures of -16°C in both January and February. Such temperatures are rarely experienced in the Netherlands. Suitable habitat this species might especially find within the larger rivers, streams in the eastern parts of the Netherlands in larger lakes like e.g. Veluwe Lake and Loosdrecht Lake.

**Centrarchus macropterus – Flier**

*C. macropterus* occurs primarily on the Coastal Plain from the Potomac River drainage, Maryland, to central Florida, and west to the Trinity River, Texas. The species penetrates the Mississippi Embayment to southern Illinois and southern Indiana, where it occurs above the Fall Line (Page & Burr, 1991).

*C. macropterus* is a lowland species, inhabiting swamps, vegetated lakes, ponds, sloughs, and backwaters and pools of small creeks and small rivers. The species usually is associated with densely vegetated, clear waters (Page & Burr, 1991; Jenkins & Burkhead, 1994; Pflieger, 1997; Boschung & Mayden, 2004). *C.*

*macropterus* is among the earliest, lowest temperature, spawners in the family. The ovaries enlarge and continue developing in the fall and over winter (Conley, 1966), which is likely an adaptation for early spawning. Nest-building is initiated at 14°C and the brief 10-14 day spawning period begins at water temperatures of 17°C in March and April (Dickson, 1949; Conley, 1966; Pflieger, 1997).

There is no information on the thermal biology of the species although its distribution is towards the southern edge of the range of centrarchids suggesting that they may respond poorly to the cold winters and relatively cool summers of the Netherlands. In aquaristics this species is considered to be sensitive to low temperatures and it is generally advised to overwinter this species in the Netherlands indoor.

**Enneacanthus chaetodon - Blackbanded Sunfish**

*E. chaetodon* is sporadically distributed below the Fall Line in Atlantic and Gulf slope drainages from New Jersey to central Florida and west to the Flint River, Georgia. Large distributional gaps occur across the range (e.g., entire western Chesapeake basin), and populations in Georgia and Florida are isolated and widely scattered (Gilbert, 1992b; Jenkins & Burkhead, 1994). Four areas of concentration are evident. Three of these, the pine barrens of New Jersey, the sandhills in southeastern North Carolina, and the central highlands of Florida, are characterized by well-drained sandy soils with vegetation of pine and scrubby oak species and dystrophic, acidic waters. The fourth area is the acidic Okefenokee Swamp in Georgia (Gilbert, 1992b).

*E. chaetodon* inhabits vegetated lakes, ponds, and quiet sand- and mud-bottomed pools and backwaters of creeks and small to medium rivers (Page & Burr, 1991). Knowledge of the reproductive behaviour and biology of *E. chaetodon* is limited largely to aquarium observations by hobbyists, and almost entirely based on anecdotal accounts and unpublished reports (summaries by Hardy (1978) and Jenkins & Burkhead (1994).

There is no information on the thermal biology of the species although its distribution is towards the southern edge of the range of centrarchids suggesting that they may respond poorly to the cold winters and relatively cool summers of the Netherlands. In aquaristics this species is considered to be sensitive to low temperatures and it is generally advised to overwinter this species in the Netherlands indoor.

**Enneacanthus gloriosus - Bluespotted Sunfish**


The *E. gloriosus* occurs in the Coastal Plain and Piedmont of Atlantic and Gulf slope drainages from southern New York south to southern Florida and westward to the Biloxi Bay drainages of southeastern Mississippi (Page & Burr, 1991; Jenkins & Burkhead, 1994; Ross, 2001). An introduced population is established in the Black River drainage, Mississippi (Peterson & Ross, 1987), and populations in the Lake Ontario drainage, New York, and Susquehanna River drainage, Pennsylvania, are of unknown provenance (Smith, 1985; Fuller *et al*., 1999).

*E. gloriosus* inhabits vegetated lakes, ponds, and sluggish sand- and mud-bottomed pools and backwaters of creeks and small to large rivers (Fox, 1969; Page & Burr, 1991; Peterson & VanderKooy, 1997; Snodgrass & Meffe, 1998). In spring samples in North Carolina, the species occurred most often in beaver ponds rather than unimpounded stream channels (Snodgrass & Meffe, 1998). In coastal Mississippi drainages, the species almost exclusively used side-ponds of oxbows, avoiding main channel habitats. Female and male gonad-to-body-weight ratios show initial increases as water temperatures rise above 15°C, remain high throughout much of the summer, but decline if temperatures remain above 27°C (Snyder & Peterson, 1999b). Thermal preferenda of *E. gloriosus* have been determined (Casterlin & Reynolds, 1979; Stauffer, 1981) and like other centrarchids, they approach 30°C. There is no information on the winter biology of this species.

There is insufficient information on the thermal biology of the species although its distribution is towards the southern edge of the range of centrarchids suggesting that they may respond poorly to the cold winters and relatively cool summers of the Netherlands. In aquaristics this species is considered to be sensitive to low temperatures and it is generally advised to overwinter this species in the Netherlands indoor.

**Enneacanthus obesus - Banded Sunfish**


*E. obesus* occurs primarily on the Coastal Plain of Atlantic and Gulf slope drainages from southern New Hampshire south to central Florida and west to the Perdido River drainage of Alabama (Page & Burr, 1991; Boschung & Mayden, 2004). Across the range, the species can be rare to relatively common (Smith, 1985; Laerm & Freeman, 1986; Jenkins & Burkhead, 1994; Boschung &

Mayden, 2004; Marcy *et al*., 2005). An introduced population is established in the Black River drainage of Mississippi (Peterson & Ross, 1987).

*E. obesus* inhabits heavily vegetated lakes, ponds, and sluggish sand-or mud-bottomed pools and backwaters of creeks and small to large rivers (Page & Burr, 1991). The species is perhaps one of the most acid tolerant fishes known (Gonzalez & Dunson, 1987) and occurs in waters with pH 3.7 (e.g., New Jersey, Graham & Hastings, 1984; Graham, 1989; Georgia, Freeman & Freeman, 1985). When males and females collected from ponds in fall were exposed in the laboratory to 15 h of daylight and 21.7°C water temperature, ovary volume, ova size, testis volume, and male breeding colours developed rapidly (about 38 days), and nest building and spawning occurred. Peak spawning and egg development occurred in June and July in a Connecticut reservoir at surface water temperatures of 23-27°C. Most details of reproductive biology, spawning behaviour, and aspects of parental care are undocumented. Nothing is known about the winter biology of this species (Rollo, 1994; Schleser, 1998).

There is no information on the thermal biology of the species although its distribution is towards the southern edge of the range of centrarchids suggesting that they may respond poorly to the cold winters and relatively cool summers of the Netherlands. In aquaristics this species is considered to be sensitive to low temperatures and it is generally advised to overwinter this species in the Netherlands indoor.

**Pomoxis annularis - White crappie**

*P. annularis* is native to the Great Lakes, Hudson Bay (Red River), and Mississippi River basins from New York and southern Ontario west to Minnesota and South Dakota and south to the Gulf of Mexico and in Gulf drainages from Mobile Bay, Georgia and Alabama, west to the Nueces River, Texas (Page & Burr, 1991). The species has been introduced and is established over most of the United States (Fuller *et al*., 1999).

*P. annularis* inhabits sand-and mud-bottomed pools and backwaters of creeks and small to large rivers, lakes, ponds, and reservoirs (Page & Burr, 1991). The greater adaptability of *P. annularis* to turbid waters than *P. nigromaculatus* is often noted. In rivers in Missouri, tagged individuals covered 34-42 km in 21-91 days (Funk, 1957) and others have noted movements up to 30 km (review *in* Hansen, 1951; Siefert, 1969a). Increased movement in spring and early summer is attributed to aggregation in spawning areas and post-spawning foraging (Guy *et al*., 1994). *P. annularis* is among the earliest, lowest temperature spawners in the family. The testes and ovaries enlarge and continue developing in the fall and over winter (Morgan, 1951b; Whiteside, 1964), which is likely an adaptation for early spawning. Spawning occurs at water temperatures of 11-27°C with most spawning taking place at 16-20°C.

Given the broad temperature (particularly their tolerance of prolonged winter conditions) and turbidity tolerances of *P. annularis* and low temperature spawning suggest that this species could do well in the waters of the Netherlands if introduced. Being flexible in its habitat preferences *P. annularis* is likely to find suitable habitats in most regions in the Netherlands.

**Pomoxis nigromaculatus - Black Crappie**

The native range presumably includes Atlantic Slope drainages from Virginia to Florida, Gulf Slope drainages west to Texas, and the St. Lawrence River-Great Lakes and Mississippi basins from Quebec to Manitoba and south to the Gulf of Mexico (Page & Burr, 1991). The wide introduction and establishment of *P. nigromaculatus* renders accurate determination of the native range difficult (Page & Burr, 1991; Fuller *et al*., 1999). As the introduced *P. nigromaculatus* became abundant in some California waters, the only native centrarchid, the Sacramento perch (*A. interruptus*), declined or disappeared (Moyle, 2002). Historical shifts in distribution and relative abundance suggest *P. nigromaculatus* has declined or been replaced by *P. annularis* because of increased turbidity of waters (e.g., South Dakota, Carlander (1977); Illinois, Smith (1979); Ohio, Trautman (1981); Wisconsin, Becker (1983)).

*P. nigromaculatus* inhabits lakes, ponds, sloughs, and backwaters and pools of streams and rivers. The species is most common in lowland habitats, large reservoirs, and navigation pools of large rivers but is rare in upland rivers and streams. *P. nigromaculatus* usually is associated with clear waters, absence of noticeable current, and abundant cover (e.g., aquatic vegetation, submerged timber) (Carlander, 1977; Werner *et al*., 1977; Conrow *et al*., 1990; Page & Burr, 1991; McDonough & Buchanan, 1991; Keast & Fox, 1992; Etnier & Starnes, 1993; Pflieger, 1997). The species is apparently moderately tolerant of oligohaline conditions, occasionally entering tidal waters (usually < 5.0 ppt salinity; Rozas & Hackney, 1974; Moyle, 2002).

Field and laboratory observations indicate *P. nigromaculatus* is tolerant of long exposures to extremely low temperatures (<1°C) and dissolved oxygen (ca. 1 ppm), particularly in winter (e.g., Cooper & Washburn, 1946; Moyle & Clothier, 1959; Siefert & Herman, 1977; Carlson & Herman, 1978; Knights *et al*., 1995). *P. nigromaculatus* move to shift seasonal habitats or track resources, to avoid extreme physical conditions, and in response to environmental changes. Most nesting and spawning occur at water temperatures of 14-22°C (to 26°C) with peak activity (most active nests) at about 18°C (Carlson & Herman, 1978; Becker, 1983; Colgan & Brown, 1988; Pine & Allen, 2001; Cooke *et al*., 2006). Spawning is most protracted in Florida, occurring over a 12 week period from late January to May with peaks in March and April. The spawning season is later (April to June or even July in northern lakes) and shorter (21-37 days) at more northerly latitudes (Reid, 1950b; Huish, 1954; Becker, 1983; Keast, 1985c; Pope *et al*., 1996; Travnichek *et al*., 1996; Pope & Willis, 1998; Pine & Allen, 2001; Cooke *et al*., 2006). The ovaries enlarge and continue developing in the fall and over winter (Schloemer, 1947; Morgan, 1951a), which is likely an adaptation for early spring spawning.

Given the broad temperature tolerances of *P. nigromaculatus* (particularly their tolerance of prolonged winter conditions) and low temperature spawning suggest that this species could do well in the waters of the Netherlands if introduced. The occupied habitats are diverse and available in the Netherlands. In addition, salinity tolerance may be relevant to coastal brackish canals.

**Lepomis auritus - Redbreast Sunfish**

*L. auritus* is native to the Atlantic and Gulf slopes from New Brunswick to central Florida and west to the Apalachicola and possibly the Choctawhatchee river drainages of Georgia and Florida. The native or introduced status in the Tallapoosa and upper Coosa rivers of Alabama and Georgia, where the species is widespread and common, is uncertain (Boschung & Mayden, 2004). The species has been widely introduced and is established well outside its native range (e.g., Rio Grande to southeastern Ohio River basin) and in some areas (e.g., upper Tennessee River drainage) may be displacing native *Lepomis* (Page & Burr, 1991; Etnier & Starnes, 1993; Fuller *et al*., 1999; Miller 2005).

*L. auritus* inhabits rocky, sandy, or mud-bottomed pools of creeks and small to medium rivers and can also occur in lakes, ponds, or reservoirs (Page and Burr, 1991). The species is usually associated with cover (e.g., instream wood, stumps, or undercut banks), and in streams, abundance increases with decreasing water velocity and increasing depth and cover (Meffe and Sheldon, 1988). Nest building and spawning begin as water temperature increases from about 17 to 20°C and continues to 31°C. Spawning is protracted (April-early June to August or even October), depending in part on latitude (Bass & Hitt, 1974; Lukas & Orth, 1993). Nesting activity decreases over the summer and is related strongly to the number of degree-days accumulated after water temperatures reach 20°C, although declines may also be related to re-nesting by unsuccessful males or declining numbers of spawning ready females (Sandow *et al*., 1975; Lukas & Orth, 1993).

*L. auritus* rarely encounters in its native range winter air temperatures below 2°C. Also summer temperatures in the Netherlands are clearly different from this species subtropical native range. It is therefore less likely to do well in the Dutch climate. But as especially its spawning temperatures are within a range of temperatures that can be found in the Netherlands it can not be excluded to be able to establish in the Netherlands. Habitat is not likely to be limiting in the Netherlands.

**Lepomis cyanellus - Green Sunfish**

*L. cyanellus* is native to the east-central United States, west of the Appalachians from the Great Lakes, Hudson Bay, and Mississippi River basins from New York and Ontario to Minnesota and South Dakota and south to the Gulf Slope drainages from the Escambia River, Florida, and Mobile Basin, Georgia and Alabama, west to the lower Rio Grande basin, Texas and northern Mexico (Page & Burr, 1991; Miller, 2005). The species has been widely introduced and is established over much of the United States including Atlantic and Pacific slope drainages and Hawaii (Page & Burr, 1991; Fuller *et al.*, 1999).

*L. cyanellus* is a highly successful, aggressive, competitive species occurring in a variety of habitats including clear to turbid headwaters, sluggish pools of large streams, isolated, dry-season stream pools, and shallow shorelines of lakes, ponds, and reservoirs (Werner & Hall, 1977; Werner *et al.*, 1977; Capone & Kushlan, 1991; Page & Burr, 1991; Etnier & Starnes, 1993; Taylor & Warren, 2001; Smiley *et al.*, 2005). The species is among the most tolerant *Lepomis* to adverse conditions of high turbidity (<3500 FTU), low dissolved oxygen (< 1 ppm), and high temperatures (average critical thermal maxima 37.9°C, acclimated at 26°C; McCarraher, 1971; Horkel & Pearson, 1976; Matthews, 1987; Smale & Rabeni, 1995ab; Beitinger *et al.*, 2000). Spawning is protracted (mid May to early August), the initiation of spawning depending in part on latitude (Hunter, 1963; Kaya & Hasler, 1972; Carlander, 1977; Pflieger, 1997). Nest building and spawning begin as water temperatures increase to 20°C, and peak spawning occurs between about 20-28°C (Hunter, 1963). Nesting activity decreases and gonadal regression occurs as water temperatures remain over 28°C for extended periods (Hunter, 1963; Kaya, 1973). Experimental evidence suggests that *L. cyanellus*, when properly acclimated, survives well at temperatures near 1°C water temperature (Cortemeglia & Beitinger, 2008).

*L. cyanellus* is a hardy ubiquist with a broad temperature tolerance that makes survival in the Netherlands likely. Also outdoor survival of this species in garden ponds, e.g. the fishes of fig. 4.3, shows that it is probably capable to survive Dutch winter temperatures. *L. cyanellus* would likely have problems with reproduction given that spawning starts at ~20°C. This might reduce its invasiveness.

**Lepomis gibbosus - Pumpkinseed**

*L. gibbosus* is native to Atlantic Slope drainages from New Brunswick south to the Edisto Rriver, South Carolina, and to the Great Lakes, Hudson Bay, and upper Mississippi River basins from Quebec and New York west to southeast Manitoba and North Dakota and south to northern Kentucky and Missouri. The species has been widely introduced and is established over much of the United States and southern Canada, including some Pacific Slope drainages (Scott and Crossman, 1973; Page & Burr, 1991; Fuller *et al*., 1999; Moyle, 2002).

*L. gibbosus* inhabits in its native range vegetated lakes and ponds and quiet vegetated pools of creeks and small rivers (Page & Burr, 1991). Spawning is protracted (early May to August), the initiation of spawning depending in part on latitude and population size-structure (Burns, 1976; Carlander, 1977; Danylchuk & Fox, 1994; Fox & Crivelli, 1998). Gonadal development in both sexes accelerate as water temperatures warm to 12.0°C and photoperiod lengthens to 13.5 h (Burns, 1976). A combination of long photoperiod (16 h) and warm temperature (25°C) induces nest-building behaviours in males (Smith, 1970). Nest building and spawning begin as water temperatures increase to 17°C, and peak spawning occurs between about 20-22°C, but continues to at least 26°C (Miller, 1963; Fox & Crivelli, 1998; Cooke *et al*., 2006). *L. gibbosus* already exist in Europe (including the Netherlands) and would thus have a reasonable potential for establishing in Dutch waters if introduced.

According to literature (Laughlin & Werner, 1980, Garcia-Berthou & Moreno-Amich, 2002) *L. gibbosus* prefers water bodies with a considerable vegetation cover. This preference is especially apparent in larvae and juveniles and decreases with age. Exposed mineral soil is an important habitat element for reproduction (Danylchok & Fox, 1996, Van Kleef *et al*., 2008, unpublished data H. van Kleef). Nests are build on gravel and sand substrates. If the mineral soil is covered by silt, males increase the size and depth of the nest until the mineral soil is exposed. When the organic layer exceeds seven centimeters, it becomes too thick for the fish to penetrate and unsuitable for reproduction. Sometimes dead leaves or branches can serve as an alternative nesting substrate. Due to its dependence on mineral substrate *L. gibbosus* is able to benefit from nature management practices that expose sandy substrates (Van Kleef *et al*., 2008). Common examples are dredging of moorland pools, creating ponds for amphibian habitat and removal enriched soils on former farmland.

Habitat suitable for *L. gibbosus* is common in the Netherlands. *L. gibbosus* are recorded from standing waters, such as moorland pools ponds, lakes, river meanders and canals, but the species is also encountered in streams (Klaar *et al*. 2004) and rivers (Balon 1959). Most Dutch records come from streams. Although reproduction in flowing waters is common in Southern Europe, it is rare and less successful in the Netherlands. Most Dutch stream populations originate from standing waters in the streambed that are only occasionally in contact with the stream (Unpublished data H. van Kleef). Because reproduction is rare in Dutch streams, *L. gibbosus* abundance in these waters is often low. In standing waters densities of this species can be much higher.

**Lepomis macrochirus - Bluegill**

*L. macrochirus* is native to the St. Lawrence-Great Lakes system and Mississippi River basin from Quebec and New York to Minnesota and south to the Gulf of Mexico and in Atlantic and Gulf slope drainages from the Cape Fear River, Virginia, to the Rio Grande River, Texas and Mexico (Page & Burr, 1991; Miller, 2005). The species has been widely introduced and is now established and often exceedingly abundant in suitably warm waters of most of North America (Fuller *et al*., 1999; Moyle, 2002; Miller, 2005) and other continents (e.g., South Africa, Korea, Japan.

*L. macrochirus* inhabits all types of warmwater lacustrine habitats (e.g., oligohaline estuaries, swamps, lakes, ponds, reservoirs, canals) as well as pools of creeks and small to large rivers. In lacustrine environments, whether natural or human-made, the bluegill is often the most abundant centrarchid (Desselle *et al*., 1978; Becker, 1983; Page & Burr, 1991; Peterson & Ross, 1991; Jenkins & Burkhead, 1994). The species is among the most tolerant *Lepomis* to adverse conditions of low dissolved oxygen (<1.0 ppm) and high temperatures (average critical thermal maxima 40.4-41.4° C, acclimated at 35° C) (Moss & Scott, 1961; Matthews, 1987; Smale & Rabeni, 1995ab; Beitinger *et al*., 2000; Miranda *et al*., 2000; Killgore & Hoover, 2001). *L. macrochirus* can survive winter conditions of <1° C and <2 mg/liter dissolved oxygen (Magnuson & Karlen, 1970; Petrosky & Magnuson, 1973; Knights *et al*., 1995), but winter anoxia, often associated with ice over of shallow lakes, limits their distribution in northern lakes (Tonn & Magnuson, 1982; Rahel, 1984). *L. macrochirus* indigenous to fresh or brackish waters showed no preference in salinity over a range of 0 to 10 ppt (Peterson *et al*., 1993). Nest building and spawning begin as water temperatures increase to 20°C, and spawning continues up to about 31°C (Morgan, 1951ab; Banner & Hyatt, 1975).

Despite the fact that water temperatures in the Netherlands are lower than the preferences for *L. macrochirus*, the species has shown repeatedly that its broad environmental tolerances make it an effective colonizer. This species is known to survive winter conditions like they occur in the Netherlands well. As such, *L.*

*macrochirus* should be considered a potential risk to Dutch fauna, especially as recorded behavior in areas where they have become naturalized is comparable to the in the Netherlands invasive *L. gibbosus*.

**Lepomis megalotis s.l. - Longear Sunfish**

*L. megalotis* s.l. (including both *L. megalotis* s.s. and *L. peltastes*) is native to the Mississippi River basin west of the Appalachian Mountains from Indiana west to eastern Illinois and south to the Gulf of Mexico and to Gulf Slope drainages from the Choctawhatchee River, Florida, west to the Rio Grande, Texas, southern New Mexico, and northeastern Mexico (Page & Burr, 1991; Miller, 2005). *L. megalotis* s.l. is generally common, and often the most abundant *Lepomis* in upland or clear streams throughout its range. *L. megalotis* s.l has expanded its range in recent decades north and westward in the Missouri River, Missouri, as a likely result of clear water conditions imposed on that system by upstream reservoirs (Pflieger, 1997). *L. megalotis* s.l. has been introduced sparingly outside its native range and is established in the upper Ohio River basin (New and Kanawha, above the Falls, rivers), the Atlantic Slope (Potomac River drainage and Maryland coastal plain), upper Rio Grande (New Mexico), and perhaps, the Pacific Slope of Mexico (Rio Yaqui) (Fuller *et al*., 1999; Miller, 2005).

*L. megalotis* s.l. inhabits rocky and sandy pools of headwaters, creeks, and small to medium rivers (Page & Burr, 1991) and can thrive along shorelines of reservoirs (Bacon, 1968; Gelwick & Matthews, 1990; Bettoli *et al*., 1993; Etnier & Starnes, 1993; Pflieger, 1997). In some rivers, *L. megalotis* s.l. can be the most abundant centrarchid (Gunning & Suttkus, 1990). The species is tolerant of low dissolved oxygen (e.g., 100 % survival at < 1 ppm for 3 days) and high water temperatures (critical thermal maxima >34°C) (Matthews, 1987; Smale & Rabeni, 1995ab; Beitinger *et al*., 2000). Spawning is protracted and may include up to six relatively discrete nesting periods occurring from late May to mid-July or August at intervals of about 12-days (Huck & Gunning, 1967; Boyer & Vogele, 1971; Carlander, 1977; Jennings & Philipp, 1994). Observations in Missouri reservoirs indicate spawning temperatures range from 22-28°C with nest abandonment occurring if water temperature abruptly decreased below or increased above this range (Witt & Marzolf, 1954; Boyer & Vogele, 1971), but in a Louisiana stream, nesting occurred at 29-31°C (Huck & Gunning, 1967).

*L. megalotis s.l.* experiences in its native range a range of thermal conditions including those similar to temperatures experienced in the Netherlands. Also experencies in Germany, where this species is present in pet trade, suggest that *L. megalotis s.l.* will survive Dutch winters well. Both species show in their native range a more restricted habitat choice, but it is unknown how this species might behave when introduced.

**Micropterus dolomieu - Smallmouth Bass**
*M. dolomieu* is native to the St. Lawrence-Great Lakes, Hudson Bay (Red River), and Mississippi River basins from southern Quebec to North Dakota and south to northern Alabama and eastern Oklahoma (Hubbs & Bailey, 1938; Page & Burr, 1991). The species has been introduced widely and is now established throughout southern Canada and the United States, except in Atlantic and Gulf slope drainages, where it is rare from south of Virginia to eastern Texas (MacCrimmon & Robbins, 1975; Page & Burr, 1991; Jenkins & Burkhead, 1994; Snyder *et al*., 1996; Fuller *et al*., 1999).

*M. dolomieu* inhabits clear, cool, runs and pools of small to large rocky rivers and the rocky shorelines of lakes and reservoirs (Page & Burr, 1991). In Ozark Border streams in Missouri, abundance of *M. dolomieu* is related inversely to percent pool area and maximum summer water temperature, a pattern opposite to that observed for largemouth bass (Sowa & Rabeni, 1995). Across its broad range, *M. dolomieu* occupies a wide variety of habitats depending on life-stage, food availability, and habitat conditions, but the most consistent physical habitat association for adults in rivers, lakes, and reservoirs is proximity to submerged cover (e.g., steep drop-offs, ledges, crevices, boulders, stumps, logs, logjams). The habitat, environmental tolerances, bioenergetics, and spatial ecology of *M. dolomieu* from hatching to adult in both lake and riverine environments are documented extensively.

Latitudinal differences in temperature and regional variation in annual temperatures exert considerable influence on *M. dolomieu* distribution, abundance, growth, and survival. A model using temperature, food availability, and lake depth to predict young-of-the-year growth and winter mortality accurately delimited the northern distributional limit of the species (Shuter & Post, 1990). Average July temperatures <15°C prevent young-of-the-year from reaching sufficient size to overwinter, precluding long-term viability of populations on the northern edge of the range (Shuter *et al*., 1980). At northern latitudes, a short-growing season and long, cold winters combined with variability in food availability (e.g., low productivity, high competition) and hence energy reserves can dramatically increase overwinter mortality (to 100%) of young-of-the-year *M. dolomieu* (Oliver *et al*., 1979; Shuter *et al*., 1989; Lyons, 1997; Curry *et al*., 2005). In an analysis of data for 409 *M. dolomieu* populations across North

America, age-at-length was correlated negatively with mean air temperature (and degree days >10°C) (Beamesderfer & North, 1995). In a study of 129 geographically widespread populations, temperature related climate differences were significantly related to growth and were most influential in the first four years of life (Dunlop & Shuter, 2006). In natural settings, *M. dolomieu* spawn from about April to mid-July at southern latitudes and mid-May to mid-June on the northern edge of the range (Pflieger, 1966a; 1975; Neves, 1975; Hubert & Mitchell, 1979; Vogele, 1981; Wrenn, 1984; Graham & Orth, 1986; Ridgway & Friesen, 1992). Spawning activity and active nests span a broad range of temperatures (12.0-26.7°C); however, most spawning is initiated as water temperatures gradually rise and exceed 15°C, and peak spawning continues to 22°C (e.g., Pflieger, 1966a; Smitherman & Ramsey, 1972; Neves, 1975; Carlander, 1977; Shuter *et al*., 1980; Vogele, 1981; Wrenn, 1984; Graham & Orth, 1986; Cooke *et al*., 2003a).

Thermal conditions and present habitats in The Netherlands would be suitable to establishment of wild populations of *M. dolomieu*, but likely the thermal conditions of the Netherlands may limit summer growth (and hence later survival) of *M. dolomieu*. This may effect its invasive behavior, but especially in optimal habitats with little competition this species might do well.

**Micropterus floridanus - Florida Bass**

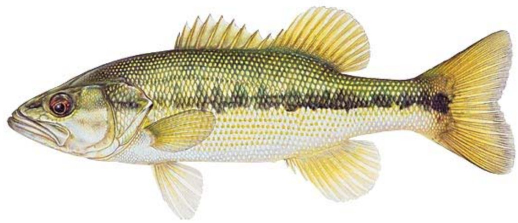
*M. floridanus* is native to peninsular Florida (Bailey & Hubbs, 1949; Philipp *et al*., 1981; 1983; Page & Burr, 1991). *M. floridanus* and *M. salmoides* have an extensive hybrid zone across the southeastern United States in large part as result of stocking of *M. floridanus* outside its native range (see *M. salmoides*).

*M. floridanus* inhabits clear vegetated lakes, reservoirs, canals, ponds, swamps, and backwaters as well as pools of creeks and small to large rivers (Page & Burr, 1991). Adults often center home activity areas in close association with structure (e.g., logs, piers) or mixed beds of emergent and submergent aquatic macrophytes but also frequent open water without cover (McLane, 1948; Mesing & Wicker, 1986; Colle *et al*., 1989; Bruno *et al*., 1990).

*M. floridanus*, having evolved in a subtropical climate, is more adapted to high temperatures and apparently less adapted to low temperatures than its temperate climate sister species, the *M. salmoides*. *M. floridanus*, along with *L. macrochirus*, has the highest reported critical thermal maxima among centrarchids, exceeding 41°C (acclimation temperatures >30°C, Fields *et al*., 1987; Beitinger *et al*., 2000). Spawning can occur as early as December in southern Florida, as water temperatures cool to about 18.3°C, but peak spawning is generally from February to April at water temperatures between about 18.0-21.1°C (as low as 14°C, up to about 27.8°C) (Clugston, 1966; Chew, 1974).

*M. floridanus* (or hybrids with *M. salmoides*) are unlikely to establish in the Netherlands given that the endemic range of the species is the southern USA where water temperatures are much warmer.

**Micropterus punctulatus - Spotted Bass**



*M. punctulatus* is native to the Mississippi River Basin from southern Ohio and West Virginia to southeastern Kansas and south to the Gulf and in Gulf drainages from the Choctawhatchee River, Alabama and Florida, west to the Guadalupe River, Texas (Robbins & MacCrimmon, 1974; Page & Burr, 1991; Miller, 2005). Populations in the Apalachicola River Basin were likely introduced (Bailey & Hubbs, 1949; Williams & Burgess, 1999). *M. punctulatus* was widely introduced and is established outside its native range across most of the southern half of the western United States and in some river systems has rapidly expanded its range after introduction (e.g., Missouri River) (Robbins & MacCrimmon, 1974; Pflieger, 1997; Fuller *et al*., 1999; Moyle, 2002).

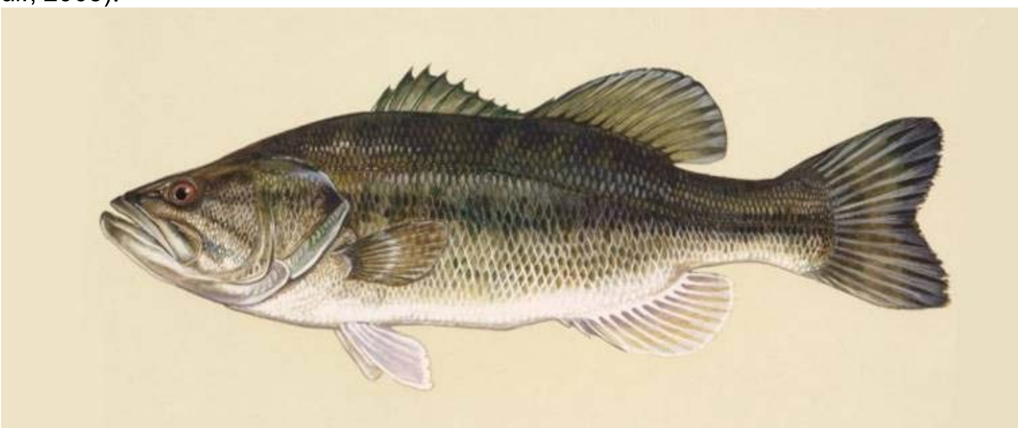
*M. punctulatus* inhabits gravelly flowing pools and runs of creeks and small to medium rivers and reservoirs (Page & Burr, 1991). In streams, *M. punctulatus* is commonly associated with low-velocity pools, particularly those with vegetation, log complexes, rootwads, or undercut banks (Lobb & Orth, 1991; Scott & Angermeier, 1998; Tillma *et al*., 1998; Horton and Guy, 2002; Horton *et al*., 2004). The habitat requirements of the species can be broadly characterized as intermediate between those of *M. dolomieu* and *M. salmoides*. *M. punctulatus* is associated with warmer, more turbid water than *M. dolomieu*, and faster, less productive waters than *M. salmoides* (Trautman, 1981; Layher et al., 1987; Pflieger, 1997).

Depending in part on latitude and water temperature, spawning occurs over a one to two month period from March to May or early June with the most intensive nesting occurring within about two weeks of initial spawning activity (Ryan *et al*., 1970; Gilbert, 1973; Olmsted, 1974; Vogele, 1975a; Sammons *et al*., 1999; Greene & Maceina, 2000). Active nests have been observed at temperatures as low as 12.8°C, but most spawning occurs between 14°C and 23°C (Howland 1932a; Ryan *et al*., 1970; Smitherman & Ramsey, 1972; Gilbert, 1973; Olmsted, 1974; Vogele, 1975ab; Aasen & Henry, 1981; Sammons *et al*., 1999). Ecologically, *M. punctulatus* can function as the only top carnivore in small, even intermittent, headwater streams and often is the dominant top predator in large rivers and reservoirs (Cross, 1967; Trautman, 1981; Pflieger, 1997).

Given that *M. salmoides* and *M. punctulatus* are morphologically similar and frequently hybridize, there is potential for risk of introduction although it is unlikely that *M.*

*punctulatus* per se would be the target – it would probably be *M. salmoides* that are misidentified. *M. punctulatus* (or hybrids with *M. salmoides*) are unlikely to establish in the Netherlands given that the endemic range of the species is the southern USA where water temperatures are much warmer.

**Micropterus salmoides - Largemouth Bass**
*M. salmoides* is native to the St. Lawrence-Great Lakes, Hudson Bay (Red River), and Mississippi River basins from southern Quebec to Minnesota and south to the Gulf of Mexico and in Gulf drainages from about Mississippi or Alabama west to the Rio Grande and Soto la Marina in northeastern Mexico (Page & Burr, 1991; Miller, 2005). On the Atlantic Slope, early introductions of “largemouth bass” in many drainages obscured the northern limit of the native range (Jenkins & Burkhead, 1994). Critical evaluation of early records and reports and evaluation of nuclear encoded allozyme data across Virginia suggests the species occurred historically on the Atlantic Slope to the Tar River of North Carolina but not beyond (Jenkins & Burkhead, 1994; Dutton *et al.*, 2005).



*M. salmoides* inhabits lakes, ponds, swamps, marshes, and backwaters and pools of creeks and small to large rivers as well as impoundments (Page & Burr, 1991). The species occurs and often thrives in an array of lacustrine habitats including saline marshes along the Gulf of Mexico and Atlantic Coast (Peterson and Meador 1994); bottomland hardwood swamps and associated floodplain lakes (Rutherford *et al.,* 2001), and vegetated glacial lakes (Werner *et al*., 1977).

Temperature exerts considerable influence on *M. salmoides* populations across the broad band of latitude comprising the total range of the species. The species has a relatively high critical thermal maxima of 38.5-40.9°C (acclimated at >30°C, Smith & Scott, 1975; Fields *et al*., 1987; Beitinger *et al.*, 2000; Currie *et al*., 1998; 2004), so that high temperatures are not particularly limiting. In contrast, the summer thermal regime or alternatively the duration and severity of winters profoundly affect the distribution, growth, and survival of *M. salmoides*. In a synthesis of growth data across North America (from Carlander, 1977), over half the latitudinal variation in growth (size-at-age) for *M. salmoides* (including *M. floridanus*) was accounted for by differences in monthly mean air temperatures (degree days >10°C) across a north-south latitudinal gradient (McCauley & Kilgour, 1990). The northern distributional limit for *M. salmoides* was estimated as a thermal unit isocline of 550 day-degrees above 10°C in extreme southern Canada. Spawning activity can begin in early spring at a water temperature as low as 12°C, but most individuals initiate spawning after the water temperature reaches and exceeds 15°C. The spawning season extends over two to ten weeks, peaks between water temperatures of 15 and 21°C, and winds down as waters warm to and consistently exceed 24°C. Spawning occurs from mid-May to mid-June or even early July at north-temperate latitudes and shifts to earlier dates at progressively lower latitudes (e.g., mid-March to May or early June in Mississippi and Alabama) (Kramer & Smith, 1960a; Allan & Romero, 1975; Becker, 1983; Miller & Storck, 1984; Isely *et al*., 1987; Goodgame & Miranda, 1993; Annett *et al*., 1996; Post *et al*., 1998; Sammons *et al*., 1999; Greene & Maceina, 2000; Cooke *et al*., 2006).

*M. salmoides* has done well when introduced around the world. It has rather broad temperature tolerances. Although *M. salmoides* can handle much warmer temperatures than experienced in The Netherlands, the species does well in moderate north temperate regions such as central Ontario and southern Quebec, which suggests that the species could do well in The Netherlands. The occupied habitats are diverse and available in the Netherlands.

### 5.1.6 Overview probability of establishment

All 34 centrarchid species, which are endemic to North America, could certainly survive and quite possibly reproduce in the freshwaters of the Netherlands during the late spring, summer and early fall when water temperatures are moderate (e.g., 14 to 22°C). All centrarchids can survive under such thermal conditions provided that they have ample food and avoid predators. Nonetheless, the temperatures in the Netherlands are lower than the preferred temperatures for all centrarchids (i.e., 28 to 32°C), although there are also many parts of their endemic range where those temperatures are rarely achieved. It is unlikely that any of the 34 centrarchid species would experience summer temperatures in the Netherlands that would exceed their thermal tolerances. The critical thermal maxima of centrarchids are so high (e.g., >36°C) that even in North America those temperatures are rarely seen for most species except in the face of thermal pollution (e.g., thermal effluent).

Water temperatures experienced during the winter can also influence the invasion potential of centrarchids in the Netherlands. Although absolute water temperatures in and of themselves, even when approaching 2°C and with ice cover, are unlikely to be directly lethal for most species (except those from the southern USA such as the Florida bass), it is believed that the northern limit of centrarchid distributions are regulated by the fact that during winter months, foraging is restricted and starvation occurs. In Netherlands temperatures rarely fall below 0°C which would be typical of the mid-latitude regions of North America where many of the centrarchids are sympatric. Although the moderate temperatures in the Netherlands are unlikely to be lethal, given that the temperatures deviate from optimal that there would be expected to be a number of energetic, behavioural and life-history consequences that would likely influence population biology and dispersal.

Given our analysis, ten species are considered to have a high probability of establishment based on their thermal biology (table 5.1), their northern distribution in North America, and the fact that these species are flexible in the occupied habitats and are likely to find suitable habitats: *A. rupestris, P. annularis, P. nigromaculatus, L. cyanellus, L. gibbosus, L. macrochirus, L. megalotis s.l. (L. megalotis s.s.* & *L. peltastes), M. dolomieu* & *M. salmoides*.

Three species are considered to have a medium probability of establishment: *L. auritus, L. humilis* and *L. gulosus*. *L. gulosus* requires high spawning temperatures (>21°C), and both *L. humilis* and *L. auritus* have a northern subtropical distribution with winter temperatures rarely below 2°C. But as we lack sufficient knowledge on their thermal tolerances and thus their flexibility we prefer to consider the probability of establishment of these species as medium.

Seventeen species are considered to have a low probability of establishment (table 5.1). These species have a southern distribution in North America and are not known to be invasive in temperate climates. These species are likely to have a low tolerance for Dutch winter temperatures and to have spawning/growth/optimal temperatures that are not likely to be encountered in the Netherlands. We acknowledge the fact that too little data on their actual temperature tolerance is available to exclude the possibility of establishment of these species. We therefore consider the probability of establishment of these species as being low.

Four species are considered to have an uncertain probability of establishment. For these species there was too little information available in our review. As these species are extremely unlikely to be introduced in the Netherlands no further attempts have been made to assess the probability of establishment further.

*Table 5.1: The probability of establishment of 34 species of centrarchid fishes with comments on their thermal biology.*

| Latin Binomial | Comments on Thermal Biology | Probability of establishment |
|---|---|---|
| ***Centrarchinae*** | | |
| *Acantharchus pomotis* | Unknown – lives in mid-latitude regions of North America that would be somewhat warmer than temperatures experienced in the Netherlands | uncertain |
| *Ambloplites ariommus* | Unknown – lives in mid-latitude regions of North America that would be somewhat warmer than temperatures experienced in the Netherlands | uncertain |
| *Ambloplites cavifrons* | Unknown – lives in mid-latitude regions of North America that would be somewhat warmer than temperatures experienced in the Netherlands | uncertain |
| *Ambloplites constellatus* | Unknown – lives in mid-latitude regions of North America that would be somewhat warmer than temperatures experienced in the Netherlands | uncertain |
| *Ambloplites ruprestris* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |

| | | |
|---|---|---|
| *Archoplites interruptus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Centrarchus macropterus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Enneacanthus chaetodon* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Enneacanthus gloriosus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Enneacanthus obesus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Pomoxis annularis* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Pomoxis nigromaculatus* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| ***Lepominae*** | | |
| *Lepomis auritus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 2°C | medium |
| *Lepomis cyanellus* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Lepomis gibbosus* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Lepomis gulosus* | Rather limited endemic range where water temperatures are moderate. This species has high spawning temperatures (>21°C) | medium |
| *Lepomis humilis* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 2°C | medium |
| *Lepomis macrochirus* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Lepomis marginatus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Lepomis megalotis* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Lepomis microlophus* | Tends to reside in regions of the southern US where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Lepomis miniatus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Lepomis peltastes* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Lepomis punctatus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Lepomis symmetricus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| ***Micropterinae*** | | |
| *Micropterus cataractae* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Micropterus coosae* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |

| | | |
|---|---|---|
| *Micropterus dolomieu* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Micropterus floridanus* | Common in southern USA where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C. Species does not exist in northern USA or Canada despite introductions suggesting that the species would not survive thermal conditions in the Netherlands | low |
| *Micropterus henshalli* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Micropterus notius* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Micropterus punctulatus* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |
| *Micropterus salmoides* | Lives in a range of thermal conditions including those similar to temperatures experienced in the Netherlands – can withstand colder winters and warmer summers | **high** |
| *Micropterus treculii* | Limited endemic range where water temperatures are much warmer than those experienced in the Netherlands. In addition, the species rarely encounters winter air temperatures below 5°C | low |

### 5.1.7 Impact of climate change on the probability of establishment.

Freshwater fishes are cold blooded animals that rely on behavioral thermoregulations to modify their internal body temperatures. As such they are likely to be relatively quickly affected by temperature changes, making it necessary to include climate change when assessing the probability of establishment.

In future scenario's it is in general anticipated that temperatures will rise in the Netherlands (Klein tank & Lenderink, 2009). The differences between the four scenario's presented by Klein tank & Lenderink (2009) are large (table 5.2). A review of the different scenario's is not included in this study.

With the Netherlands having current thermal ranges that are lower then the 'preferred temperatures' of most centrachid species (fig. 5.2), it is to be anticipated that both the probability of establishment and the chance of these species becoming invasive will increase with any temperature rise. This accounts for species with a high, medium or low probability of establishment (table 5.1). Especially when considering scenario 4 (table 5.2) those species that are considered medium (*L. auritus, L. humilis* and *L. gulosus*) need to be adjusted to high. Only *L. auritus* is considered to have potential to be introduced in the Netherlands as it is present in North American trade.

The species considered to have a low probability of establishment will probably need a variable correction. It is not anticipated that any of these species should be adjusted to high.

*Table 5.2: Temperature change in the Netherlands in the period 1990-2050 according to four scenario's (Klein Tank & Lenderink, 2009) .*

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Winter | 0,9°C | 1,1°C | 1,8°C | 2,3°C |
| Spring | 0,9°C | 1,2°C | 1,8°C | 2,6°C |
| Summer | 0,9°C | 1,4°C | 1,7°C | 2,8°C |
| Autumn | 0,9°C | 1,3°C | 1,8°C | 2,7°C |

## 5.2 Elassomatidae

### 5.2.1 Temperature tolerance

The Elassomatidae is a family with a mainly subtropical distribution (Gilbert, 2004). This is reflected in the reported temperature tolerances of these species (table ). Although *Elassoma*-species can withstand low temperatures even close to the freezing point for a short period they do not survive Dutch winters, as they can't handle longer periods of low temperatures (Arnold, 1990; J. Bohlen, pers. com.). Experiences of aquarianists show that they can be kept outside during a large part of the year, but have to de moved inside during the winter (J. Klungers, pers. com.). Of the four species with no data concerning their temperature tolerances is expected that they, because of their southern distributions, are likely to be comparable with those of e.g. *E. evergladei*.

*Table 5.3: Temperature tolerance of the Elassomatidae.*

| Species | tolerance | *references* |
|---|---|---|
| *Elassoma alabamae* | no data | |
| *Elassoma boehlkei* | no data | |
| *Elassoma evergladei* | 12°C -24°C, 10°C - 30°C | Fischarten-Datenblätter Aqua4you, 2010; Riehl& Baensch, 1991 |
| *Elassoma gilberti* | no data | |
| *Elassoma okatie* | no data | |
| *Elassoma okefenokee* | 10°C - 30°C | Baensch & Riehl, 1985 |
| *Elassoma zonatum* | 10°C - 25°C | Baensch & Riehl, 1995 |

### 5.2.2 Habitat availability

The typical habitats of the Elassomatidae, slow flowing and standing waters with dense vegetations, are common in the Netherlands. E.g. habitats occupied by limnophilic species such as the weatherfish (*Misgurnus fossilis*) and Crucian carp (*Carrasius carrasius*) would be suitable for *Elassoma*-species. Like for the already mentioned indigenous species would suitable habitat especially be available in the Holocene parts of the Netherlands, but also in Pleistocene parts suitable habitats are present locally.

### 5.2.3 Conclusion probability of establishment

Although suitable habitats are present it is, based on the data about their temperature tolerance, not likely that any of the *Elassoma*-species would be able to establish populations under natural conditions. Also when possible climate changes are considered these species are unlikely to establish in even 2050, see also 5.1.7.

None of the species belonging to the Elassomatidae will be treated in the forthcoming chapters.

# 6 The probability of spread & endangered areas

None of the centrarchids is known to have anadromous migration, but long-distance exploratory movements are not uncommon and have been recorded in several species.

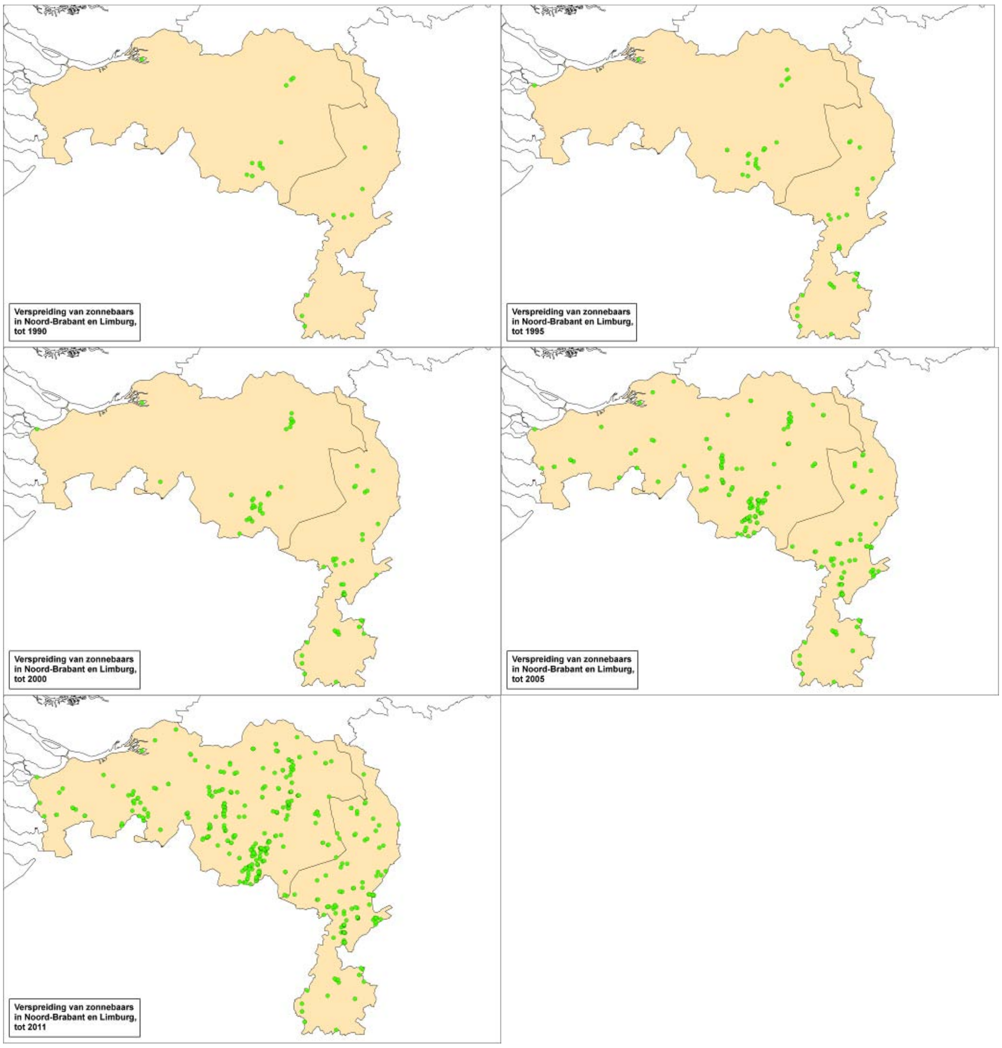
For example, *A. rupestris* movements of >161 km (Funk, 1957; Storr *et al*., 1983) are documented. In rivers in Missouri, tagged individuals of *P. annularis* covered 34-42 km in 21-91 days (Funk, 1957) and others have noted movements of this species up to 30 km (review *in* Hansen, 1951; Siefert, 1969a). Although observed in few individuals, *L. macrochirus* ranged as far as 17 linear km in Tennessee streams. About 20% of successive recaptures were ≥250 m apart over four years (Gatz & Adams, 1994), and in a North Carolina swamp stream *L. macrochirus* moved upto 3.4 km in 33 days (Whitehurst, 1981).

Because of these common movements it is likely that after establishing reasonable populations centrarchids will spread to other regions.

<u>Probability of spread and endangered areas of *Lepomis gibbosus* in the Netherlands</u>
As long as *L. gibbosus* is being sold and/or being kept in garden ponds, new introductions into nature are likely to occur. The high population density in the Netherlands and good infrastructure makes even the most remote water bodies vulnerable for introductions. The species is already present in connected water bodies throughout the country. It has even been recorded from the islands Terschelling and Schiermonnikoog. Via these connected waters it is likely to spread to the rest of the country. I.e. distribution *of L. gibbosus* in the province of Brabant has increased exponentially since 1990 (Unpublished data H. van Kleef, fig. 6.1).

Improvements of stream connectivity for facilitating migration of fish will also result in increased migration opportunities for *L. gibbosus*. Measures taken for meeting targets of the European Water Framework Directive, such as nature development, as well as water retention measures will locally create conditions suitable for large scale reproduction. Therefore, the probability of spread is likely to increase.

However, this does not mean that ecological damage will occur in all colonised waters. Damage by *L. gibbosus* invasions will be largest in water bodies where human disturbance (often nature management measures) have exposed large areas of mineral soil. Examples of high impacted water are: dredged moorland pools and dune slacks, meadow ponds created for amphibians, nature development areas, sand excavation pits and urban waters.




*Figuur 6.1: Distribution Lepomis gibbosus in the south of the Netherlands during five time periods: <1990. < 1995, <2000, <2005 and <2011. Based on data provided by RAVON & Limnodata.*

# 7 Impact

## 7.1 Ecological impact

### 7.1.1 Reported ecological impact of Lepomis gibbosus

*L. gibbosus* is listed among the top ten introduced fish species with adverse ecological effects (Casal, 2006). It is considered a threat for native fish species (Welcomme, 1988) through competition for food and predation on eggs and juveniles. Densities decreases of fish species have been reported to regularly coincide with sharp increases in *L. gibbosus* abundances (Tomoček *et al*., 2007 and literature therein). The species is also held responsible for the locally strong decline and disappearance of endangered amphibians, such as *Pelobates fuscus, Triturus cristatus* and *Hyla arborea* (Bosman, 2003) and dragonflies (Janssen, 2000), including several species covered by Natura 2000.

*Figure 7.1: Common spadefoot (left, Pelobates fuscus) & European tree frog (right, Hyla arborea), species sensitive to L. gibbosus invasion. Photos by Erwin van Maanen.*

When food is limited, larger *L. gibbosus* individuals feed on smaller specimens. Preferred prey are aquatic macro- and microinvertebrates, such as *Daphnia*, Mollusca, Coleoptera, Hemiptera, and Diptera. In a Dutch diet study eleven different prey taxa were found (Van Kleef *et al*., 2008). Densities of these taxa are decimated when *L. gibbosus* is abundant (Osenberg *et al.,* 1992, Van Kleef *et al*., 2008). There are even reports that the mere presence of *L. gibbosus* can negatively influence the behavior, morphology and reproduction of the gastropod *Physa acuta* (Turner & Montgomery, 2003) and the midge *Chironomus tentans* (Ball & Baker, 1996). The impact of feeding by high numbers of *L. gibbosus* can extend outside the aquatic habitat (G.H. Copp, pers. com.). A study on riparian spider assemblages revealed that spider abundance and species richness decreased when *L. gibbosus* was abundant in the local stream. Apparently *L. gibbosus* can sufficiently reduce numbers of hatching stream invertebrates, such as mayflies and stoneflies, and induce food limitation in riparian predator species.

Nest building by male *L. gibbosus* may in theory damage vulnerable vegetation. During a pilot study in the moorland pool "Zwart water" in Flanders (Unpublished data H. van Kleef) demonstrated that nesting activity resulted in the destabilizing of *Littorella uniflora* plants, an endangered species in the Netherlands. However, abundance of *L. gibbosus* was relatively low in this moorland pool and the damage to the vulnerable vegetation was temporary. It is conceivable that at higher densities this kind of damage will be permanent. Furthermore, *L. gibbosus* has been shown to enhance water turbidity and concentrations of phosphorus and nitrogen (Angeler *et al*., 2002). As these substances are important nutrients for plant growth, increased concentrations can lead to shifts in plant species composition and changes in ecosystem functioning.

*Figure 7.2: Littorella uniflora plants. Photo by Dirk Kruijt.*

### 7.1.2 Reported ecological impact of Micropterus salmoides

Adult *M. salmoides* are top predatory fish, which are likely to effect colonized waters mainly by predation and competition with other predatory fish. There are a few reports of impacted populations of amphibians (Gilliland, 2010) and Weyla *et al*. (2010) reported on a shift of the macro invertebrate fauna in South African river towards more smaller, more cryptic/inconspicuous taxa due to predation by introduced *M. salmoides*. The reports on impact on fish populations are much more numerous, some examples are given.

The introduction of *M. salmoides* in two Italian lakes is reported to have severely affected local populations of alborella (*Alburnus alborella*) and also reduced the native predatory fish populations (pike (*Esox lucius*) and European perch (*Perca fluviatilis*)). In another Italian lake the introduction of *M. salmoides* reduced a naturalized population of *L. gibbosus*. Also in South Africa, Japan and Madagascar *M. salmoides* is thought to be responsible for reducing populations of native fish species (Lever, 1996). In Japan the severity of the impact varied with the water depth. In shallower waters the predation was most severe. In deep waters *M. salmoides* achieved a more ecological balanced situation (Nomura & Furuta *in* Lever, 1996). In Mexico introductions of *M. salmoides* are linked to the local extirpation of Cyprinodontidae species (Cooke *et al.,* 2009).

*Figure 7.3: Alborella (left) a species comparable to the in the Netherlands commonly occurring common bleak (right).*

In general, the introduction of *M. salmoides* often leads to the decrease of smaller fish species, in Europe especially small Cyprinidae (Cooke *et al*., 2009). This consumption of large numbers of small-bodied fish, many of which are consumers of plankton, algae and zooplankton, might change ecosystems. Spencer and King (1984) found that ponds with largemouth bass had very low phytoplankton biomass and supported dense populations of submerged macrophytes, while ponds without bass featured intense algal blooms and low zooplankton biomass. Lasenby and Kerr (2000) reported that introductions of largemouth bass into Cuba, resulted in a rise in cases of human malaria attributed to the consumption of native fish species that normally predate upon mosquito larvae.

### 7.1.3 Reported ecological impact of other species

Reported impact of other naturalized populations of centrarchid fishes is comparable with those of *L. gibbosus* and *M. salmoides*. *M. dolomieu* populations on the island of Oahu (Hawaiian Islands) are thought to have eliminated all indigenous fishes and crustaceans in two local streams (Lever, 1996). Both *L. cyanellus* and *L. macrochirus* have a tendency to overpopulate waters into which they are introduced, resulting in stunted populations (Jubb, 1965; Welcomme, 1988). This pattern is comparable with several Dutch populations of *L. gibbosus* and likely to result in the same impact on amphibians and invertebrates.

For the genera *Ambloplites, Centrarchus* and *Enneacanthus* no reports on ecological impact could be found, although *A. ruperstris* has naturalized populations in several countries.

### 7.1.4 Vector of parasites or diseases

In Europe seven species of Monogenea have been recorded from *L. gibbosus* and *M. salmoides*: *Gyrodactylus sp*., *Onchocleidis dispar*, *O. principalis*, *O. similis*, *O. sp*., *Actinocleidus oculatus* and *A. recurvatus*. The origin of the reported unidentified

*Gyrodactylus*-species is unknown. The other four originate from North America and have only been recorded from Centrarchidae (Hoffman, 1999; Galli *et al*., 2007; Sterud & Jorgensen, 2006; Ondrackova *et al*., 2010). These monogenean trematods, which are in general relatively host specific, are the only known North American fish parasites that have been introduced with Centrarchidae in Europe. Because of their host specificity no negative impact on indigenous species is expected.

At least a further 23 parasites have been recorded from European Centrarchidae populations, predominantly from *L. gibbosus* (Table 7.1). All species that could be identified to a sufficient level are common fish parasites that are considered indigenous to the European fauna. For none of these species Centrarchidae should be considered important vectors.

Reports of parasites or diseases introduced outside North America due to the introduction of centrarchid fishes and that are infectious to native species could not be found. So Centrarchidae have so far not proven to be vectors of special concern. This may not account to those countries in Southern Europe that like to sustain healthy populations of *M. salmoides*. These countries are likely to prefer to keep their countries free off largemouth bass virus, see also §3.1.5.

*Table 7.1: European parasites recorded from Lepomis gibbosus in Europe. Based on: Hoffman (1999), Kosuthova et al. (2009), Buriola et al. (2007), Piasecki & Falandysz (1994).*

| | | | |
|---|---|---|---|
| *Eimeria sp.* | Protista | *Acanthocephalus anguillae* | Acanthocephala |
| *Ichthyocotylurus platycephalus* | Trematoda | *Acanthocephalus lucii* | Acanthocephala |
| *Diplostomum sp.* | Trematoda | *Acanthocephala sp.* 1 | Acanthocephala |
| *Tylodelphys clavata* | Trematoda | *Acanthocephala sp.* 2 | Acanthocephala |
| *Bucephalus polymorphus* | Trematoda | *Paracanthocephalus sp.* | Acanthocephala |
| *Bothriocephalus sp.* | Cestoda | *Ergasilus sieboldi* | Copepoda |
| *Triaenophorus nodulosus* | Cestoda | *Neoergasilus japonicus* | Copepoda |
| *Valipora campylancristrota* | Cestoda | *Caligus lacustris* | Copepoda |
| *Proteocephalus percae* | Cestoda | *Lerneae cyprinacea* | Copepoda |
| *Camallanus lacustris* | Nematoda | *Argulus foliaceus* | Argulidae |
| *Contracaecum sp.* | Nematoda | *Unio sp.* | Bivalvia |
| *Schulmanela petruschewskii* | Nematoda | | |
| *Capillaria eupomotis* | Nematoda | | |

## 7.2 Economic and social impact

Angling is a popular leisure activity in the Netherlands of reasonable economical value (Smit *et al*., 2004). Species such as *M. salmoides* are valued for their angling possibilities. Exploitable populations will certainly be appreciated and have a small positive economic and social impact to the angling society and business.

Large bass species are appreciated for consumption. Populations of reasonable size of such species would be profitable for commercial fisheries, comparable with e.g. the pike perch. A small positive economic and social impact to the fishery industry might be possible.

## 7.3 Conclusions impact

Centrarchidae mainly effect ecosystems by predation (amphibians, smaller fish species, invertebrates, etc.) and competition with other predatory fish. Especially ecosystems, which prior to the establishment of an exotic centrarchid were lacking comparable predatory fish, are susceptible to significant ecological impact.

Centrarchidae have not been reported to be vectors of parasites or diseases of special concern. Countries that wish to sustain healthy populations of *M. salmoides* are likely to prefer to keep their countries free off largemouth bass virus.

Establishment of larger centrarchid species will have a small, positive social and economic impact to commercial fisheries, the angling society and related business.

# 8 Risk identification conform the Fisk method

The threats posed by introduced species have led to the need to develop policies to minimize the risk. For the development of such policies standardized and clear assessment tools are of great importance. One of the available tools is the Fish Invasiveness Screening Kit (FISK), which has already been applied in the U.K., Belgium and Balearus (Copp *et al*., 2005; Copp *et al*., 2009, Mastitsky *et al*., 2010; Verreycken *et al*., 2010). The results of this method are presented in figure 8.1 (page 80).

*L. cyanellus, L. macrochirus, L. gibbosus*, *M. dolomieu, M. salmoides, P. annularis* and *P. nigromaculatus* are according to the FISK assessment species that are lickely to establish in the Netherlands and to have negative effects om local fauna (“reject”).

*A. rupestris* scores relatively low as it is not a desired species in aquaculture, angling or aquaristics and because of the lack of information on its possible impact. *L. auritus* scores relative low as its climate tolerances are not covered by the Dutch climate in the present situation and because of the absence of information on its possible impact. Lastly *L. megalotis s.l.* also scores low because of of the absence of information on its possible impact.

| | Fish Invasiveness Scoring Kit (G.H. Copp, R. Garthwaite & R.E. Gozlan) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Latin name:** | *Ambloplites rupestris* | *Lepomis auritus* | ***Lepomis cyanellus*** | ***Lepomis macrochirus*** | *Lepomis megalotis* | ***Lepomis gibbosus*** | ***Micropterus dolomieu*** | ***Micropterus salmoides*** | ***Pomoxis annularis*** | ***Pomoxis nigromaculatus*** |
| 1 | 1,01 | Is the species highly domesticated or cultivated for commercial, angling or ornamental purpose | N | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 2 | 1,02 | Has the species become naturalised where introduced? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 3 | 1,03 | Does the species have invasive races/varieties/sub-species? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 4 | 2,01 | Is species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-interr | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 5 | 2,02 | What is the quality of the climate match data (1-low; 2-intermediate; 3-high)? | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 6 | 2,03 | Does the species have broad climate suitability (environmental versatility)? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 7 | 2,04 | Is the species native to, or naturalised in, regions with equable climates to the risk assessment | Y | N | N | N | N | Y | Y | Y | Y | Y |
| 8 | 2,05 | Does the species have a history of introductions outside its natural range? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 9 | 3,01 | Has the species naturalised (established viable populations) beyond its native range? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 10 | 3,02 | In the species' naturalised range, are there impacts to wild stocks of angling or commercial spe | ? | ? | Y | Y | ? | Y | Y | Y | Y | Y |
| 11 | 3,03 | In the species' naturalised range, are there impacts to aquacultural, aquarium or ornamental sp | ? | ? | Y | Y | ? | N | Y | Y | Y | Y |
| 12 | 3,04 | In the species' naturalised range, are there impacts to rivers, lakes or amenity values? | ? | ? | Y | ? | ? | Y | Y | Y | ? | ? |
| 13 | 3,05 | Does the species have invasive congeners? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 14 | 4,01 | Is the species poisonous, or poses other risks to human health? | N | N | N | N | N | N | N | N | N | N |
| 15 | 4,02 | Does the species out-compete with native species? | ? | ? | ? | ? | ? | Y | ? | Y | Y | Y |
| 16 | 4,03 | Is the species parasitic of other species? | N | N | N | N | N | N | N | N | N | N |
| 17 | 4,04 | Is the species unpalatable to, or lacking, natural predators? | N | N | N | N | N | N | N | N | N | N |
| 18 | 4,05 | Does species prey on a native species (e.g. previously subjected to low (or no) predation)? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 19 | 4,06 | Does the species host, and/or is it a vector, for recognised pests and pathogens, especially non | N | N | N | N | N | N | N | N | N | N |
| 20 | 4,07 | Does the species achieve a large ultimate body size (i.e. > 10 cm FL) (more likely to be abando | Y | N | Y | N | N | N | Y | Y | Y | Y |
| 21 | 4,08 | Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle? | N | N | Y | Y | ? | N | N | N | Y | Y |
| 22 | 4,09 | Is the species desiccation tolerant at some stage of its life cycle? | N | N | N | N | N | N | N | N | N | N |
| 23 | 4,10 | Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use) | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 24 | 4,11 | Does feeding or other behaviours of the species reduce habitat quality for native species? | ? | ? | ? | ? | ? | Y | Y | Y | ? | ? |
| 25 | 4,12 | Does the species require minimum population size to maintain a viable population? | ? | Y | ? | ? | ? | ? | ? | ? | ? | ? |
| 26 | 5,01 | Is the species a piscivorous or voracious predator (e.g. of native species not adapted to a top p | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 27 | 5,02 | Is the species omnivorous? | N | N | N | N | N | N | N | N | N | N |
| 28 | 5,03 | Is the species planktivorous? | Y | Y | Y | Y | Y | Y | N | N | Y | Y |
| 29 | 5,04 | Is the species benthivorous? | Y | Y | Y | Y | Y | Y | Y | N | Y | Y |
| 30 | 6,01 | Does it exhibit parental care and/or is it known to reduce age-at-maturity in response to enviro | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 31 | 6,02 | Does the species produce viable gametes? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 32 | 6,03 | Does the species hybridize naturally with native species (or uses males of native species to acti | N | N | N | N | N | N | N | N | N | N |
| 33 | 6,04 | Is the species hermaphroditic? | N | N | N | N | N | N | N | N | N | N |
| 34 | 6,05 | Is the species dependent on presence of another species (or specific habitat features) to comple | N | N | N | N | N | Y | N | N | N | N |
| 35 | 6,06 | Is the species highly fecund (>10,000 eggs/kg), iteropatric or have an extended spawning seas | N | N | N | N | N | Y | N | N | N | N |
| 36 | 6,07 | What is the species' known minimum generation time (in years)? | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 2 |
| 37 | 7,01 | Are life stages likely to be dispersed unintentionally? | N | N | N | N | N | Y | N | N | N | N |
| 38 | 7,02 | Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant n | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 39 | 7,03 | Are life stages likely to be dispersed as a contaminant of commodities? | N | N | N | N | N | N | N | N | N | N |
| 40 | 7,04 | Does natural dispersal occur as a function of egg dispersal? | N | N | N | N | N | N | N | N | N | N |
| 41 | 7,05 | Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping s | N | N | N | N | N | N | N | N | N | N |
| 42 | 7,06 | Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 43 | 7,07 | Are eggs of the species known to be dispersed by other animals (externally)? | N | N | N | N | N | N | N | N | N | N |
| 44 | 7,08 | Is dispersal of the species density dependent? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 45 | 8,01 | Any life stages likely to survive out of water transport? | N | N | N | N | N | N | N | N | N | N |
| 46 | 8,02 | Does the species tolerate a wide range of water quality conditions, especially oxygen depletion | Y | ? | Y | Y | Y | Y | N | Y | Y | Y |
| 47 | 8,03 | Is the species susceptible to piscicides? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 48 | 8,04 | Does the species tolerate or benefit from environmental disturbance? | ? | ? | ? | ? | ? | Y | N | N | ? | ? |
| 49 | 8,05 | Are there effective natural enemies of the species present in the risk assessment area? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| | | **Outcome:** | Evaluate | Evaluate | Reject | Reject | Evaluate | Reject | Reject | Reject | Reject | Reject |
| | | **Score:** | 13 | 12 | 26 | 23 | 16 | 28 | 23 | 25 | 25 | 25 |
| | | **Biogeography** | 6 | 6 | 17 | 15 | 9 | 15 | 20 | 20 | 16 | 16 |
| | | **Score partition:** **Undesirable attributes** | 3 | 2 | 4 | 3 | 2 | 4 | 4 | 5 | 5 | 5 |
| | | **Biology/ecology** | 4 | 4 | 5 | 5 | 5 | 9 | -1 | 0 | 4 | 4 |
| | | **Biogeography** | 8 | 10 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | | **Questions answered:** **Undesirable attributes** | 9 | 10 | 9 | 9 | 8 | 11 | 10 | 11 | 10 | 10 |
| | | **Biology/ecology** | 23 | 22 | 23 | 23 | 23 | 24 | 24 | 24 | 23 | 23 |
| | | **Total** | 40 | 42 | 41 | 42 | 41 | 45 | 44 | 45 | 43 | 43 |

*Figure 8.1: Results of the FISK assessments of ten species of Centrarchidae.*

# 9 Risk Management

## 9.1 Prevention of entry and spread

Obviously, the prevention of fish entries and further spread saves problems. Prevention seems a straightforward tool to impede further expansion of *L. gibbosus* but, considering the diversity of the (un)intentional trade in ornamental fish, the actual implementation can be rather complicated. Different types of prevention act on different levels within an introduction pathway. Prevention consists of communication and legislation if one considers the sources of fish: the international trade. Education is the prime tool for preventing deliberate introductions. Several prevention procedures are discussed here, based on the different sources and motives that were identified in chapter 4.

<u>Pet trade</u>

Banning species from trade can be achieved either by legislation or by means of an agreement with the pet trade. Both legislation and agreements have certain (dis)advantages. The advantage of legislation is its stringent implication: all traders must commit to it. The disadvantage of legislation is that it can be a difficult and long lasting procedure to implement by law. Additionally, juridical conflicts with international trade agreements have previously shown to be a serious obstacle for legislation. Finally, if a broad social basis for legislation is lacking, the number of illegal trades might increase significantly.

The effectiveness of an agreement highly depends on the number of joining traders and the availability of alternative resourses (i.e. other species) for the company. The advantage of an agreement is that an agreement can be relatively easily achieved. The disadvantage is its informal status, creating profitable opportunities for companies who do not want to commit themselves to the agreement.

Both legislation and covenants use lists of species. Lists can be either positive or negative. A positive list summarizes the species, which are allowed in trade. A negative list lists the species, which are not allowed. Nowadays, the trade in ornamental fish is the second most important source of new and recently established fish species. During inquiries among wholesalers for this study, we experienced some willingness to support a possible agreement or a call for a ban of certain species. This commitment can be partly explained by the fact that so many species are involved in the ornamental fish trade. A few banned species will not harm any pet company, since many alternative freshwater fish are left to trade in. However, the difficulty with the large number of traded species is that its hard to formulate species lists. It is impossible to access the possible effects of all species that might show up in the trade. Due to the continuous request for ‘something new’, a large number of species is to be expected in near the future. In other words a ‘complete’ positive species list is hard to assemble. A (motivated) negative species seems a better applicable starting point for an agreement with the aquarium trade.

In table 9.1, proposals for negative species lists are given. A drawback of such species lists is the increased risk of the import of wrongly identified specimens. Using a list which is mainly based on genera would overcome this problem. A proposal for a genera list is also given in table 9.1.

For comparison the UK list of species covered by the “The Prohibition of Keeping or Release of Live Fish (Specified Species) Order 1998, made under the Import of Live Fish (England and Wales) Act 1980” is checked for centrarchid species. According to this list all centrarchids are actually included: “sunfish (including pumpkinseed, basses, crappies and bluegills”. This legislation is considered effective in keeping new species out for the most part but less effective for ensuring that existing non-native species don't get into the wild due to human releases (G. Copp, pers. com.).

*Table 9.1. Possible negative species lists.*
*A = List of species known to be invasive in the Netherlands, B = List of species known to be invasive in Europe, C = List of suspected species, D = List of genera including suspected species*

| A | B | C | D |
|---|---|---|---|
| *Lepomis gibbosus* | *Ambloplites rupestris* | *Ambloplites rupestris* | *Ambloplites* |
| | *Lepomis gibbosus* | *Lepomis auritus* | *Lepomis* |
| | *Micropterus salmoides* | *Lepomis cyanellus* | *Micropterus* |
| | | *Lepomis gibbosus* | *Pomoxis* |
| | | *Lepomis megalotis* | |
| | | *Lepomis macrochirus* | |
| | | *Lepomis peltastes* | |
| | | *Micropterus dolomieu* | |
| | | *Micropterus salmoides* | |
| | | *Pomoxis annularis* | |
| | | *Pomoxis nigromaculatus* | |

Deliberate releases

The motives underlying ornamental fish introductions have been identified (see chapter 4) such as a lack of interest, overcrowding of ponds or dislike because of aggressive behavior towards other, more appreciated fish species. In all cases, education is the only possible remedy for reducing the amount of such introductions. Addressed campaigns are needed to reach potential ‘releasers’. Pet stores and garden shops can play a role in the preventing the release of ornamental fish. A drawback of public education is that it is hard to maintain. Without active maintenance, the effects of education will quickly fade away.

A possibility for providing good information is including an information leaflet (huisdierenbijsluiter) when e.g. *L. gibbosus* is actually purchased. Information leaflets have already been provided digitally for many species by the Landelijk InformatieCentum Gezelschapsdieren (LICG, www.licg.nl)). For *L. gibbosus* or other centrarchids they are not yet available. Such an information leaflet could clearly describe the negative impact of introductions and the legal aspects of doing so.

## Verkoop zonnebaars stopt

*Bericht uitgegeven door Stichting RAVON op zondag 1 augustus 2010*

**De grootste distributeur van aquarium- en vijverproducten in Nederland heeft het besluit genomen te stoppen met de verkoop van zonnebaarzen. Een belangrijke stap in de ongewenste verspreiding van deze exoot, die in veel geïsoleerde kleine wateren in ons land een ernstige bedreiging vormt voor inheemse amfibieën en andere fauna en flora.**

Aquadistri voelt als importeur en leverancier van vijverproducten een grote maatschappelijke verantwoordelijkheid en heeft derhalve besloten ter bescherming en behoud van onze inheemse flora en fauna de verkoop van zonnebaarzen per direct te staken.

Zonnebaars (foto: Arnold van Rijsewijk) & Knoflookpad (foto: Wilbert Bosman)

Al in 2003 hield RAVON een stevig pleidooi om de verkoop van de zonnebaars te stoppen. Zij schreef hiertoe alle tuin- en aquariumcentra aan met de vraag deze vis uit het assortiment te nemen. Nu heeft dit mede geleid tot het besluit van Aquadistri om te stoppen met de verkoop van de zonnebaars in Nederland. RAVON is zeer verheugd over deze verantwoordelijke beslissing van Aquadistri.

De zonnebaars, een oorspronkelijk uit Noord-Amerika afkomstige vis, is jarenlang als vijver- en aquariumvis verkocht. De vis heeft een zeer interessant broedgedrag. Eenmaal in een vijver of aquarium beland, plant ze zich zeer voortvarend voort. Dit leidt al in korte tijd tot overbevolking. Het overschot wordt vaak in geïsoleerde wateren als vennen, poelen en kolken vrijgelaten. De zonnebaars komt nu overal in Nederland voor. Onder gunstige omstandigheden is de vis ook in de vrije natuur in staat zich in rap tempo voort te planten met desastreuze gevolgen voor de inheemse fauna. De zonnebaars is weinig specifiek in zijn voedselvoorkeur en heeft nauwelijks natuurlijke vijanden. Voor onze inheemse planten en dieren kan de vis een ernstige bedreiging vormen. In Noord-Brabant verdween bijvoorbeeld één van de vier vindplaatsen van de knoflookpad door toedoen van de zonnebaars.

Creating insight in ornamental fish trade

During the preparation of the report it became clear that information on the actually imported ornamental fish species is almost impossible to obtain. A ‘hazardous’ species like the Amur sleeper (*Perccottus glenii*) has actually been imported but this is unlikely to have been registered and known to the VWA. Such information is invaluable for the management of invasive species. Also to e.g. monitor the responses ot the pet trade when *L. gibbosus* is banned from trade.

Creating insight in stocking practices

For creating an effective policy on stocking of fish in general and Centrarchids in particularly, information about the species and the numbers stocked in public waters are an important prerequisite. Even an organization such as Sportvisserij Nederland seems to lack such information currently (Soes & Broeckx, 2010).

Making it obligatory to report beforehand any stockings to a central, independent organization (such as ‘Visstandbeheerscommissies’) could create better insight in stocking practices. This may not only serve policies on exotic species, but may have an even greater use in fish disease prevention.

In the case of Centrarchids this would be profitable as illegal stockings of e.g. *Micropterus salmoides*, which might be planned by people who are ignorant of the fact that it is illegal to stock this species in public waters, can be prevented. The chance of such illegal introductions are real as Prussian carp (*Carassius gibelio*) has actually illegally been stocked for several years (W. Emmerik, Sportvisserij Nederland, pers. com.). This due to just not knowing that it was illegal. After 1 July 2010 legislation changed and it has become legal to stock *C. gibbelio*.

Preventing escapes from fish farms, garden ponds, etc.

It is permitted to keep Centrarchid fish species on private properties. But it is regulated in both the Flora- and fauna law and the Fisheries law that such waters should be isolated from public water systems in such a way that escapes are prevented. These laws also apply to fish farms.

So called fish screens are easy to install and relatively cheap. Fish screens will prevent larger fish from escaping. Screens are in general ineffective for the prevention of escapes of fry and small juveniles. Fish screens that might prevent even fry and small juveniles from escaping need a too fine mesh size, making them very laborious to maintain their functionality.

Preferably fry and small juveniles in fish farms are kept in so called recirculation systems and have no open connections with streams. Such systems can even be provided with UV-treatment killing all organisms such as fry.

Another possibility is a “sock” screen or the like fitted in the entrance of the outlet pipe to prevent escape of even the smallest fishes from the pond or tank.

Preventing colonization of isolated waters

*L. gibbosus* is present in low to high numbers in many Dutch streams. When such streams during a flood come in to contact with e.g. ponds colonization of such normally isolated waters can take place. Ponds are considered of great importance to sustain populations of endangered amphibians such as the spadefoot toad. When planning new ponds, the chance of flooding should be minimized beforehand.

## 9.2 Eradication and physical control methods

In countries where exotic species have established populations researchers have experimented with a variety of physical controls to eradicate or reduce such populations. The following control methods have been applied to reduce or eradicate established populations of exotic fishes and might be applicable to Centrarchids. With *L. gibbosus* being the only established species yet the treatment of the methods will focus on this species.

Eradication by piscicides

One of the possibilities for eradicating unwanted fish populations is the use of pesticides, which are more or less selective for fish: piscicides. Of these piscicides only rotenone has proven itself well enough to be reliable in its application (Clearwater *et al*., 2008) and extensive manuals and risk assessments are available for this piscicide (e.g. Finlayson *et al*., 2000; Turner *et al*., 2007).

Rotenone is a natural toxin that can be obtained from several tropical Leguminosae species and has been used for centuries as a selective fish poison and more recently as a commercial insecticide (Ling, 2003). It is highly toxic to fish, larvae of amphibians and other aquatic life, but has low toxicity to adult amphibians, birds and mammals. Also fish eggs are Mangum & Madrigal (1999) reported large scale rotenone treatment in the Strawberry Reservoir and River in Utah. They found that 21% of the invertebrate taxa were still missing after five years. Such outcomes are strongly influenced by recolonization possibilities, a factor that should be carefully assessed beforehand when the use of rotenone is considered.

Rotenone is non-persistent in the environment, being quickly broken down by light and heat. It does not accumulate in animals and is readily metabolised and excreted. Rotenone persistence in natural waters varies from a few days to several weeks depending on the season. The half-life of rotenone is longest in winter but may decrease to as little as a few hours in summer.

In recent years, rotenone has more often been used to remove pest or non-native fishes to allow recovery of indigenous stocks or for research on fish population structure and abundance (Bettoli & Maceina 1996). Rotenone has been used successfully to eliminate exotic trout in Australia (Sanger & Koehn 1997; Lintermans 2000) and to eradicate limited populations of European carp and mosquito fish

(Sanger & Koehn 1997). Eradication of fish with rotenone has variable success depending on the type of environment and the amount of effort expended in achieving complete dispersal of the toxicant throughout the lake or drainage. Effectiveness of treatment decreases as water bodies and catchments increase in size. Dispersing toxicant in marginal zones with abundant plant growth can also present practical difficulties. Complete coverage is sometimes difficult to achieve, and because of the rapid loss of rotenone in such areas through chemical decay and adsorption to plants and sediment, fish may find refuge long enough to evade poisoning.

In the Netherlands rotenone has at least in more recent times not been applied to eradicate fish populations. Rotenone is currently unlikely to be used because of the general negative attitude in water management towards pesticides, concerns about animal welfare and the lack of regional eradication projects using rotenone.

<u>Eradication by fishing</u>
Fishing is an often proposed solution for *L. gibbosus* invasions. However, there is very little experience with actively catching *L. gibbosus* in order to eradicate entire populations. To our knowledge only four attempts have been made in the Netherlands (Table 9.2). Two attempts were successful. Removal by dipnet fishing in a small moorland pool (2 acres) near Uden was successful according to a local herpetologist. Removal by fishing in the Rauwven was successful because removal was combined with pumping and partial filling of the moorland pool with sand in order to increase the frequency of drying up.

Invasive *L. gibbosus* populations are often subject to density dependent regulation of juvenile growth, fecundity and reproductive success. This mechanism which is the result of intraspecific competition disappears when a large part of the population is removed. Lifting density dependant regulation results in a increased reproductive success and a quick recovery of nearly-eradicated populations. So, eradication by fishing (or other means) should be done completely or is a temporary solution and requires a recurring effort.

One might also consider *L. gibbosus* control by removing part of the population on a yearly or bi-yearly basis. Although, the species would not be locally eradicated, its numbers would be suppressed and ecological damage reduced. If yearly fishing is a management option then using funnel traps could be considered. These traps are being used by researchers and are very effective in catching age 2 and older pumpkinseed (Fox & Keast 1990, Fox 1994).

*Table 9.2: Eradication attempts of L. gibbosus.*

| Location | Method | Result |
|---|---|---|
| Nameless moorland pool near Uden | Dipnet fishing | positive |
| Rauwven (2002) | Draining<br>Dipnet fishing | negative |
| Rauwven (2003) | Draining<br>Dipnet fishing<br>Seine fishing<br>Reducing depth | positive |
| Schaoppedobbe | Electric fishing<br>Dipnet fishing | negative |

Forbidding release of captured fish by recreational fishermen

Although physical control methods via commercial and recreational fishing are not considered the most successful ones, they are often the only possibility (Thresher, 1997). In Australia it is forbidden by law to release caught carp (*Cyprinus carpio*). The carp is an exotic fish species in Australia and considered harmful (Graham *et al*., 2005).

A survey in New South Wales found that even with the mentioned legislation about 11% of carp were released after capture by recreational fishermen (Graham *et al*., 2005). These recreational fishermen probably released their caught carp for ethical reasons. Australian internet forums clearly showed a lot of debate on the necessity of killing captured carp. Especially inexperienced fishermen causing considerable animal suffering are considered a problem (D.M. Soes, pers. obser.).

In the Netherlands *L. gibbosus* is not a appreciated game fishes. But the catch and release of coarse and game fishes have been much promoted and the killing of fish, even for consumption, is becoming extremely rare. This gives little ground for installing legislation or policy, which involves the killing of fish such as *L. gibbosus*. Also a discussion during a recent meeting of the Vissennetwerk (3-6-2010) clearly showed that such legislation or policy would receive little support.

Dewatering

Although *L. gibbosus* is able to temporarily survive in moist sediments, it still needs water to survive. Draining and temporary drying up of the water body may in some cases (depending on local conditions) be an efficient eradication method.

Some ecosystems, like moorland pools, are known to occasionally dry up. The organisms living in these waters are adapted to or even depend on dry periods. In these systems it may be possible to increase the frequency of drying up. This was done in the Rauwven where bottom depth was decreased by filling the deepest part of the pool with sand.

Introduction of predators

In its native area *L. gibbosus* is being consumed by *M. salmoides* (Godinho *et al*. 1997). However introducing *M. salmoides* does not seem to be a viable option for *L. gibbosus* control as *L. gibbosus* is not the preferred prey in European waters. In a Spanish lake where both species occur, *M. salmoides* was found to prey mainly on more palatable native species (Garcia-Berthou, 2002).

Introduction of native piscivorous species may be a feasible option given the right circumstances. Species such as wels catfish (*Silurus glanis*) and Northern pike (*Esox lucius*) are known to eat *L. gibbosus* (Tomecek *et al.,* 2007). Recent Dutch research on environmental factors influencing *L. gibbosus* densities, revealed a negative correlation between *L. gibbosus* numbers and predator density (unpublished data H. van Kleef). Hence, introduction of predator fish and *E. lucius* especially, may to be a viable method of *L. gibbosus* control. However, experience with this method is still lacking and thus data on its effectiveness and possible detrimental effects on native biota are absent.

Isolation of reproduction sites

*L. gibbosus* preferably reproduces on mineral sediments like gravel and sand (Danylchuk & Fox, 1996) in standing waters. On organic sediments the survival of eggs is presumably low. This is one of the reasons why *L. gibbosus* is able to reach high numbers in managed water bodies, where mineral soils have become exposed. However, the availability of optimal reproduction sites is often limited. Many populations of *L. gibbosus* in stream valleys or otherwise hydrologically connected water systems are being fed by migrating fish from small reproduction sites. By disconnecting these reproduction sites from the network, propagule pressure decreases and eventually densities are likely to decrease. Isolation of reproduction sites probably is an efficient method to decrease ecological damage in areas with high native natural values.

Filling ponds

Small meadow ponds are an important habitat for *L. gibbosus* in the Netherlands (Van Kleef *et al*., 2008). Trying to catch all the fish is unlikely to be successful. Instead it may be more effective and cost efficient to dig a new pond nearby and dump the soil in the invaded pond.

Experimental methods

With the exception of actively catching fish, experience with the above mentioned eradication and control methods is lacking. As a result it is unclear to what extent the methods are effective in regulating *L. gibbosus* densities. Furthermore, it is unknown how these methods affect other organisms and how these compare to the detrimental effects of *L. gibbosus* invasions. To improve efficiency of control methods, they should be properly evaluated by monitoring and the results should be communicated with the water management.

# 10 Conclusions

**Conclusions probability of entry**
At least six species of Centrarchidae have been encountered in the Dutch pet trade and a further ten species are available in North America for export to e.g. the Netherlands.

**Conclusions probability of establishment**
Given our analysis, ten species are considered to have a high probability of establishment based on their thermal biology: *A. rupestris, P. annularis, P. nigromaculatus, L. cyanellus, L. gibbosus, L. macrochirus, L. megalotis s.l. (L. megalotis s.s.* & *L. peltastes), M. dolomieu* & *M. salmoides*. These species are flexible in the occupied habitats and are all likely to find suitable habitats in the most regions in the Netherlands.

When considering possible climate change in the period 1990-2050 those species that are considered medium (*L. auritus, L. humilis* and *L. gulosus*) need to be adjusted to high.

The family Elassomatidae, which is also considered as they might be a potential substitute for centrarchids in trade, is considered to be of no risk as they are unlikely to survive Dutch winters.

**Conclusions probability of further spread & endangered areas**
All centrarchid species with a high probability of establishment are known to be good dispersers, making it likely that they will spread relatively easily after establishing reasonable populations.

**Conclusions impacts**
Centrarchidae mainly effect ecosystems by predation (amphibians, smaller fish species, damselflies, etc.) and competition with other predatory fish. Especially in ecosystems, which lack prior to the establishment of an exotic centrarchid comparable predatory fish are susceptible to significant ecological impact. Centrarchidae have not been reported to be vectors for parasites or diseases of special concern. Countries that wish to sustain healthy populations of *M. salmoides* are likely to prefer to keep their countries free of largemouth bass virus.

Establishment of larger centrarchid species will have a small, positive social and economic impact to commercial fisheries, the angling society and related business.

**Conclusions risk management**
When established, centrarchid populations can in most instances only be eradicated with rigorous measurements like dewatering or the use of piscicides. Obviously, the prevention of entries and further spread saves such problems. The major components of such prevention are banning potential invasive species from trade and educating

the public about when such centrarchids are actually obtained for e.g. aquaria, garden ponds or fish ponds.

# 11 Literature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**Bureau Waardenburg bv**
Adviseurs voor ecologie & milieu
Postbus 365, 4100 AJ Culemborg
Telefoon 0345-512710, Fax 0345-519849
E-mail info@buwa.nl, www.buwa.nl