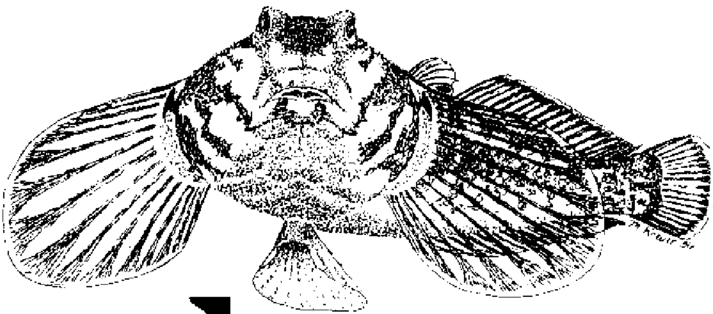

# The Round Goby

*Neogobius melanostomus* (Pallas)

## *A Review of European and North American Literature*

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# The Round Goby, *Neogobius melanostomus* (Pallas),

**A Review of European and North American Literature**

**includes:**

**— abstracts from the Round Goby Conference***
**— summary of roundtable discussion on research needs**
**— summary of roundtable discussion on outreach needs**
**— examples of outreach materials**

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## INTRODUCTION

When a nonindigenous species becomes established in a new area, the scientific community often is asked to predict potential ecological effects and range expansion of the species. In order to make these predictions, scientists must have basic biological information on the organism. This document provides the scientific community with basic biological information on the round goby, *Neogobius melanostomus* (Pallas), which entered North America in 1990. We have reviewed the currently available European and North American literature and compiled a comprehensive bibliography of goby literature, including annotations and abstracts. We also have included a listing and examples of outreach materials available on the round goby. We have not attempted to evaluate the material. Obvious typographical errors (e.g., misspellings) in the published abstracts have been corrected.

Several gaps exist in the available information, especially in areas of particular interest to researchers and managers concerned about the impact of the round goby in North America. Few data are available on optimal sampling methods other than verbal reports from various investigators (but see Steingraeber et al. 1996), and no studies have investigated methods for controlling dispersal or population growth. Data on population densities are variable due to differences in and problems with sampling methods. Reported maximum densities should therefore be treated with caution. Further research on the round goby is needed before the scientific community can reliably predict its rate and degree of range expansion, its ecological or socioeconomic impacts, and its most probable vectors of spread.

This document was stimulated by the Round Goby Conference, which was held in Chicago in February 1996. Many of the data presented at the conference were preliminary, and therefore were not incorporated into the text. However, we have included the conference abstracts as an appendix. Summaries of conference discussions on research and outreach priorities also are included.

Throughout the document, the terms "goby" and "gobies" refer to the round goby except in the "Biology of the Gobiidae" section and in the Annotated Bibliography. We use the terms "fry" and "juvenile" to distinguish between newly hatched and larger, but sexually immature life stages (see "Development" section). Three terms were encountered in the European literature that deserve definition: 1) *centner* = 100 kg (used in commercial fisheries and fisheries assessment); 2) *girlo* = strait or arm of a large river flowing into an inland sea; and 3) *liman* = an estuary. Whenever possible, we have tried to include original citations, but secondary citations are used when necessary.

## BIOLOGY OF GOBIIDAE

The round goby is in the family Gobiidae and order Perciformes. Gobiidae is the second largest teleost family after Cyprinidae, and contains approximately 212 genera and 1,875 species (Nelson 1994). Eleotridae (sleepers) is sometimes grouped under the family Gobiidae. Most species have fused pelvic fins that form a suction disc with weak adhesion. The dorsal fin, when present, is spiny with 2-8 flexible spines, and is separate from the soft dorsal fin. An external lateral line on the body is usually absent. Scales can be cycloid or ctenoid and are occasionally absent. The maximum length of gobies is 50 cm (TL), but the majority of species are less than 30 cm. The family includes the smallest vertebrate species, *Trimmatom nanus*, which grows to only 8-10 mm. The family is distributed worldwide in both salt and freshwater habitats, but the majority of species are found in subtropical to tropical marine habitats. Sixty-eight species of Gobiidae are native to the Atlantic and Pacific coasts of North America, and 10 enter fresh water (Jude et al. 1992).

The family Gobiidae is characterized by species with tolerances for extremely diverse environmental conditions. *Gillichthys miriabilis* is highly tolerant of hypoxia and is one of the most widely euryhaline fish species. This species gulps air and conducts respiratory exchange within the buccopharynx (mouth and throat). The mudskippers (*Boleophthalmus*, *Periophthalmus*, and *Periophthalmodon*) are semiterrestrial, and can spend several days out of water (Nelson 1994). Gobies also have diverse reproductive strategies including simultaneous and sequential hermaphroditism, and abbreviated and protracted iteroparity. Elaborate courtships and male displays are common. Many species are sexually dimorphic. Males may be larger than females and have different coloration that becomes intensified during the spawning season. All species lay benthic eggs attached to substrata. Some species nest in reed stems or marine worm tubes. Males usually protect the eggs. Several species have commensal relationships with other organisms such as sea urchins, sponges, corals, and burrowing crustaceans (Nelson 1994).

The subfamily Goibionellinae (Nelson 1994), previously labeled Benthophilinae (Nikol'skii 1954), is mostly confined to the Caspian and Black seas and the Sea of Azov. This subfamily evolved with changes in salinity of the seas and therefore contains members adapted for freshwater. No species in this subfamily lives in water with oceanic salinity (but see Moskal'kova 1996). Fry of this subfamily are not pelagic. Goibionellinae evolved within landlocked reservoirs, thus pelagic fry are not needed for dispersal. As denoted by their former name, Benthophilinae, these fish are primarily benthic and therefore do not have a swim bladder (Nikol'skii 1954).

## TAXONOMY

| | |
|---|---|
| **Phylum** | Chordata |
| **Class** | Actinopterygii |
| Subclass | Chrondrostei |
| Superorder | Acanthopterygii |
| **Order** | Perciformes |
| Suborder | Gobioidei |
| **Family** | Gobiidae (gobies) |
| Subfamily | Goibionellinae |
| **Genus** | *Neogobius* |
| **Species** | *melanostomus* (Pallas) |

Fossils indicate that members of the suborder Gobioidei have existed since the Eocene epoch. These fish usually lack a swim bladder and have weak dorsal fins. Gobioidei is phylogenetically related to Percoidei. Nikol'skii (1954) states that there are three families within the suborder Gobioidei, although American authors list as many as seven (Nelson 1994).

The genus *Neogobius* was originally a subgenus under *Gobius* (proposed by Il'in 1927), but was elevated to genus by Berg (1949). The new genus *Neogobius* included species in the subgenera *Apollonia*, *Ponticola*, *Chasar*, and *Eichwaldia*. Pinchuk (1992) added the subgenus *Babka* to *Neogobius*. Previous names for the round goby include *Gobius melanostomus* and *Gobius (Apollonia) melanostomus* (Berg 1949). Berg (1949) also lists the Caspian goby *N. m. affinis* (Eichwald) as a separate subspecies, but this appears to have been subsequently combined with *N. melanostomus*. Separation of the two subspecies was based partially on fewer transverse rows of scales in the Caspian goby than found on the Azov-Black Sea goby (*N. melanostomus*) (Tsyplakov 1974). Based on results of electrophoretic studies, Dobrovolov et al. (1995) suggested a rearrangement of Gobiidae that moved *N. melanostomus* to *Apollonia (Neogobius) melanostomus*.

Various sources list the following species within the genus *Neogobius*; we have not attempted to resolve or discuss differences among sources: *N.* (*Chasar*) *bathybius*, *N.* (*Eichwaldia*) *caspius* (Caspian goby), *N. cephalarges* (mushroom or ginger goby), *N. cephalargoides*, *N. fluviatilis* (Pallas) (monkey goby), *N.* (*Babka*) *gymnotrachelus* (Kessler) (toad goby - usually placed in *Mesogobius*), *N. kessleri* (Gunther) (bighead goby), *N.* (*Apollonia*) *melanostomus*, *N. ophiocephalus*, *N. platyrostris* (Pallas), *N. ratan* (ratan goby), and *N. syrman* (syrman, or syrman goby). Pinchuk (1970) reported a hybrid between *N. melanostomus* and *N. fluviatilis*.

Common names of *N. melanostomus* include: round goby, Caspian goby, kruglyak goby, Azov goby, black spotted goby [English]; kruglyak, bychok-kruglyak, bitchok-kruglijak, chomorotyj bychok, chornyi bychok, buc, kuzniec [Russian]; guvid-stronghil, guvid, negrar, strongil, babca neagra [Romanian]; bychok-koval' or kuznets (locksmith goby), chernyi bychok (black goby), trevno popche, strongil [Bulgarian]; schwarzmundgrundel, kruglyak-grundel [German]; gobie à taches noires [French]; babka bycha, babka byeza, babka obla, babka okragla [Polish]; gobio pintado [Spanish] (Berg 1949; Miller 1986; Skora and Stolarski 1996; Rudnicka, pers. obs.).

## DISTRIBUTION

*Neogobius melanostomus* is found throughout the Sea of Azov, and in all nearshore areas of the Caspian Sea, Black Sea, and Sea of Marmara near Istanbul, Turkey (Figure 1). Berg (1949) states that the round goby occurs along the entire shoreline of the Black Sea, and specifies their presence at the city of Sinop, Turkey, and in the western Transcaucasian rivers south to the city of Coruh (= Corum, Turkey). The distribution map in Miller (1986), however, indicates that the round goby does not occur along the southern shoreline of the Black Sea (Figure 1). It is unclear whether this difference is due to a biogeographical error, or a reduction in the range of the round goby since Berg (1949). Gobies ascend tributaries of the Black and Caspian seas, including the Dneister River as far as the Smotrich River (near the city of Kamenets-


*Figure 1. European distribution of the round goby as of October 1996. Areas of occurrence are denoted by thick, black lines. The * denotes the Volgo-Donskoj Canal, which connects the Volga and Don rivers.*

Podol'sk, Ukraine); the Bug River (= Yuzhnyi Bug River) to the city of Ladyzhino, Ukraine; the Dnieper River to the city of Dnepropetrovsk, Ukraine; and the River Don to the city of Rostov, Russia (Berg 1949).

The round goby was found in the Aral Sea in the late 1950s, and most likely was introduced with stocks of grey mullet from the Caspian Sea (Moskal'kova 1996). These gobies were eradicated in the late 1980s by the increase in salinity in the sea. Salinity increased from 11 ppt in 1965 to over 35 ppt in 1990 (Gleick 1993) from high evaporation rates and diversion of tributary water for irrigation (Skora 1996). In 1968, the round goby was found in the Kuybyshev Reservoir (on the Volga River) near the city of Tol'yatti, Russia (Tsyplakov 1974). The goby has since expanded its range within this reservoir. In the 1970s, the goby was recorded in the Tsimlyansk Reservoir (Tsyplakov 1974) and Volgograd Reservoir (Gavlena 1977). The goby invaded the Moscow River in the late 1980s (Sokolov and Tsepkin 1992). Moskal'kova (1996) suggested that the round goby could have arrived in the Moscow River from the Volga River as eggs attached to a barge hull.

The round goby was found in the Gulf of Gdansk in the Baltic Sea (Figure 1) in 1990 (Skora and Stolarski 1996; Skora 1996). The first specimen was collected near Hel (Poland), and was aged (by scales) at 3-4 years old. Initial introduction of the goby, therefore, could have occurred prior to 1987. The goby most likely was transported to the Baltic Sea in ballast water of one or more vessels traveling via one or a combination of the following routes: 1) from the Black Sea via the Dnieper, Pripet, Pina, Danal Krolewski, Bug, and Vistula rivers; 2) from the Sea of Azov via the Don and Volga rivers, Rybinskoe Reservoir, Onega and Ladoga lakes, to the Gulf of Finland; and 3) from the Caspian Sea via the Volga River, Rybinskoe Reservoir, Onega and Ladoga lakes, to the Gulf of Finland. By 1995, the goby occurred throughout Puck Bay, south to Gdansk, and as far north as Debki, Poland (latitude 54°50'N) (Skora 1996). In the Gulf of Gdansk, the round goby is most abundant near the city of Gdynia, Poland, in rocky areas and near breakwalls (Skora, University of Gdansk, pers. comm.). In these areas, densities are estimated at several per $m^2$ (Skora 1996).

The first round goby found in North America was caught by an angler on June 28, 1990, in the St. Clair River at Sarnia, Ontario (Jude et al. 1992; Crossman et al. 1992) (Table 1). The round goby probably was transported to North America in the ballast water of one or more oceanic vessels arriving in the Great Lakes from the area of the Black, Caspian, and Azov seas, or from the Gulf of Gdansk (Baltic Sea) (Carlton, Williams College, pers. comm.). Introduction via transoceanic ballast water has been hypothesized for several recent introductions including the zebra mussel (*Dreissena polymorpha*), quagga mussel (*D. bugensis*), tubenose goby (*Proterorhinus marmoratus*), spiny water flea (*Bythotrephes cederstromii*), and ruffe (*Gymnocephalus cernuus*) (Mills et al. 1993).

In North America, the goby remained confined to the St. Clair River until 1993. In 1993, gobies were found in the Calumet River (Illinois) near Lake Michigan, in the Detroit River (Ontario), and in Grand River Harbor (Ohio) (Table 1, Figure 2). In 1994, a single goby was collected by an angler at Goderich (Ontario) in Lake Huron, and several gobies were collected at Calumet Harbor (Illinois) and Hammond Marina (Indiana) in southern Lake Michigan. By 1995, the goby was in western Lake Superior and eastern Lake Erie. In 1996, it was found inland near Argentine (Michigan) in the Shiawassee River. It has been reported from eastern Lake Ontario, but these sightings have not been confirmed (USGS 1997).

## ANATOMY AND MORPHOLOGY

The round goby is a small, soft-bodied fish. It is most readily distinguished from all other freshwater fish in North America by the presence of fused pelvic fins that form a suction disk on the ventral surface (Figure 3).

**able 1. Data for confirmed sightings of round gobies in North America through October 1996. First sighting in a given area only is listed. EPA = Environmental Protection Agency, ILDNR = Illinois Department of Natural Resources, INDNR = Indiana Department of Natural Resources, INHS = Illinois Natural istory Survey, MDNR = Michigan Department of Natural Resources, ODNR = Ohio Department of Natural Resources, OMNR = Ontario Ministry of atural Resources, USACE = U. S. Army Corps of Engineers, USFWS = U. S. Fish and Wildlife Service, USGS = U. S. Geological Survey, — = not available.**

| ear | Date | Body of water | Location | No. | Length (mm) | Source |
|---|---|---|---|---|---|---|
| }90 | June 28 | St. Clair River | Sarnia, ONT | 2 | 109, 112 | Crossman et al. 1992, Jude et al. 1992 |
| | July 18 | St. Clair River | Dow Chemical Plant, ONT | 1 | 115 | Crossman et al. 1992, Jude et al. 1992 |
| | Aug. 29 | St. Clair River | Moore Township, ONT | 1 | 100 | Crossman et al. 1992 |
| | Nov.-Dec. | St. Clair River | Belle River Power Plant, MI | 11 | 29-118 | Jude et al. 1992 |
| }93 | Jan. | Calumet River | 114th St., Chicago, IL | 6 | — | J. Francis, INDNR |
| | Sept. 3 | Lake Erie | Grand River Harbor, OH | 6 | — | R. Thoma, Ohio EPA |
| | — | Detroit River | Peche Island, ONT | many | — | D. Dubs, University of Windsor |
| }94 | June | Lake Michigan | Calumet Harbor, IL | >100 | ≤112 | J. Janssen, Loyola University of Chicago |
| | Aug. 11 | Lake Michigan | Hammond Marina, IN | 1 | ~120 | J. Francis, INDNR |
| | fall | Lake Huron | Goderich, ONT | 1 | 150 | A. Dextrase, OMNR |
| }95 | April | Lake Michigan | Burnham Harbor, Chicago, IL | 1 | — | ILDNR |
| | June 20 | Welland Canal | Port Colborne, ONT | 7 | 165 | A. Dextrase, OMNR |
| | July 13 | Lake Erie | mouth of Ashtabula River, OH | 4 | 81-88 | S. Keppner, USFWS |
| | July 19 | Lake Superior | St. Louis Bay, Duluth, MN | 1 | 113 | USGS, Ashland, WI |
| | summer | Lake Michigan | Montrose Harbor, Chicago, IL | 1 | — | INHS |
| | — | Lake Ontario[1] | Cape Vincent, NY | 1 | — | B. Danilowicz, University of Windsor |
| }96 | June | Lake Erie | Marblehead, OH | 1 | 115 | C. Knight, ODNR |
| | June 23 | Lake Michigan | Pastrick Marina, East Chicago, IN | many | ≤165 | INDNR |
| | July | Lake Michigan | Indiana Harbor, IN | many | — | USACE |
| | July | Lake Erie | Luna Pier, Monroe, MI | — | | MDNR |
| | July 9 | Lake Erie | Erieau Harbor, ONT | 1 | 142 | A. Dextrase, OMNR |
| | July 21 | Lake Michigan | Burns Harbor, IN | 1 | — | J. Francis, INDNR |
| | Aug. 7 | Lake Michigan | Jackson Harbor, Chicago, IL | 1 | ~100 | INHS |
| | Aug. 14 | Lake Erie | Colchester, ONT | ~100 | YOY-90 | B. Ray, University of Windsor |
| | Aug. 14 | Lake Erie | Middle Sister Island | ~35 | YOY-100 | B. Ray, University of Windsor |
| | Aug. 15 | Shiawassee River | Argentine, MI | 3 | 58.3-71.7 | R. Raesly, Frostburg State University |
| | Oct. 17 | Lake Erie | Erie, PA | 2 | 62, 72 | C. Murry, PA Fish and Boat Commission |

ot yet confirmed

The following technical description is drawn from Berg (1949) and Miller (1986). Gobies are scaled on the parietal region, nape, back (all), throat (all or most), abdomen, pectoral fin peduncles, and one quarter of the gill covers. Scales on the middle and anterior nape are cycloid (as are scales on the greater part of the gill covers and throat, pectoral peduncles, and part of the abdomen [Rudnika]). The head is as wide as or wider than deep: depth is 0.9-1.2 times the width. Head length is 22-23% of total body length. Miller (1986) states that interorbital distance is four-fifths to almost equal the eye diameter, but Berg (1949) states that this distance is equal to or exceeds the eye diameter. The angle of the jaw is below the anterior quarter of the eye. The lower jaw is not prominent. The snout is 1.1-1.4 times the orbit diameter. The upper lip narrows slightly to the rear. There are usually 6, rarely 7, transverse suborbital series of pit organs. Ventral fins reach or almost reach the vent. The pelvic disk is 0.6-0.8 times the abdomen length. If present, the anterior membrane width is very shallow, with rounded, lateral lobes. The caudal peduncle depth is about two-thirds its length. The anterior dorsal fin has 5-7 spines, usually 6, and the posterior dorsal fin has 1 spine and 13-16 soft rays. The anal fin has 1 spine and 11-14 soft rays, and the pectoral fins have 17-20 soft rays. The notational abbreviation for this description is D1 VI (V-VII); D2 I + 14-16 (13-16); A I + 11-13 (11-14); P 18-19 (17-20). The round goby possesses upper and lower pharyngeal teeth, and the posterior teeth are smaller than anterior teeth (Pinchuk 1992; Ghedotti et al. 1995). The goby lacks a gas bladder and chemoreceptors.

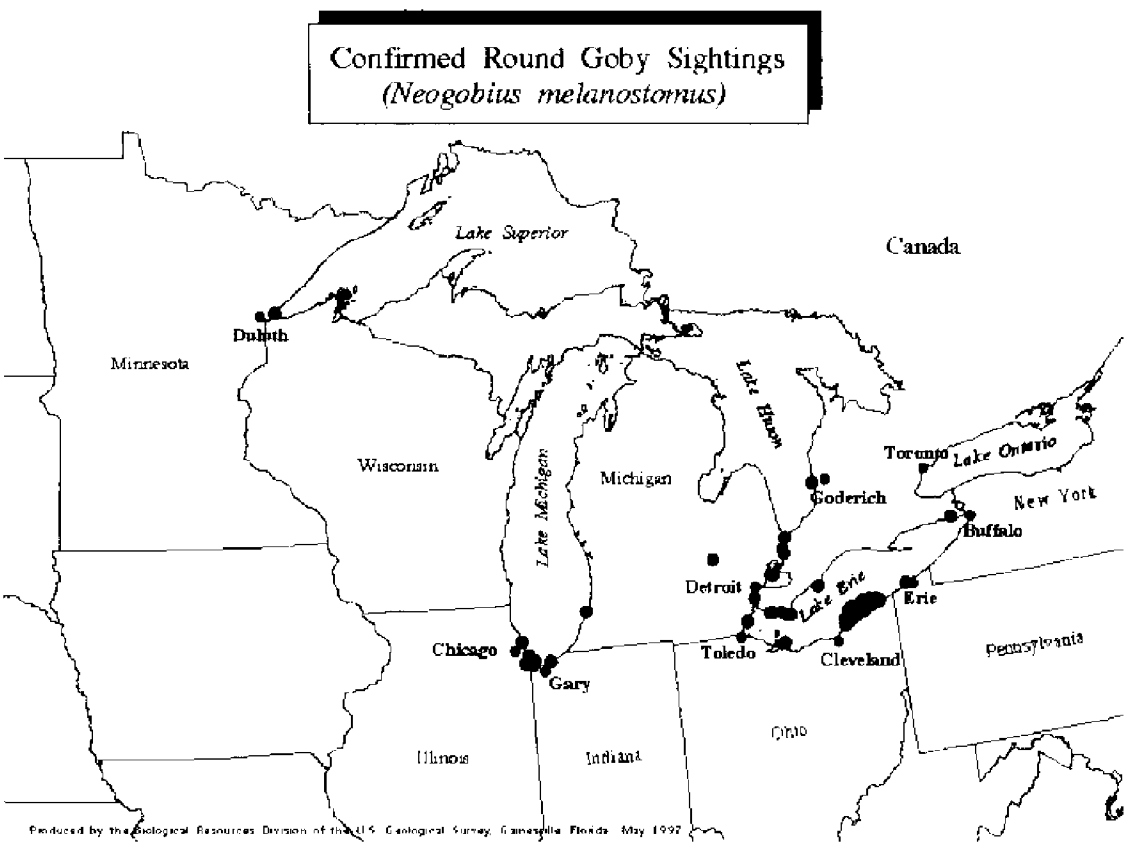


*Figure 2. North American distribution of the round goby as of October 1996.*

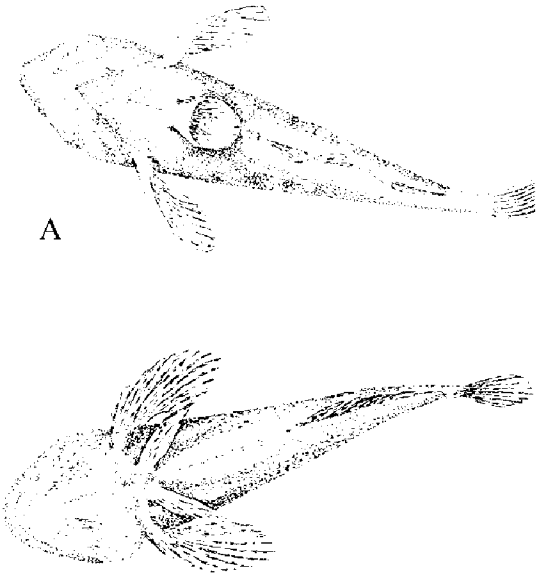


*Figure 3. Ventral view of both the round goby (a) and mottled sculpin (b). Note that round goby pelvic fins are fused into a suctorial disk, but sculpin pelvic fins are separate.*

Neuromasts are present throughout the body and head. Head neuromasts are enclosed within a canal system, but body neuromasts are not; that is, those on the body are superficial neuromasts. Thus, the round goby lacks a visible lateral line. The presence of superficial neuromasts on the body likely makes the goby more sensitive to prey than species whose body neuromasts are contained within canals (Jude et al. 1995).

The scale count along the midline to the hypural bone is usually 49-55, but ranges from 45 to 57. The vertebral count generally is 32-33, but ranges from 31 to 34. The body is brownish gray with dark brown lateral spots. Mature males are completely black during spawning and nest guarding, with yellowish spots on the body and median fins fringed in yellow. A large, oblong, black spot is usually present at the end of the first dorsal fin, beginning at the 5th ray. This spot is distinct but not unique, as sculpins often have a dark mark in this location. Gobies without this spot have been found in Lake Erie (Cavender, The Ohio State University, pers. comm.). Juveniles have a light border around the black spot.

In its fourth year, a goby normally reaches 215 mm TL (180 mm SL), but gobies as long as 290 mm TL (250 mm SL) have been found (Berg 1949). The relationship between total length (TL) and standard length (SL) of 331 gobies collected at Calumet Harbor (Illinois) is illustrated in Figure 4. Although males grow faster than females, the length/weight relationship of both sexes is similar (Figure 5a and b).

Both sexes have an erectile urogenital papilla between the anus and the base of the anal fin (Figure 6). The female urogenital papilla is broad and blunt, 0.3-0.5 mm long and 0.2-0.4 mm wide. The male papillae are somewhat longer, with a length of 0.3-0.6 mm and a terminal slit (Juszczyk 1975; Miller 1984).

Males have two pairs of glands associated with the testes. One pair, the seminal vesicles (sperm-duct glands) is appended to the sperm duct behind the testes. The size of these glands increases with sexual maturation. Miller (1984) referred to the other pair as "cement glands," and they are associated with the posterior end of the testes. In a prespawning male these accessory glands are large, vascularized, slightly translucent, elongated lobes. These lobes lie exterio-laterally to the testes in the dorsal portion of the body cavity, anterior to the vent. The glands secrete a viscous colloidal fluid, the function of which is unclear (Miller 1984). The fluid may promote sperm viability, enhance contact of sperm with eggs, or be used by the male to coat the nest prior to egg deposition (Juszczyk 1975; Miller 1984; Miller 1994).

## PHYSIOLOGY

The round goby is eurythermal. In native habitats, its temperature tolerance is between -1 and +30°C (Moskal'kova 1996). The goby seemingly is resistant to temperature stress. Anglers near Calumet Harbor (Illinois) often catch round gobies from 16°C lake water and immediately place them in buckets of 32°C water. We have collected these gobies, transferred them to coolers with 16°C water, and maintained them in laboratory aquaria with few fatalities. The metabolic rate of the goby during summer (20-24°C) is 5-6 times higher than during winter (0.5-3.5°C) (Skazkina and Kostyuchenko 1968). In the Black Sea, gobies actively feed at water temperatures of 27°C (Svetovidov 1964).

Gobies will leave areas in which dissolved oxygen is less than 50-60% of saturation (Skazkina 1966). The threshold oxygen concentration of the goby is low and ranges between 0.3 and 0.9 ml/L depending on the mass of the fish. Skin respiration comprises 13% of total respiration (Moskal'kova 1996). Gobies can tolerate a flow rate of 0.34 m/s for 3-4 min. At higher flows, they remain close to the bottom, likely using their pelvic fins to brace against the current (Skazkina 1972). In laboratory experiments, gobies 75-110 mm (SL) were active during 28.6% of a 24-hr period. Oxygen debt after 8-10 min of activity was paid after approximately 1 hr. Mean metabolic rate was calculated as 140% of standard metabolic rate and 50% of active metabolic rate (Skazkina 1972). Hexachlorane concentrations of 0.006-0.012 mg/L negatively affected oxygen consumption. Respiration intensity did not recover after the gobies were moved to hexachlorane-free sea water (Zambriborshch and Lai 1978). Blood of the goby exhibits high oxygen affinity (P-50 = 12.6 $\pm$ 0.5 mm Hg), a pronounced Bohr effect (r = -0.31 $\pm$ 0.02), and low oxygenation heat ($\Delta H$ = -8.4 $\pm$ 0.3 kcal/mol $O_2$) (Soldatov 1993a). Soldatov attributes the wide distribution of the goby to these characteristics.

Data on salinity tolerance of the goby were not given in the papers we reviewed. The range in

Figure 4

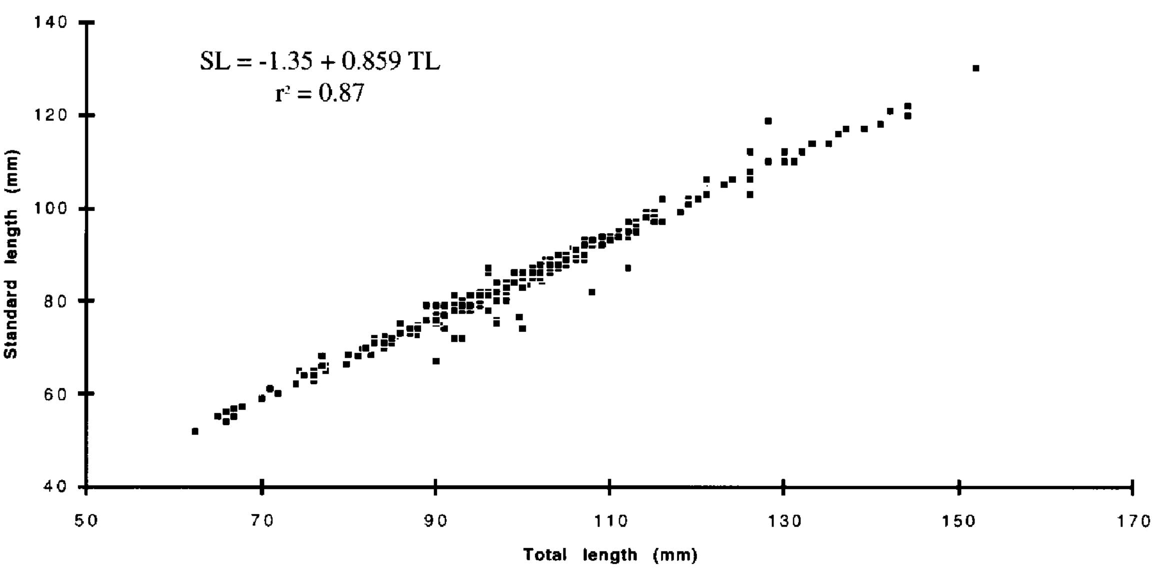


*Figure 4. Regression of total length (mm) and standard length (mm) of 331 round gobies collected from Calumet Harbor (IL) in 1995.*

salinities of the waters it inhabits in Europe, however, indicates its salinity tolerance. Average salinity of the Caspian Sea is 12.8 ppt, and varies from 1 ppt near the outlet of the Volga River to 13.5 ppt near the Kara-Bogaz Gulf. Gobies also have been found in Kadak Bay on the eastern coast of the Caspian Sea where salinity was 40.6 ppt (Kazancheev 1981). Salinity of the Black Sea is 19 ppt in the upper oxygenated waters, and is 4-8 ppt in the Gulf of Gdansk. The goby successfully reproduces in both fresh and saline water. It has been shown that embryonic development proceeds normally at salinities of 4.2-19.5% (*sic*; we presume ‰ was intended) (Moskal'kova 1996).

## GENETICS

The round goby has a relatively low level of genetic variability. Five (16.1%) of 31 protein

**Figure 5a (females, n=126)**

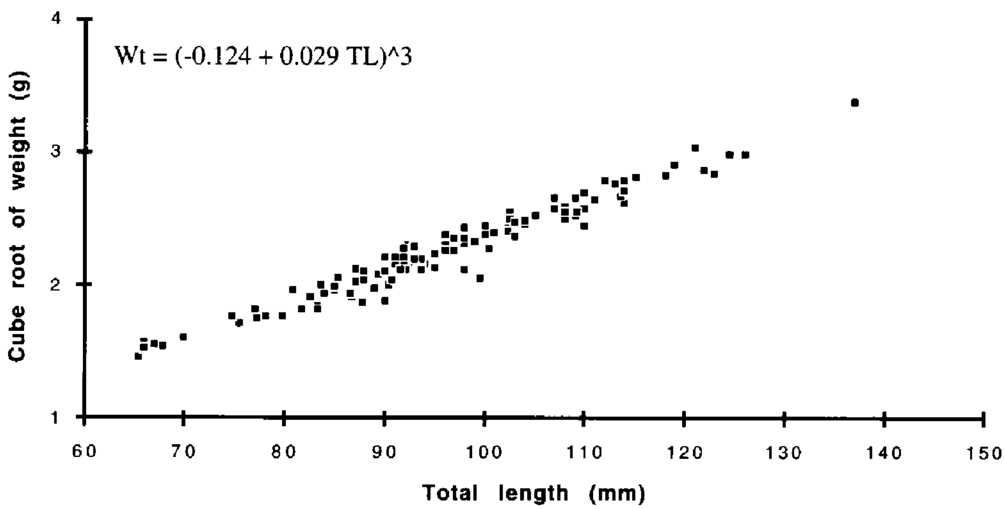


**Figure 5b (males, n=142)**

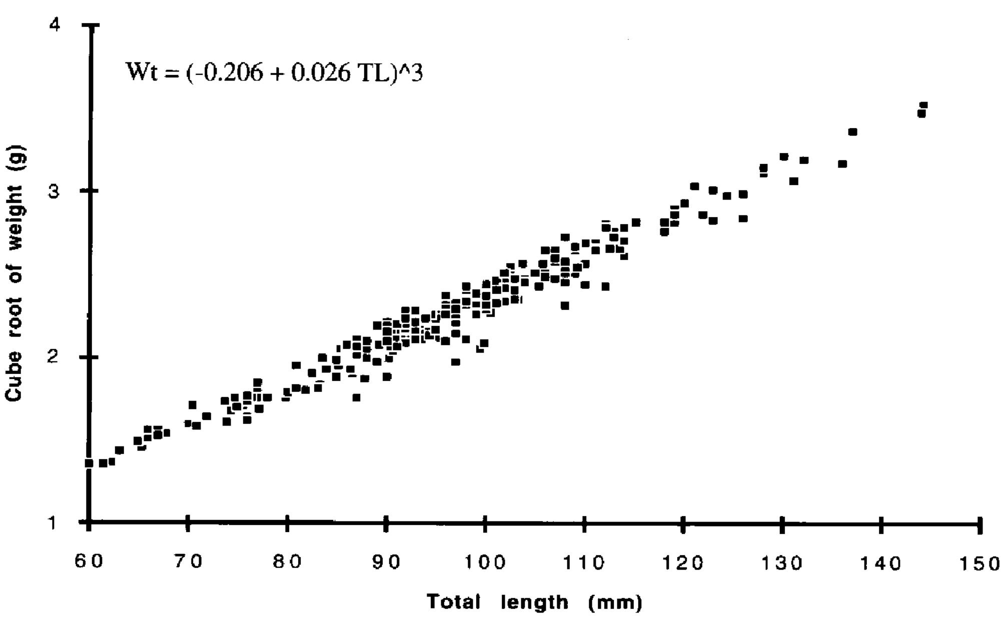


*Figure 5. Regression of total length (mm) and cube root of weight (g) of round goby (a) females and (b) males collected from Calumet Harbor (IL) in 1995.*

loci examined by Wallis and Beardmore (1984 a and b) were polymorphic, and mean heterozygosity was 0.021 (Table 2). Polymorphism and average heterozygosity of eight other gobiid species (*Knipowitschia caucasica* and *Pomatoschistus* spp.) were 12.9-32.3% and 0.021-0.092, respectively (Wallis and Beardmore 1984a and b). Mitochondrial DNA analysis of the cytochrome b sequence of 29 gobies from North America (St. Clair River and Lake St. Clair) and 15 from Europe (Black Sea near Varna, Bulgaria) revealed 5 haplotypes. The most common haplotype was found in gobies from both continents. The presence of two unique haplotypes in each population, however, suggests that the Varna population is not the source of the gobies introduced into North America (Dougherty et al. 1996).

*Neogobius fluviatilis fluviatilis* and *N. f. pallasi* have 2N = 46 acrocentric chromosomes, and *N. kessleri* has 2N = 30 (females) and 29 (males) metacentric and acrocentric chromosomes (Grigoryan and Vasil'ev 1993a,b). The three species all have 46 chromosome arms, which suggests that *N. kessleri* has undergone Robertsonian fusions of acrocentric chromosomes to form metacentrics.

## HABITAT AND BEHAVIOR

Round gobies occur on coarse gravel, shell, and sand in inshore areas to depths of 20 m in the Black Sea and the Sea of Azov (Miller 1986). In the Caspian Sea, gobies occur to 70 m, and are often associated with eelgrass (*Zostera*) (Moskal'kova 1996). In the Kuybyshev Reservoir, gobies occur in silted sand at depths of 5-10 m and in river beds to 30 m (Tsyplakov 1974). Gobies also occur in lower and middle reaches of rivers, but only in slightly brackish or fresh water (Miller 1986, but see "Physiology" section). During spring-autumn in the

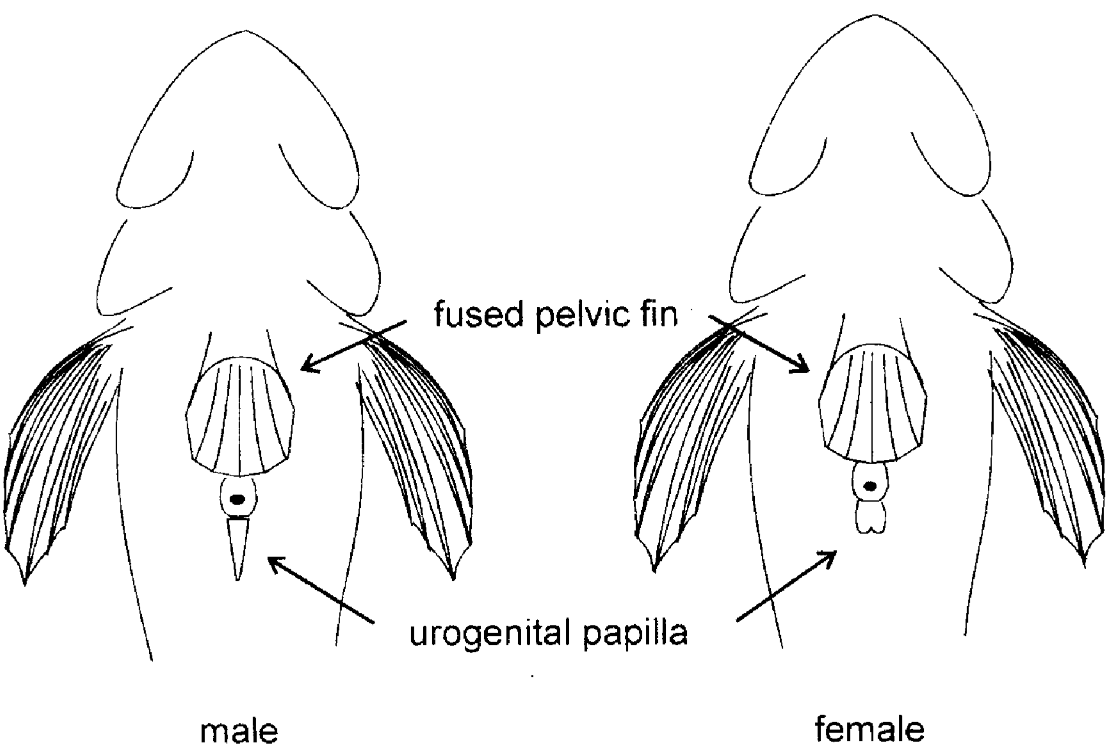


*Figure 6. Ventral view of male and female round gobies including urogenital papillae.*

Black Sea, round gobies are found in slowly flowing rivers, lagoons, and brackish coastal water to 20 m (Jude and DeBoe 1996), but they migrate to deeper water (50-60 m) in winter (Miller 1986). During spring, round gobies migrate to inshore areas of the northern Caspian Sea even while these areas are still partially frozen (Nikol'skii 1954). Gobies prefer littoral areas where wave action maintains high dissolved oxygen levels and reduces the amount of decaying material. In the Gulf of Gdansk, gobies are associated with stone/sand areas, mussel beds, marine structures, and sunken objects. In Puck Bay, Gulf of Gdansk, gobies inhabit areas with a humus/mud/sand substratum overgrown with benthic flora (Skora 1996).

In the St. Clair River, round gobies are associated with large cobble to depths of 3 m and macrophytes (e.g., *Elodea canadensis*, *Myriophyllum* spp., and *Potamogeton* spp.) in depths of 1.5-4.6 m. They also have been impinged on industrial screens at 6 m depth (Jude et al. 1992; Jude et al. 1995; Jude and DeBoe 1996). Fry were collected in *Chara* beds presumably where spawning occurred (Jude et al. 1995). Macrophytes and cobble provide large interstices for refuge and spawning (Jude and DeBoe 1996), but the goby apparently is not restricted to these habitats (Jude et al. 1992; Jude and DeBoe 1996). In Calumet Harbor (Illinois), gobies were abundant on both cobble and sand, although adults were less abundant on sand than juveniles. Gobies also will move onto sandy beaches to feed at night (Jude et al. 1992). In the St. Clair River, there is an inverse relationship with depth and number of round gobies, but a direct relationship with depth and length of individuals, which may be due to gear bias (Jude et al. 1995). Round gobies were not collected in shallow nearshore areas of Lake St. Clair until May 8 in 1993 ($T_{water}$ =7.8°C), but were abundant from shore to 5 m on November 5, and in December trawls at 3, 5, and 7 m. These depth and seasonal distributions are different from patterns in their native range (see preceding paragraph).

**Table 2. Electrophoretic analysis of 31 loci in the round goby with allelic mobility and frequency of the 5 polymorphic loci (from Wallis and Beardmore 1984b). IUBNC = International Union of Biochemical Nomenclature Committee.**

| Enzyme | Loci | IUBNC Number | Allelic Mobility | Frequency |
|---|---|---|---|---|
| Malate dehydrogenase | MDH-1 | 1.1.1.37 | 224 | 0.937 |
| | | | 175 | 0.063 |
| Phosphoglucose isomerase | PGI-B | 5.3.1.9 | 92 | 0.063 |
| | | | 78 | 0.937 |
| Phosphoglucomutase | PGM-B | 2.7.5.1 | 60 | 0.063 |
| | | | 55 | 0.937 |
| Phosphomannose isomerase | PMI | 5.3.1.8 | 75 | 0.083 |
| | | | 65 | 0.917 |
| Sorbitol dehydrogenase | SDH | 1.1.1.14 | 96 | 0.929 |
| | | | 70 | 0.071 |
| Adenylate kinase | AK | 2.7.4.3 | | |
| Creatine kinase | CK-A, CK-B | 2.7.3.2 | | |
| Esterase | EST-0,1,2,3 | 3.1.1.1 | | |
| Isocitrate dehydrogenase | IDH-L, M | 1.1.1.42 | | |
| Lactate deydrogenase | LDH-A,B,C | 1.1.1.27 | | |
| Malic enzyme | ME-1,2 | 1.1.1.40 | | |
| Muscle protein | MP-1,2,3,4,5,6 | — | | |
| Peptidase | PEP-A | 3.4.11-13 | | |
| 6-Phosphogluconate dehydrogenase | PGD | 1.1.1.44 | | |
| Phosphoglucose isomerase | PGI-A,B | 5.3.1.9 | | |
| Phosphoglucomutase | PGM-A | 2.7.5.1 | | |
| Superoxide isomerase | SOD | 1.15.1.1 | | |

Gobies maintained in laboratory aquaria by Jude et al. (1992, 1995) tended to remain on the bottom, closely associated with rocks. Generally, individuals rest momentarily on their pelvic fins, then move to a new resting place via a tail beat or pectoral fin stroke. Larger fish favored crevices and areas under rocks. On one occasion, Jude noted that a large, frightened individual buried its whole body in pea gravel in an apparent predator-avoidance reaction (Jude et al. 1992). The goby appears to detect prey only while stationary, and is able to feed nocturnally (Jude et al. 1995).

Dubs and Corkum (1996) examined territorial behavior of the goby. When in an aquarium containing a refuge, gobies spent more time in the refuge during the day than at night. When an intruder (round goby or mottled sculpin) was introduced at night, the resident goby spent more time in the refuge. Resident gobies had significantly more aggressive behaviors (approaching, chasing, and biting) than either intruder. Goby intruders displayed significantly more aggressive behaviors than resident sculpins, and thus were able to displace resident sculpins on several occasions. When this occurred, the intruder goby periodically would leave the refuge and charge the displaced sculpin. Attempts by the resident sculpin to reclaim the refuge were prevented by the intruder goby.

## REPRODUCTION

Females reach sexual maturity in their second year and males in their third year (Nikol'skii 1961). Oocytes begin development in September, preparatory for spawning the following spring (Kulikova 1985). At water temperatures of 9-26°C, gobies move into shallow, nearshore waters (0.2-1.5 m depth) to spawn, with males preceding females (Kovtun 1979; Moskal'kova 1996). Spawning commences in April in the Black and Caspian seas, and continues through June (Romania), July (Sea of Azov), or September (Varna, Bulgaria, and Azerbaijan). In the delta of the Volga River, gobies spawn from May-June in the river channel (Kazancheev 1981). Gobies in the Gulf of Gdansk have ripe gonads during April-September, and probably spawn from April-July (Skora and Stolarski 1996).

Females spawn repeatedly, laying 5-6 batches of eggs at intervals of 18-20 d in captivity (Kovtun 1977). The inter-spawning interval is 28 d in water temperatures of 15-17°C, and 15-17 d at temperatures above 20°C (Kulikova 1985). The number of eggs spawned per female per year varies from 200 to 9,771 (Kovtun 1977), but reported figures vary widely (Nikol'skii 1961; Miller 1986). Energy investment in egg production increases with age from 20.1% of total energy expended (3.7 kcal) in year 1, to 46.7%(9.4 kcal) in year 2, and to 50.6% (10.4 kcal) in year 3. Annual mass of spawned eggs also increases from 2.0 g, to 5.2 g, to 5.7 g in years 1, 2, and 3, respectively (Skazkina and Kostyuchenko 1968).

Characteristic of an intermittent spawner, the endocrine system in the round goby is active year-round. Therefore, gobies can be readily induced to spawn in the laboratory by manipulating temperature. Injecting females with 25-50 IU of human chorionic gonadotropin per gram body mass stimulated rapid vitellogenesis, ooctye development, and subsequent spawning (Kulikova 1985). Only eggs that began yolk accumulation, however, were stimulated. Hormone dosage needed to stimulate further development decreased as eggs approached maturity (Kulikova 1985).

Nests are generally under stones, under logs, or in cavities. Gobies also will use artificial substrata, such as beer cans, for nesting (Lashbrook, Bizarre Images, pers. comm.). Artificial reefs constructed in the Sea of Azov were colonized rapidly by gobies, thus enhancing local population levels (Izergyn 1994). A male attracts females to his nest by producing a call. A receptive female responds with a quieter call. The male goby then prepares a nest site by coating the substrate with exudate from the "cement gland" (see "Anatomy and Morphology" section). As each egg is extruded, one fish (presumably the female) glues the extended base of each oval egg to the undersurface of the roof of the nest cavity forming dense, single-layer rows (Moskal'kova 1996) (Figure 7).

The male guards the nest from predators and fans the eggs to maintain oxygenation, reduce fungal infection, and reduce siltation. If the male is removed from a nest, the eggs are rapidly consumed by gobies, other fish, and crayfish. Males may eat unfertilized or fungally infected eggs, and may consume the entire brood if stressed. Males defend their nests by spitting sand, flaring their gills, lunging and biting at intruders, and producing a growling sound for 1-1.5 s which can carry 5-10 m (Protasov et al. 1965). While spawning and nest guarding, males turn very dark with indistinct yellow spots. Males may also develop a yellow line on the edge of their fins. Their cheek areas usually become enlarged, emphasizing head size and thus likely enhancing aggressive signals such as gill flaring. Miller (1984) stated that males do not feed during egg incubation, which leads to emaciation, skin ulceration, and possibly death after a single reproductive season. Rudnicka, however, has dissected nest-guarding males and observed food in their guts. Literature we reviewed suggests that males invariably die at the end of their first reproductive season, but no data are provided to support this assertion.

A single nest may contain up to 10,000 eggs from 4 to 6 females. Contribution of eggs from more than one female often is apparent by the presence of eggs at different stages of development. Predation on eggs is related to clutch size. A small clutch of 2,000-3,000 eggs (from 1 to 2 females) may lose little to predation, whereas a large clutch of 8,000-10,000 eggs may lose 50-70% to predation (Kovtun 1979). Fertilization is typically high, and may reach 95%. In other goby species unfertilized eggs are round, and fertilized eggs are cone-shaped (Daoulas et al. 1993). This also may be true for round gobies (but see Moskal'kova 1996). A large, successful male may hatch 95% of the eggs in his nest (Rudnicka, pers. obs.).

Kovtun (1979) noted a strong correlation between sex ratio and year-class strength. In years in which the male to female ratio was high (up to 1.9), survival of fry was 6-14%. In years when the sex ratio was low (1.1-1.4), survival was 70-93%. Presumably a predominance of females in the population leads to larger egg clutches that cannot be adequately defended by the male. The sex ratio can be highly skewed by nearshore fishing in spring when males have moved onto spawning grounds, but females remain in deeper water (Kovtun 1979).

## LABORATORY REARING

In spring, gobies readily spawn in the laboratory if shelter (e.g., half sections of PVC pipe) is available for depositing and guarding eggs. In winter, gobies can be induced to spawn by raising the water temperature (Moiseyeva and Rudenko 1978). If the water temperature

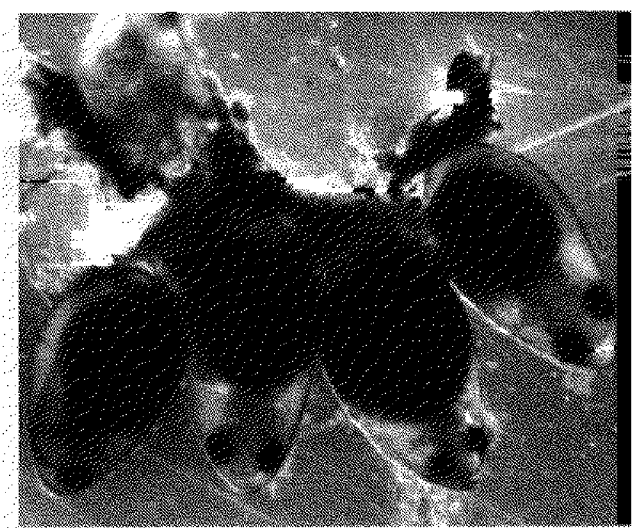

*Figure 7. Photo of developing eggs of the round goby. Note asymmetric shape of the eggs and the "cement" affixing eggs to substratum.*

fluctuates, males may abandon the nest. Males also tend to consume or abandon the eggs if the nest is disturbed. Without tending from the male, fungus rapidly covers and kills the eggs. Abandoned eggs can be incubated, however, by moving the substratum and attached eggs to a separate, aerated (e.g., with an air stone) container, and vertically orienting the substratum so that aerated water flows across the eggs. The substratum can be oriented horizontally, but dead eggs must be removed daily. Direct contact between eggs and airflow may cause turbulence too severe for egg survival (Wolfe, pers. obs.). Prophylactic treatment of eggs with methylene blue helps reduce fungal infection, but may destroy the neuromast sensory system.

In the laboratory, fry will feed on juvenile brine shrimp within a few days of hatching. Adult gobies can be maintained on a diet of black worms (= blood worms), but other prey items may be equally acceptable. Adult densities equivalent to three 120-mm fish (approximately 75 g total biomass) can be maintained in a 15-gal aquarium; higher densities may result in high mortality. Refugia will help reduce aggression among adult gobies in aquaria.

## DEVELOPMENT

Eggs are large (3.4-3.8 mm), and are relatively high in protein (27.6%) and fat (5.7%) (Moskal'kova 1989; Moskal'kova 1996). Within the egg, the eyes develop early and are light sensitive prior to hatching (Table 3). The day before hatching, the entire cornea stratifies into 2 layers, an inner cornea and an outer protective layer, which are separated by a channel. The channel and an elastic area in the inner cornea provide protection against injuries. These structures are reduced and modified with growth (Moskal'kova 1996). Gonads develop completely, and early stages of gametogenesis occur within the egg (Moiseyeva 1993). Gametogenesis is asynchronous in the sex cell population, which forms the basis for repeat-spawning. The embryo develops a working digestive system in which peristalsis occurs. The embryo repeatedly swallows yolk material and perivitelline fluid, assimilates some yolk protein in the hindgut, and excretes the remaining fluid into the perivitelline space (Moskal'kova 1980, 1989). This "coprophagy" and embryonic development of the digestive system possibly are unique, but may occur in other benthic fishes with large yolk sacs. These traits may account for the absence of a planktonic feeding period in juvenile gobies.

Eggs develop in 14-15 d at 19-21°C (Moskal'kova 1989), and 18-20 d at 17.5-19°C (Moiseyeva 1983) (Table 4). Development within the egg is highly advanced, thus the goby lacks a true larval stage. Fry reared in the laboratory by Logachev and Mordvinov (1979) emerged from eggs at 5.5-5.7 mm in length. By the third day after hatching, fry were 6.0-6.2 mm. Newly hatched fry were capable of swimming speeds averaging 2.0 cm/s, and were active 7.1% of the experimental period. After three days, fry were swimming at 4.4 cm/s and were active almost 30% of the experimental period.

Advanced development within the egg makes goby fry less vulnerable to predation and habitat variation (Moskal'kova 1996). Fry starved for 20 d developed normally (Moskal'kova 1996), but fry starved for 26 d could not recover (Bitukova et al. 1980). With their suctorial pelvic fins, emergent fry attach themselves to the nest substratum among the empty egg membranes. Fry remain in the nest for 4-9 d, then settle on nearby substrata (Moskal'kova 1996).

## AGE AND GROWTH

In their native range, gobies typically live to 4 yr and reach a maximum length of 250 mm (SL) (Berg 1949; Nikol'skii 1954). Males grow faster than females and reach a larger size (Nikol'skii 1954) (Table 4, Figure 5a,b). Males reach about 100-130 mm (SL) in their first year, and by 3-4 yr are 170-180 mm. Females reach only 80-110 mm (SL) in their first year, and maximum female length is 130-140 mm (Berg 1949; Jude et al. 1992). Daily growth increments for males are 1.5 times greater than for females. Annual growth increments decrease with female age, and increase with male age (Skazkina and Kostyuchenko 1968) (Table 4). At 3 years, males may weigh three times more than females. The period of maximum growth is August-September for females and July-October for males. Male and female biomasses decrease in winter (Skazkina and Kostyuchenko 1968).

In the Sea of Azov, growth was most rapid in the first and second years of life. Dominant size class in the Sea of Azov ranged from 80 to 150 mm (SL) for females and from 100 to 160 mm for males. Round gobies collected in trawls in the Kuybyshev Reservoir (Russia) varied between 22 mm (SL) (2.2 g) and 85 mm (12.9 g) with a maximum of 135 mm (85.3 g) (Tsyplakov 1974). Natural mortality in the Sea of Azov is 55.1% and 89.8% for 2- and 3-year olds, respectively (Kovtun et al. 1976). Faster growth usually results in earlier death (Kostjuchemki 1961).

In the Gulf of Gdansk, Skora and Stolarski (1996) examined 211 round gobies collected in 1990-1993. The largest of these was a 246-mm male, but specimens of 250-mm have been collected in these waters. The male to female ratio was 4:1, and males were larger than

**Table 3. Developmental stages of round goby embryos incubated at 17.5-19°C (from Moiseyeva 1983).**

| Age (d) | Developmental characteristics | Length (mm) |
|---|---|---|
| 1.5 | head and body discernible; rudiments of optic cup present | 1.6-1.8 |
| 3 | segmentation of trunk, formation of tail bud, differentiation of eye bud | 1.8-2.0 |
| 4 | eye lens, intestinal tract, Wolffian ducts formed; heart contracts slowly | 2.2-2.4 |
| 6 | formation of pectoral fins, further development of caudal area; blood cells pigmented, internal pigments appear; head curved toward free apical end of egg | 3.2-3.5 |
| 8 | segmentation of trunk and caudal area almost complete; 3 gill arches and opercula visible; eyes pigmented, pectoral and pelvic fins well-developed | 4.5-4.7 |
| 12 | formation of unpaired fins; liver and blood vessels on yolk sac well developed; intestines and urinary bladder formed, lumen of intestine filled with yolk | 5.0-5.4 |
| 18 | branchial respiration begins, eyes mobile, yolk sac decreases and becomes oval; pigment cells on head, yolk sac, and body are well developed; gonads fully developed, embryo moves to bottom of egg prior to hatching. | 5.5-5.8 |

**Table 4. Weight gain and food consumption for female and male round gobies in the Sea of Azov. All measurements are in grams (from Skazkina and Kostyuchenko 1968).**

| | Annual weight gain | | Food consumption: Daily (% of body wt.) | | Food consumption: Annual | |
|---|---|---|---|---|---|---|
| Age | F | M | F | M | F | M |
| 0 to 1+ | — | — | 0.6 (5.4%) | 0.9 (5.3%) | 2241 | 324.6 |
| 1+ to 2+ | 16.6 | 29.3 | 1.0 (4.5%) | 1.9 (4.4%) | 376.8 | 709.6 |
| 2+ to 3+ | 12.1 | 43.0 | 1.3 (3.9%) | — | 492.9 | — |
| 3+ to 4+ | 11.4 | — | — | — | — | — |

females. The mass of males, however, was lower than the mass of females of the same length. The age of fish collected ranged from 2 to 5 yr, and 2-3 year olds constituted 90%. Mean length of 2-, 3-, and 4-year olds was 152 mm, 182 mm, and 212 mm, respectively. Growth in the Gulf of Gdansk was slower than in the Sea of Azov, but higher than in the Caspian Sea. Round gobies collected from the St. Clair River ranged from 29 to 180 mm (TL) (Crossman et al. 1992; Jude et al. 1992; Jude et al. 1995), and gobies collected from Calumet Harbor (Illinois) in 1995 ranged from 60 to 152 mm (TL) ( Wolfe and Marsden, unpubl. data).

In Russia, gobies were first aged using the last two vertebrae, but otoliths have been used more recently. Annulus formation in otoliths tends to occur in April or May in the Sea of Azov (Kostjuchemki 1961). Bil'ko (1971) described the otolith technique as follows: "After drying, the otoliths of the gobies were covered with polystyrene dissolved in benzene to which dimethylphthalate had been added." A more accepted method, however, is immersion of dry otoliths in glycerine (Rudnicka, pers. obs.).

## DIET

The round goby is a benthic feeder. Its diet is composed primarily of crustaceans and molluscs, including zebra mussels. Polychaetes, small fish, goby eggs, and chironomid larvae also are eaten (Berg 1949; Miller 1986). In the Sea of Azov, the goby was the primary consumer of benthos, consuming up to 13% of the annual production. Its diet during the primary feeding period (spring-fall) was 90% molluscs, and during winter was 11-41.8% fish (mainly *Clupeonella*; Skazkina and Kostyuchenko 1968). The diet of gobies analyzed by Kovtun et al. (1974) was 78% molluscs, 10% crustaceans, 6% worms, and 3% fish (Table 5). Gobies of all sizes ate molluscs and crustaceans. Small- and medium-sized gobies also ate worms (presumably polychaetes), but only larger individuals ate other fish (Skazkina and Kostyuchenko 1968; Kovtun et al. 1974) (Table 5). In the Caspian and Black seas, 45% and 80% (respectively) of the goby diet was molluscs (Nikol'skii 1954). In the estuary of the Dnieper River, their diet was dominated by bivalve molluscs (43.4%), amphipods (corophids 22.1% and gammarids 4.4%), and unidentified molluscs (15%), but also included polychaetes (7.2%), mysids (2.1%), fish (gobies 4.3% and percids 0.3%), bryozoans (0.5%), chironomids (0.05%), and gastropods (0.1%) (Strautman 1972). Mean annual food consumption of the goby can be 23 times its own mass (Skazkina and Kostyuchenko 1968).

In North America, gobies also primarily consume benthic organisms. Stomachs of 31 gobies collected in the St. Clair River near Algonac (Michigan) contained chironomids (larvae and pupae), which averaged 31% by volume of stomach contents in 47-59-mm (TL) fish (Jude et al. 1995). Gastropods and bivalves (Sphaeriidae and zebra mussels) made up 39% of the diet of 47-59-mm fish and 82% of the diet of 80-90-mm fish. Gobies 40-60 mm long concentrated on large benthic cladocerans (*Eurycercus*). Other items in the stomachs were *Gammarus*, Ceratopogonidae, Ephemeroptera (*Caenis, Stenonema, Ephemera, Baetis*), Odonata (*Macromia*), Diptera (*Atherix* pupae and larvae), Oligochaeta, Ostracoda, Decapoda (crayfish), and Trichoptera. Larger fish contained more chironomids and zebra mussels than smaller fish. Diets of 12 gobies 70-84-mm (SL) in size collected from the upper Detroit River were, by volume, 58% zebra mussels, 6% snails, and 36% miscellaneous invertebrates including *Hexagenia*, crayfish, and zooplankton (Ray and Corkum, in press).

The goby ingests zebra mussels intact; divers in the St. Clair River have observed gobies wresting zebra mussels from the substratum and swallowing them whole (Johnson and Lashbrook 1993). The goby generally crushes the zebra mussels with its pharyngeal teeth, and shells are discarded before the soft body is swallowed (Ghedotti et al. 1995; Jude et al.

1995). While splitting or crushing shells, the goby may keep zebra mussels in its mouth from less than 1 hr to more than 12 hr. Gobies whose stomachs contained crushed shells and even whole mussels have been collected (Ghedotti et al. 1995; Jude et al. 1995; Wolfe and Marsden, unpubl. data). Zebra mussels in guts often appear intact (i.e., valves are entire and still attached), but the body tissue is missing (Wolfe, pers. obs). Intact mussels also can be passed through the anus (Wolfe and Marsden, pers. obs.).

In laboratory experiments, Ghedotti et al. (1995) found that 60-80-mm and 80-100-mm (SL) gobies consumed an average of 47 and 36 zebra mussels per day, respectively. Sizes of zebra mussels consumed depended on predator-prey size relationships. Zebra mussels in the 7x13-mm size range were too large for a 100-mm goby and 6x12-mm mussels were too large for a 72-mm goby, the latter having a 6x8-mm gape (mussel dimensions given by Ghedotti et al. are presumably width x length). Consumption rates averaged 5.4 zebra mussels per hr in a 140-min time trial. Gobies ate over 100 small (<4 mm) zebra mussels, however, within a 24-hr period. When presented with clumps of zebra mussels, gobies removed and consumed edible sizes from the clumps, selecting smaller sizes first. Gobies preferred individual and clumped zebra mussels over native sphaeriid clams (*Sphaerium* sp.). When zebra mussels and sphaeriids were offered together, gobies ate twice as many zebra mussels as sphaeriids. Likewise, when offered both zebra mussels and native snails (*Planorbis*), gobies crushed snails, but consumed zebra mussels before snails.

Ray and Corkum (in press) also conducted laboratory experiments on predation of gobies on zebra mussels. They found that 55-69-mm (SL), 70-84-mm, and 85-103-mm gobies could consume 6.0-9.9-mm zebra mussels, but only the 85-103-mm gobies could consume 10-12.9-mm zebra mussels. The 85-103-mm gobies could not consume zebra mussels larger than 12.9 mm. The size of zebra mussels consumed by a goby presumably was limited by an individual's gape, which is related positively to its body length. Ray and Corkum (in press) also found a positive relationship between total mass of mussels (6.0-9.9 mm) available and mass consumed by gobies; amount consumed increased up to 1.02 g of available mussels, but then leveled. Round gobies ate 1.0 g of 6.0-9.9-mm mussels (about 6-7 mussels) in 24 h. Gobies will consume eggs (see "Reproduction" section) and young-of-the-year of conspecifics (Jude, pers obs.). In captivity, gobies consumed dead rainbow smelt (*Osmerus mordax*), and attacked, killed, and consumed a variety of fishes including tubenose gobies, rainbow darters (*Etheostoma caeruleum*), and greenside darters (*Etheostoma blennioides*) (Jude et al. 1995). One goby also was observed consuming a 51-mm adult trout perch (*Percopsis omiscomaycus* ) (Jude, pers. obs.). Under natural conditions, however, these species likely would be able to escape round gobies.

## PREDATORS

In the Azov, Caspian, and Aral seas, Gobiidae (including *N. melanostomus*) are or were an important food source for commercially

**Table 5. Occurrences of taxa in diet of round gobies from the Sea of Azov as a function of round goby size in cm (SL) (from Kovtun et al. 1974).**

| | Round goby length (sample size) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Taxon** | 6(29) | 7(31) | 8(63) | 9(54) | 10(46) | 11(73) | 12(26) | 13(20) | 14(26) |
| **Molluscs** | 60 | 75 | 72 | 73 | 73 | 71 | 67 | 53 | 57 |
| **Crustaceans** | 40 | 25 | 10 | 16 | 16 | 23 | 19 | 40 | 29 |
| **Worms** | 0 | 0 | 18 | 11 | 9 | 3 | 4 | 0 | 0 |
| **Fish** | 0 | 0 | 0 | 0 | 2 | 3 | 10 | 7 | 14 |

important pike (*Esox lucius*), sturgeon (*Huso huso, Acipenser guldenstadti colchicus, A. stellatus*), asp (*Aspius aspius*), and pikeperch (*Lucioperca lucioperca*) (Nikol'skii 1954; Yablonskaya 1979). A decline in sturgeon in the Sea of Azov has been linked to the decline in round gobies (Abedikova 1980). In the Volgograd Reservoir, bighead gobies (*N. kessleri*) consume round gobies (Gavlena 1977). Seals and dolphins prey on round gobies in the Black and Caspian seas (Moskal'kova 1996). In the Black Sea, the main enemies of round goby fry are shrimp (*Leander*), isopods (*Idotea*), amphipods (*Gammarus*), and barnacle nauplii (Logachev and Mordvinov 1979). The swimming speed and activity of newly hatched gobies are ≤0.5 times that of their predators. By the third day after hatching, however, round goby swimming speed approximates the speed of their invertebrate predators (Logachev and Mordvinov 1979).

In North America, Jude et al. (1995) examined stomach contents of fish randomly caught from the St. Clair River for evidence of predation on the goby. Of five walleye (*Stizostedion vitreum*) examined, one had eaten two gobies. Smallmouth bass (*Micropterus dolomieui*), rock bass (*Ambloplites rupestris*), tubenose gobies, and stonecats (*Noturus flavus*) also had eaten round gobies. Stomachs of yellow perch (*Perca flavescens*) contained round goby young-of-the-year. Cannibalism also occurs as described previously.

## PARASITES

Parasites of 11 fishes (including *N. melanostomus*) from the Aral Sea and lower reaches of Amu-Darja River were examined by Yusupov and Urazbaev (1980). Parasites of these fishes included nine species of Urceolariids: *Trichodina acuta* Lom. *Trichodina domerguei* (Wallengren), *Trichodina* spp., *Trichodinella nigra luciopercae* Lom. *Trichodinella* spp., and *Tripartiella* (*Paratrichodina*) *incisa* Lom.

Seven species of parasites (*Diplostomum* sp., *Eustrongylides tubifex, Rhabdochona decaturensis, Spinitectus* sp., *Spiroxys* sp., *Leptorhynchoides thecatus*, and glochidia) were found in 144 gobies collected from the St. Clair River and Lake St. Clair (Michigan) during June-September 1994 (Muzzall et al. 1995). More species parasitized gobies from Lake St. Clair than gobies from the St. Clair River. *Diplostomum* sp. occurred most frequently in fish from both locations. All seven species parasitize other fishes in Lake Huron and Lake Erie, indicating that parasites arriving with round goby colonizers have not become established in the Great Lakes (Muzzall et al. 1995).

Of approximately 67 gobies collected from Hammond Marina (Indiana), 4 had parasites. Three of these four fish were parasitized by *Acanthocephalus dirus*, and one was parasitized by an unidentified nematode (Camp, Purdue University-North Central, pers. comm.).

## POPULATION DYNAMICS

In the Sea of Azov, the goby population has fluctuated widely from 10.1 billion to 2.3 billion individuals ($184 \times 10^6$ to $11 \times 10^6$ kg) during the period 1956-1973 (Kovtun et al. 1976). A population decline during 1968-1972 prompted a variety of hypotheses concerning causes of the decline, such as siltation of spawning sites, storms during the reproductive season, high production following harsh winters, and varying food supply for immature gobies (Kovtun et al. 1976). Kovtun et al. (1976) suggested that hypotheses related to these factors were unsubstantiated. They stated that the population dynamics in the Sea of Azov were controlled by a rapid recruitment rate, which is due to the short life cycle, repeat spawning, early maturation, and high fecundity of the round goby. Kovtun et al. (1976) showed that round goby stocks were significantly related to mollusc production (food supply), organic matter concentration (high concentrations can result in anoxic conditions), and water temperature. They found a correlation between the survival rate of first-year fish and their sex ratio; the sex ratio fluctuated widely between 1961 and 1975. Abedikova (1980) attributed the decline of the goby in the Sea of Azov to increased salinity during 1969-1977 caused by decreased inflow of fresh water.

In the Sea of Azov, 2-year old fish constituted the majority of the commercial catch (Kovtun et al. 1976). Average age of commercially caught fish in summer varied between 0.73 and 1.47 yr during 1968-1973. Dominant sizes in commercial catches in the Sea of Azov in 1939 were 130-160 mm (males) and 110-150 mm (females) (Berg 1949).

Information on round goby population dynamics in North America is limited. Existing information suggests only that they are highly fecund. For example, no round gobies were caught at Harsens Island in the St. Clair River delta in the fall of 1989. By the following spring, they composed most of the angling catch (Ghedotti et al. 1995).

## COMMERCIAL FISHERY USE

In the Black and Caspian seas, the round goby is fished commercially using trawls, fine-mesh seines, long-lines, and angling. Commercial catches in the northern Black Sea in the 1930s and 1940s were 3-4,000 tons (Skora 1996). During the same period, commercial catches in the Aral Sea ranged from 2,000 to 35,000 tons annually, with a record catch of almost 50,000 tons in 1956. Gobies are sold fresh (eaten fried or salted) or canned in a tomato sauce. Canning production ceased, however, with the decline of the fishery in the 1970s (Rudnicka, pers. obs.). Decline of the goby population is blamed on overfishing and habitat degradation, including harbor development, increased siltation, pollution, and eutrophication.

In the Gulf of Gdansk, the round goby is caught incidentally in eel traps (up to 50 kg/day/boat) and is becoming a popular sport fish near Gdynia (Skora 1996). Gobies currently sell for about $0.30/lb in Poland (Skora 1996).

## POTENTIAL IMPACTS

In its native range, the round goby does not negatively affect populations of any other species (Rudnicka, pers. obs.), although it can compete for food with sturgeon, bream, and roach (Nikol'skii 1954). This lack of negative effects is presumably because the goby has co-evolved and established an ecological equilibrium with these species. In the Black, Caspian, and Azov seas, the goby is prey for a number of sport and commercially sought species. Gobies may reduce populations of native fishes, such as eelpout (*Zoarces viviparus*) and black goby (*Gobius niger*), through competition for food and refugia (Skora 1996).

Observations in the St. Clair River suggest that mottled sculpin (*Cottus bairdi*) and logperch (*Percina caprodes*) populations have decreased coincident with an increase in the round goby population (Jude et al. 1995). Displacement of sculpins by gobies may be due to competition for food and/or competition for habitat, particularly spawning habitat. Both species are benthic feeders, benthic dwellers, and benthic spawners. Round gobies, however, are larger, more fecund, and more aggressive than native mottled sculpins (Jude et al. 1995; Dubs and Corkum 1996). Gobies have a longer reactive distance to *Daphnia* prey items in the dark than do mottled sculpins ($5.2 \pm 1.74$ versus $3.7 \pm 1.27$ mm), which suggests that gobies may have a competitive advantage in acquiring prey at night. Gobies also are aggressive and territorial during the breeding season. In aquaria, they have been observed to attack, kill, and consume smaller tubenose gobies, rainbow darters, and greenside darters (Jude et al. 1995). While these observations were made in an artificially confined situation, they indicate that gobies may drive native species from optimal habitats. Jude et al. (1992) suggested that because the round goby consumes primarily benthos, it may compete with and prey on eggs and juveniles of other benthivorous fish, such as logperch, mottled sculpin, and darters (Jude et al. 1995).

Decline of the logperch population in the St. Clair River may be due to predation of round gobies on logperch eggs (Jude et al. 1995). Logperch spawn in sandy areas and give no parental care. At night, round gobies move into these sandy areas and may be feeding on logperch eggs. Rainbow and johnny darter (*Etheostoma nigrum*) populations have not declined in the St. Clair River (Jude et al. 1995).

Round gobies also may negatively affect deepwater sculpins (*Myoxocephalus thompsoni*). In its native range, the goby overwinters at a depth of 60 m. Thus, in Lakes Superior, Michigan, Huron, and Erie, winter habitat of the goby would overlap with year-round habitat of the deepwater sculpin. These speculations are supported by a similar situation in Europe, in which introduction of a relative of the round goby, *Gobius niger*, into a Dutch lake caused a severe decline in the population of a congener of the deepwater sculpin (*Myoxocephalus scorpious*) (Jude et al. 1995).

Piscivorous fish consume round gobies, which in turn consume zebra mussels. Thus, the round goby indirectly makes zebra mussel biomass available to piscivores. Availability of zebra mussel biomass to piscivores may affect food webs (e.g., through increased piscivore populations), and may cause toxic substances (e.g., PCBs and mercury) ingested by zebra mussels to be incorporated into piscivore biomass. These toxic substances could then be passed to humans who consume piscivorous fish.

## MONITORING AND CONTROL

Standard fisheries sampling methods inadequately sample round goby populations. Angling can yield up to one goby per minute per angler using small hooks baited with worms or maggots (Marsden and Wolfe, unpubl. data). This method, however, generally is time-intensive, spatially limited, and biased toward larger individuals. We have not caught gobies <46 mm by hook-and-line. Bottom trawls permit sampling over a relatively large area, but optimal habitat for gobies (rocky cobble areas) is not optimal for trawling. Electroshocking is effective only in shallow water (<1 m) because gobies move downward when stunned, and thus are difficult to retrieve in deeper (>1 m) water (Thoma, Ohio EPA, pers. comm.). Seines are limited to use in nearshore areas, and minnow traps yield small catches per unit effort (Steingraeber et al. 1996; Marsden and Wolfe, unpubl. data). Goby densities can be estimated with quadrats by divers, but juveniles are difficult to see on complex substrata (e.g., cobble) and all ages likely hide under rocks. Quadrats can be used accurately on sand, but juveniles generally are more common than adults on this substratum (Marsden and Wolfe, pers. comm.). Nothing is currently known about responses of gobies to fish toxins.

Steingraeber et al. (1996) sampled portions of the Illinois Waterway System (e.g., Little Calumet River and Cal-Sag Channel) with minnow traps, Windermere traps, set lines, bottom trawls, seines, and hook-and-line. They concluded that trawling over rocky substrata was the most effective method. Capture rates were as high as 76 gobies/hr. However, trawls caught smaller gobies than other gears. Angling caught 0.140 gobies/hr, set lines caught 0.020 gobies/hr, and Windermere traps caught 0.002 gobies/hr.

The possibility that gobies will spread downstream to the Mississippi River through the Illinois Waterway System has stimulated efforts to create a dispersal barrier to prevent or restrict the downstream movement of the round goby. One dispersal barrier under consideration would attempt to confine the goby above the Des Plaines River (Keppner and Theriot 1997). This barrier would consist of two electrical barriers (separated by < 0.4 mi) in the Illinois Waterway System. If gobies are detected below the first electrical barrier, a chemical piscicide (e.g., rotenone) could be applied between the 2 barriers. The effectiveness of these methods on the round goby, however, needs to be examined.

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## FOREIGN JOURNAL TITLES AND TRANSLATIONS

| Journal | English Translation |
|---|---|
| Biol. Morya (Biologiya Morya) [Sea Biology] | Sov. J. Mar. Biol. (Soviet Journal of Marine Biology) |
| Dokl. Akad. Nauk. SSSR Ser. Biol. (Doklady Akademii Nauk SSSR Biological Science Section) | Dokl. Biol. Sci. (Doklady Biological Sciences) |
| Gidrobiol. Zh. (Gidrobiologicheskii Zhurnal) | Hydrobiol. J. (Hydrobiological Journal) |
| Mikrobiol. Zh. (Mikrobiologicheskii Zhurnal) | |
| Przegl. Zool. (Przeglad Zoologiczny) | |
| Tr. AzCherNIRO (Azov-Black Sea Research Institute for Sea Fisheries and Oceanography, Kerch) | |
| Trudi Daghestansksqo Ped. Inst (Transactions of the Daghestan Pedagogic Institute) | |
| Vestn. Mosk. Univ. Ser. 16, Biol. (Vestnik Moskovskogo Universiteta Seriya 16 Biologiya) | |
| Vestn. Zool. (Vestnik Zoologii) | |
| Vopr. Ikhtiol. (Voprosy Ikhtiologii) | J. Ichthyol. (Journal of Ichthyology) |
| Zh. Evol. Biokhim. Fiziol. (Zhurnal Evolyutsionnoi Biokhimii i Fiziologii) | |
| Zool. Pol. (Zoologica Poloniae) | |
| Zool. Zh. (Zoologicheskii Zhurnal) [Journal of Zoology] | |

## ANNOTATED BIBLIOGRAPHY *

* Portions of some of the following translated abstracts have been edited for brevity and clarity.

**Abedikova, T.M. 1980. Some regularities in the growth of sturgeons Acipenseridae in the Sea of Azov, USSR. Vopr. Ikhtiol. 20:473-480.**
Language: RUSSIAN
Weight and age were determined annually in approximately 570 specimens of *Acipenser guldenstadti colchicus* and 700 specimens of *A. stellatus* from 1960 to 1977. Temperature and flow of fresh water from rivers were the most important and most variable factors in marine food productivity levels. The 1960-1964 period was characterized by high inflow of river water with corresponding lower salinity of sea water and the 1969-1977 period by low inflow of fresh water and increased salinity of sea water. The wide range of annual fluctuations in average size of sturgeon groups of the same age was caused by temperature effects during the most critical (autumn-spring) fattening period. Growth compensation (related to life span, late maturity, and spawning, which did not occur every year) was realized with a 2-3 yr. periodicity under different salinity levels. At similar temperatures a decrease in average fish length during periods of greater salinity was observed beginning at the age of maturity. The difference in growth increased with age. Linear growth of younger-aged groups remained the same. Decreased growth rates in older groups were related to a decrease of *Neogobius melanostomus* (basic food of older groups) due to greater salinization and to the separation of habitats of predator and prey.

**Belokopytin, Y.S., and G.E. Shul'man. 1987. Temperature correlation of energy metabolism in fish in the Black Sea and in the Sea of Azov, USSR. Gidrobiol. Zh. 23:61-64.**
Language: RUSSIAN
The dependence of energy metabolism (by oxygen) on temperature in six species of fish (little and common mullets, atherine, high body pickerel, whiting, *Neogobius melanostomus*) was determined from the authors' data and those available in literature. The temperature coefficient Q10 is calculated on the basis of the average values of oxygen uptake per mass unit by the equation Q = ak for the temperature range of 2.5-27°C. The Q10 for each species of fish decreases when the temperature rises. Average species values of the coefficient in cryophilic species within the range of 10-20°C are higher than in thermophilic ones (limits of 1.74-2.74). The average value of Q10 for all the studied species at 10-20°C equals 2.18.

**Bilko, V.P. 1968. Fecundity of commercial gobiids (Gobiidae) of the Dnieper Bug estuary, USSR, *Neogobius fluviatilis*, *Neogobius melanostomus*, *Neogobius syrman*, *Mesogobius batrachocephalus*. Zool. Zh. 47:1045-1053.**
Language: RUSSIAN
In the Black Sea gobiids *Neogobius fluviatilis, N. melanostomus, N. syrman,* and *Mesogobius batrachocephalus,* an interrelation is revealed between the amount of roe laid for one time and number of portions laid by separate species. More fecund gobiid species are characterized by an earlier spawning.

**Bilko, V.P., and L. I. Vybornaya. 1972. Age variability of fish from the family Gobiidae. Vestn. Zool. 6:36-41.**
Language: RUSSIAN
Age variability of plastic characters was studied in males and females of *Neogobius melanostomus* (Pallas) and *Mesogobius batrachacephalus* (Pallas) from the family Gobiidae in the Dnieper-Bug liman.

**Bitukova, Y.E., N.K. Tkachenko, and A.V. Chepurnov. 1980. Tolerance of *Neogobius melanostomus* (Pallas) fry to fasting under artificial conditions. Sea**

**Ecology 1:92-98.**
Language: RUSSIAN
We studied the point of no return during starvation (26 days); includes histological analyses of tissues. (translated by S. Rudnicka).

**Bogachik, T.A. 1967. Morphological adaptations in the digestive apparatus of the Black Sea Gobiidae. Vopr. Ikhtiol. 7:108-116.**
Language: RUSSIAN
Includes excellent figures depicting morphological differences between *Neogobius melanostomus* and *N. fluviatilis*: teeth, muscles of jaw, and molariform teeth. (translated by S. Rudnicka).

**Chekunova, V.I. 1974. Rate and level of metabolism in fishes of different ecological groups. Vopr. Ikhtiol. 14:312-319.**
Language: RUSSIAN
It has been established that the level of ordinary metabolism of sea fishes, measured within the temperature limits of their range, is dependent on mode of life (membership of a benthic, benthopelagic, or pelagic ecological grouping) and, within the same ecological group, on the geographic location of the species range, which determines the degree of stenothermy. Metabolic level may vary appreciably in fishes in the course of the year. The amplitude of these alterations depends on the range of temperature fluctuations within the range of the species. These fluctuations are indiscernible in the most stenothermal species and slight in fishes of northern latitude, but in the fishes of our southern seas, the extreme values of metabolic level differ by 5 to 6 times.

**Chekunova, V.I. 1983. Ecological groups of marine cold-loving fishes and their energy metabolism. Vopr. Ikhtiol. 23:829-838.**
Language: RUSSIAN
Five ecological groups (pelagic fishes, coastal benthopelagic-pelagic fishes, benthopelagic-pelagic fishes, benthopelagic fishes, and Chaenichthyidae) were isolated among cold-loving fishes of the world on the basis of experimental data and data from the literature. Species considered were *Clupea harengus membras*, *Gadus morhua callarias*, *Sprattus fuegensis*, *Notothenia ramsayi*, *N. rossi marmorata*, *N. gibberifrons*, *N. corriceps neglacta*, *Pseudochaenichthus georgianus*, *Chaenocephalus aceratus*, *Sarda sarda*, *Salmo trutta trutta*, *Gobio gobio*, *Phoxinus percnurus*, *Symphodus ocellatus*, *Umbrina cirrosa*, *Scorpaena porcus*, *Platichthys flesus luscus*, *Neogobius melanostomus*, *N. syrman*, and *Engraulis encrasicholus*. The groups differ in their mode of life, diet, and the rate of metabolism. Mathematical reliability of the differences between the levels of metabolism was established for all groups. The highest metabolism level was found in pelagic fishes; it decreased in the following sequence: coastal benthopelagic-pelagic fishes, benthopelagic-pelagic fishes, benthopelagic fishes, and Chaenichthyidae.

**Daoulas, C., A.N. Economou, T. Psarras, and R. Barbieri-Tseliki. 1993. Reproductive strategies and early development of three freshwater gobies. J. Fish Biol. 42:749-776.**
Three species of gobiid fish inhabit the freshwater Lake Trichonis of western Greece. Two of these species, *Economidichthys pygmseus* and *E. trichonis*, are endemic, and the third is the widespread *Knipowitschia caucasica*. There are habitat separations between the three species. *E. pygmaeus* and *E. trichonis* prefer vegetated areas, the first being fully demersal at all stages of development and the second being semi-demersal. *Knipowitschia caucasica* prefers sandy bottoms and is distributed in shallower waters. Female *E. pygmaeus* and *E. trichonis* spawn in nests prepared by the males in the cavities of broken reeds. The males subsequently guard the eggs until they hatch, with females playing no role in

parental care. *E. trichonis* is probably the smallest freshwater European species. Its eggs are ovoid, measuring about 0.64 x 0.58 mm, from which tiny unpigmented and incompletely developed pelagic larvae hatch out after an incubation period lasting less than 1 day at a water temperature of 19.5°C. The eggs of *E. pygmaeus* are cylindrical and larger, measuring about 2.38 x 0.89 mm, from which relatively large, strongly pigmented and ontogenetically more advanced larvae hatch out after a longer incubation period. Both species reproduce only once in their lifetime, at the age of 1 year, and die shortly after spawning, but the breeding season involves several spawnings by each individual fish. These biological, developmental, and reproductive characteristics are discussed in relation to current theories on evolution of life histories.

**Dobrovolov, J.S., T.U. Georgiev, and S.G. Dobrovolova. 1995. Comparative electrophoretic investigations of the species of the family Gobiidae (Pisces) in the Bulgarian sector of the Black Sea. Proceedings of the Institute of Fisheries (Varna) 23:48-68.**

Language: RUSSIAN

Comparative investigations on the myogens, hemoglobins, and seven enzymic systems, such as EST, LDH, MDH, ME, SOD, PGM, and 6PGDH, of 19 species of the family Gobiidae (12 of these species belong to the genera *Gobius*, *Neogobius*, *Mesogobius*, and *Zosterisessor* ) were performed by using horizontal starch-gel electrophoresis and isoelectric focusing. According to the electrophoretic approach to biochemical systematics (total electrophoretic motility of LDH tetramer $B_4$ and genetic distance), which is in agreement with the morphological analyses of one coauthor, the aforementioned four genera should be united into three and arranged as follows: a) genus *Gobius* - Mediterranean immigrants (*G. niger*, *G. cobitis*, *G. paganellus*, and *G. ophiocephalus*); b) genus *Neogobius* - relic pontocaspian species with two subgenera - *Mesogobius* (*M. batrachocephalus* and *M. gymnotrachelus*) and *Ponticola* (*N. platyrostris*, *N. cephalargoides*, *N. ratan* and *N. kessleri*); and c) genus *Apollonia* (*N. melanostomus* and *N. fluviatilis*). The rest of the species, such as *Aphya minuta*, *Pomatoschistus minutus*, *Pomatoschistus marmoratus*, *Knipowitschia caucasica*, *Benthophiloides branneri*, and *Benthophilus stellatus*, are well-differentiated in species as well as in generic relation. A myogenic polymorphism was established with *N. melanostomus* (unilocus, two-allelic), a lactate dehydrogenase one with *P. marinoratus* (Ldh A-locus, two-allelic), an esterase one with *N. platyrostris* (unilocus, two-allelic) and *N. cephalargoides* (unilocus, three-allelic), and a malate dehydrogenase one with *N. platyrostris* and *P. marmoratus* (unilocus, two-allelic).

**Dokholyan, B.K., and A.K. Magomedov. 1983. The effect of sodium naphthenate on the viability and physiological and biochemical indices of fish. Vopr. Ikhtiol. 23:1013-1019.**

Language: RUSSIAN

Three-year-old sturgeon (*Acipenser guldenstadti*) and round goby (*Neogobius melanostomus*), yearling and 3-year-old vobla (*Rutilus rutilus caspicus*), and 2-month-old *R. frisii kutum* and chum (*Oncorhynchus keta*) fingerlings were studied. The fish inhabited the Caspian Sea (USSR). Substantial deviations of the blood parameters and carbohydrate metabolism were observed in fish with a relatively high viability. The harmless concentrations of sodium naphthenate were 0.5 and 1.0 mg/l with respect to hematological and biochemical parameters. The dose of 0.15 mg/l was recommended as the maximum permissible concentration of sodium naphthenate in sea water, taking into consideration the presence of other hydrobionts that were more sensitive to this compound than the fish.

**Dokholyan, V.K., A.M. Akhmedov, T.P. Akhmedova, and G.S. Shleifer. 1981. Mercury accumulation and its effect on fishes. Vopr. Ikhtiol. 21:537-547.**
Language: RUSSIAN
Mercury accumulation and distribution in fish organs and tissues and its effect on survivability as well as physiological-biochemical indices of the blood and brain were studied in the sturgeon, *Acipenser guldenstadti*; the roach, *Rutilus rutilus caspicus*; the Caspian round goby, *Neogobius melanostomus affinis*; the kutum, *R. frisii kutum;* and the keta, *Oncorhynchus keta*. Natural immunity factors were also studied. Experiments were conducted using 150-L tanks (sturgeon, roach, round goby) and small aquariums (kutum, keta) at 20-22°C and 1-30-day exposures using $HgCl_2$ at 1-100 µg/L. Critical levels of Hg accumulation were determined for each species. The experiments demonstrated that metabolic processes were inhibited or altered and blood protective functions were weakened when Hg accumulation reached critical levels in the fish body.

**Dokholyan, V.K., G.S. Shleifer, T.P. Akhmedova, and A.K. Magomedov. 1980. Effect of dissolved petroleum products on the vital activity of some Caspian Sea fish species. Vopr. Ikhtiol. 20:733-738.**
Language: RUSSIAN
The effect of dissolved petroleum fractions on *Acipenser guldenstadti, Rutilus rutilus caspicus, Neogobius melanostomus affinis, Abramis brama orientalis, R. frisii kutum*, and *Oncorhynchus keta* was studied. Sensitivity of different species to dissolved petroleum differed. Significant deviations were revealed in hematological, immunological, and biochemical indices, whose degree of expression depended on the concentration of the petroleum fractions and the duration of the experiment.

**Drokin, S.I., E.F. Kopeika, and V.I. Grishchenko. 1989. Spermatozoa of marine and freshwater fish species: characteristics of their lipid composition and differences in cryoconservation resistance. Dokl. Akad. Nauk. 304:1493-1496.**
Language: RUSSIAN
A study was made of differences in the cryoconservation resistance between the spermatozoa of marine and freshwater fishes (*Psetta maeotica, Neogobius melanostomus, Cyprinus carpio, Ctenopharygodon idella, Mullus barbatus, Diplodus annularis, Sarotherodon mossambicus, Lepomis gibbosus*, and *Ictiobus cyprinellus*) and of the way in which these differences are reflected in lipid composition. Thin layer and gas-liquid chromatography were used to study the composition of neutral lipids and phospholipids, and fatty acid characteristics of phosphatidylcholine, phosphatidylethanolamine, and their plasmalogens. The spermatozoa of marine fish species were found to be more cryoresistant than those of freshwater fishes. The fatty acids of marine fishes were, in most cases, more unsaturated than those in the spermatozoa of freshwater fishes. The cholesterol-phospholipid ratio was 2.5-3 times higher in all marine fishes.

**Falandysz, J., K. Galecka, and W. Czarnowski. 1994. Fluorine in selected tissues of some species of Baltic birds, molluscs, and fish. Bromatologia I Chemia Toksykologiczna 27:359-365.**
Language: POLISH
Fluorine was detected in the bones and feathers of marine birds (*Phalacrocorax carbo, Gavia stellata, Podiceps cristatus, Cepphus grylle, Clangula hyemalis*, and *Aythya fuligula*), bones of fish (*Neogobius melanostomus, Platychthis flesus, Gadus morhua*), and shells of molluscs (*Mytilus edulis, Macoma baltica*, and *Cardium glaucum*) taken from the Gulf of Gdansk and northwestern Poland. Our investiga-

tions suggest a background concentration of fluorine exists in the examined animals. Fluorine pollution was associated with the presence of a phosphate fertilizer plant and a landfill depot of phosphate wastes located in close vicinity of the Gulf of Gdansk. Further investigation into the bioaccumulation of fluorine in a wide variety of animals from the Gulf and dead Vistula Channel is necessary.

**Gavlena, F.K. 1977. The bighead goby, *Neogobius kessleri*, in Volgograd Reservoir. J. Ichthyol. 17:318-319.**
Studies of *Neogobius kessleri* in the Volgograd Reservoir [Russian SFSR, USSR] showed that this species has successfully populated areas of sandy-pebbled substrate in the lower and middle parts of the reservoir. Morphologically, the fish from the reservoir differed very little from those found at the mouth of the Volga. The gobies in the reservoir were bottom feeders, and thus, competed with some valuable commercial fish species. Their intestinal contents included Gammaridae (primarily *Dikerogammarus haemobaphes*), *Neogobius kessleri* and *N. melanostomus*, *Paramysis lacustris*, Corophium, terrestrial insects, *Dreissena polymorpha*, and plant remnants. The parasitic nematode, *Camallanus truncatus*, was found in the intestines of 39% of the specimens studied. The gobies spawned in June on coastal rocks.

**Il'in, B.S. 1927. Identification of gobies (Gobiidae) of the Azov and Black seas. Tr. Azov- Chernomor. Nauch.-Promysl. Edspeditsii 2:128-143.**
Language: RUSSIAN and GERMAN
Provides information on diet, food, and first descriptions of gobies (round, tubenose, and other species) in the northwest region of the Black Sea; the round goby is named *Apollonia*. (translated by S. Rudnicka).

**Jude, D.J., and S.F. DeBoe. 1996. Possible impact of gobies and other introduced species on habitat restoration efforts. Can. J. Fish. Aquat. Sci. 53:136-141.**
Many fish habitat modifications involve riprap placement on sandy substrate. Because exotic species may be favored, a field experiment was designed to test differences in fish abundance in riprap, sand, and macrophyte-dominated substrate. We used a 3-m-long seine to sample areas of sand, riprap (N = 5 each), and aquatic macrophytes (N = 2) three times during 1994 in the St. Clair River near Algonac, Michigan. Diversity was high, with 24 species of fish collected. Round gobies (*Neogobius melanostomus*) were most often collected in riprap and macrophyte habitat, with riprap habitat having a significantly greater mean catch on 16 August. On the other two dates, mean catches were not significantly different between macrophyte and riprap habitat, but both were significantly greater than the mean catch in sandy areas. Densities of tubenose gobies (*Proterorhinus marmoratus*) were similar between sandy and macrophyte habitats, but significantly greater in riprap habitat. Gizzard shad (*Dorosoma cepedianum*), alewife (*Alosa pseudoharengus*), and white perch (*Morone americana*) were mostly associated with open water sandy habitat. Zebra mussels (*Dreissena polymorpha*) were common on riprap substrate but were rarely seen on sandy substrate. Fishery managers must be cautious in their selection of habitat modification choices to avoid favoring undesirable species.

**Jude, D.J., R.H. Reider, and G.R. Smith. 1992. Establishment of Gobiidae in the Great Lakes basin. Can. J. Fish. Aquat. Sci. 49:416-421.**
A tubenose goby (*Proterorhinus marmoratus*), a European endangered species native to the Black and Caspian seas, was recovered on 11 April 1990 from the traveling screens of the Belle River Power Plant located on the St. Clair River, Michigan [USA]. Subsequently, anglers caught three round gobies (*Neogobius*

*melanostomus*) in the St. Clair River near Sarnia, Ontario (Canada). Thirty-one tubenose gobies and eleven round gobies were impinged or trawled at or near the power plant in the fall and winter of 1990-1991. Nine round gobies (29-61 mm total length) are believed to be young-of-the-year. These species were probably transported to the Great Lakes in ballast water, may have successfully colonized the St. Clair River, and will probably spread throughout the Great Lakes. They are expected to directly impact other benthic fishes, such as sculpins (*Cottus* spp.), darters (*Etheostoma* spp.), and logperch (*Percina caprodes*), and in turn act as prey for walleye (*Stizostedion vitreum*).

**Juszczyk, D. 1975. Studies on the morphology of gonadal blood vessels in certain bony fishes (Teleostei). Zool. Pol 24:393-454.**
Provides detailed anatomical description of oocytes and gonads and associated organs in males and females of several species, including *Neogobius melanostomus*.

**Juszczyk, D. 1976. Appearance of pathologic changes in the ovaries of certain gobies (Gobiidae) raised in aquaria. Przegl. Zool. 20:338-342.**
Language: POLISH
The ovaries of *Mesogobius batrachocephalus* and *Neogobius melanostomus* undergo pathologic changes upon completion of spawning. The hindered resorption of the nonextricated oocytes and the accompanying necrosis of the ovarian wall may be the cause of death in females.

**Kalinina, E.M. 1976. Reproduction and early development of gobies from the Azov and Black seas. Kiev, Nauk Dumka, Russia.**
Language: RUSSIAN
Provides descriptions of early life stages and development of tubenose, round, and other gobies. (translated by S. Rudnicka).

**Kazanskii, A.B. 1982. Studying a fish community in the Tsimlyanskoye Reservoir, Russia, USSR, using a mathematical model. Vopr. Ikhtiol. 22:355-364.**
Language: RUSSIAN
The condition of seven commercial fish spp. populations was described using a mathematical model from the literature: *Blicca bjoerkna, Abramis brama, A. ballerus, Pelecus cultratus, Stizostedion volgense, S. lucioperca* and *Silurus glanis*. *Clupeonella cultriventris caspia, Neogobius melanostomus, N. fluviatilis, Benthophilus stellatus*, and 24 other fishes were also included in the model. The model described the dynamics of fish numbers and biomass for many years with regard to trophic relations and changes in spawning conditions. The model was studied for sensitivity to changes in parameters and structure. Problems in optimizing catch in selective and nonselective fishing were discussed. The strategy of variable intensity and the strategy of variable selectiveness of fishing were proposed.

**Kobegenova, S.S. and M.K. Dzhumaliev. 1991. Morphofunctional features of the digestive tract in some Gobioidei. Vopr. Ikhtiol. 31:965-973.**
Language: RUSSIAN
The structure of the digestive tract was studied in *Mesogobius batrachocephalus, M. gymnotrachelus, Neogobius ophiocephalus, N. ratan, N. melanostomus, N. fluviatilis*, and *Periophthalmus sp.* In the majority of the species, no anatomical differentiation of the stomach was observed. However, gastric glands were found at the beginning of the foregut. The number of the glands and their size vary in different species. No mucus was found in the gastric epithelium. The absence of secretory granules was found to be characteristic of gastric gland cells, which points to the absence of gastric functional activity. Reasons for the loss of gastric digestion in Gobioidei is discussed.

**Kostyuchenko, V.A. 1961. Age and growth of the round goby *N. melanostomus* (Pallas) in the Azov Sea. Tr. AzCherNIRO 19:45-60.**
Language: RUSSIAN
Until 1952 scientists used vertebrae for aging gobies. This paper contains pictures of otoliths and is the first describing use of otoliths for aging gobies. Fast-growing fish die earlier, and males and females grow at different rates. If food is abundant, gobies grow, but their condition stays the same under low and high ration levels, regardless of size. This paper gives the percentage of the population that formed an annulus by a given date, usually April or May, but it varied. Growth compensation was recorded. (translated by S. Rudnicka).

**Kovtun, I.F. 1979. Significance of the sex ratio in the spawning population of the round goby, *Neogobius melanostomus*, in relation to year-class strength in the Sea of Azov. J. Ichthyol. 19:161-163.**
Material gathered during 1961-1975 indicated that one significant factor in the formation of population fecundity is the sex ratio in the spawning population, with the most favorable ratio being about 1:1. At the present time, with the population of immature gobies in the Sea of Azov at its lowest point (2-3 billion individuals), the spring fishing, based on the catch of males, should be discontinued.

**Kovtun, I.F., M.Y. Nekrasova, Y.A. Dombrovskii, and N.I. Revina. 1976. Application of regression analysis for forecasting the size of the round goby stock in the Sea of Azov. Hydrobiol. J. 12:37-41.**
Linear regression models are given for the number of *Neogobius melanostomus* (Pallas) [in the Azov Sea, USSR]. Coefficients of multiple correlation for number and biomass are equal to 0.85 and 0.84, respectively. Using the models obtained, the number and biomass of *N. melanostomus* (Pallas) may be predicted 1 year in advance.

**Kulikova, N I. 1985. Effect of chorionic gonadotropin on the growth and maturation of oocytes in the Caspian round goby, *Neogobius melanostomus* (Gobiidae). J. Ichthyol. 25:86-98.**
The possibility of using choriogonin for the stimulation of oocyte growth and maturation was studied in *Neogobius melanostomus*. Physiologically favorable doses of choriogonin may be an effective stimulator of trophoplasmic growth of egg cells in *N. melanostomus*. Oocytes of various vitellogenesis phases had various reactions to hormonal action. The intensification of vitellogenesis after administration of choriogonin was observed only in the yolk accumulation phases of oocytes. Egg cells from earlier stages of vitellogenesis (cytoplasm vacuolation and fat deposition) were beyond the sphere of hormonal action. Presumably, the stimulating effect of choriogonin manifested itself in the intensified secretory activity of follicular epithelium cells and increased synthesis of sex steroid hormones.

**Kunin, M.A. 1980. Biological indices of the eastern bream *Abramis brama orientalis* in relation to varying availability of food in water bodies. Vopr. Ikhtiol. 20:635-643.**
Language: RUSSIAN
By 1969-1970 the eastern bream had become slow growing and its biological indices had decreased as a result of the deterioration of the fodder base of the Aral Sea and a decrease in the biomass of Chironomidae larvae from 7.16 $g/m^2$ (1954) to 0.79 $g/m^2$ (1967). In comparison with 1940-1950, slower linear and gravimetric growth, decreased absolute fertility, earlier maturation with smaller dimensions, and decreased fatness were noted in bream. In addition to Chironomidae, fodder contained Cladocera, Copepoda, Insecta (imago), Polychaeta, and Mollusca. *Neogobius melanostomus* (Pallas), *N. fluviatilis* (Pallas), and *Atherina mochon pontica* (Eichwald) were present in the Aral Sea.

Analogous changes in biological indices of eastern bream were observed during its acclimatization in oligotrophic water bodies of Central Asia and Kazakh, USSR.

**Kuz'mina, V.V. 1990. Biocenotic aspects of the physiology of hydrobiont feeding. Ekologiya (Sverdl) 0:52-58.**
Language: RUSSIAN
Hypotheses about the significant contribution of the enzymes of an ingested organism during the digestive processes of a predator and the appreciable adaptivity of the enzyme systems of trophic partners were studied. The hypotheses were substantiated by comparing the level of activity of certain hydrolases supporting the depolymerization of protein and carbohydrate components in the tissues of food objects by the enzymes of the predator and by the enzymes within the food objects. The following 15 species are discussed: (*Lota lota*, *Esox lucius*, *Aspius aspius*, *Abramis brama*, *Rutilus rutilus*, *Blicca bjoerkna*, *Cyprinus carpio*, *Silurus glanis*, *Perca fluviatilis*, *Squalis acanthias*, *Gaidropsarus mediterraneus*, *Trachurus mediterraneus ponticus*, *Spicara smaris*, *Scorpaena porcus*, *Neogobius melanostomus*.)

**Kuz'mina, V.V. 1992. Digestive enzyme activity of the intestinal mucosa in ecologically different teleost fish in the Black Sea. Vopr. Ikhtiol. 32:141-148.**
Language: RUSSIAN
The activity of principal enzyme groups responsible for membrane digestion was studied in *Gaidropsarus mediterraneus*, *Merlanguis merlangus euxinus*, *Liza aurata*, *Serranus scriba*, *Pomatomus saltator*, *Trachurus mediterraneus ponticus*, *Sciaena umbra*, *Diplodus annularis*, *Spicara smaris*, *Mullus barbatus ponticus*, *Symphodus tinca*, *Neogobius melanostomus*, *Mesogobius batrachocephalus*, *Neogobius ratan*, *Scorpena porcus*, and *Platichthys flesus luscus*. The effect of some ecological factors, feeding in particular, on the functions of the enzymes was described.

**Logachev, V.S., and Y.E. Mordvinov. 1979. Swimming speed and activity of larvae of round goby and some predatory crustaceans of the Black Sea. Sov. J. Mar. Biol. 5:227-229.**
The authors experimentally determined the swimming speed and activity of round gobies (*Neogobius melanostomus*) at age 0-2 days and also of the main enemies of its larvae, the predatory invertebrates shrimp (*Leander*), *Idotea*, *Gammarus*, and nauplii of barnacles. It is established that the speed of recently hatched larvae of round gobies is half or less than half of that of the predators, and their activity is 2-5 times lower. On the third day after hatching, their swimming speed reaches the average speed of the predatory invertebrates, but they still lag behind in activity. The indicators obtained for larvae of round gobies and other fishes (anchovy, scad, red mullet, and crucian carp) allow us to assume that the highest number of deaths of the larvae as the result of their being eaten by invertebrates occurs at the earliest stage of development.

**Matyjewicz-Juszczyk, D. 1973. Capillary networks of the ovarian follicles in *Mesogobius batrachocephalus* and *Neogobius melanostomus*. Zool. Pol. 22:215-226.**
The ovarian follicles, like the oocytes, show a geoidal shape in both species. The arterial pole of the follicle is placed above the animal pole of the oocyte, and the venous pole above the vegetative pole. The arterial pole is supplied by one or more arterioles, while several venules leave the venous pole. In both species the capillaries disperse radially from the arterial pole and converge at the opposite pole into a characteristic vascular ring with efferent venules. The capillaries form a network composed of a few meshes in the venous ring of *Neogobius melanostomus*, while the center of the ring is devoid of vessels in *Mesogobius batrachocephalus*. The total length of vessels in a 1-$mm^2$ area and a 1-$mm^3$ volume of the follicle in *Mesogobius*

*batrachocephalus* was calculated in various stages of the oocyte growth. The results were compared with the vascular network of mature follicles in the flounder, carp, pond-loach, rainbow trout, and *Mesogobius*.

**Mezhnin, F.I. 1979. Morphology and topography of interrenal and suprarenal glands of bony fishes. Biol. Nauki. 0:33-38.**
Language: RUSSIAN
Histological structure, topographic position, and interrenal and suprarenal glands were studied in 11 species of bony fish: *Caspialosa volgensis, C. caspia, Clupeonella delicatula, Clupeonella grimmi, Clupeonella engrauliformes, Syngnathus nigrolineatus caspius, Atherina mochon caspicus, Lucioperca marina, Benthophilus, Neogobius melanostomus,* and *Pomatoschistus caucasicus*. The fish represented 5 families: Clupeidae, Syngnathidae, Atherinidae, Percidae, and Gobiidae. Differences in the volumes of interrenal and suprarenal tissues in sea and freshwater inhabitants were shown, as well as histological structure, degree of association, and topographic position of these tissues, not only in representatives of various families but also in closely related species.

**Miller, P.J. 1984. Tokology of gobies. Pages 119-153 *in* G.W. Potts and R.J. Wootton, eds. Fish reproduction. Academic Press, Ltd., London.**
Use of the term "tokology" for reproductive biology is explained. The tokology of gobioid fishes is reviewed from four aspects: mode, machinery, dynamics, and fitness, with most attention paid to the last two. Mode concerns sexuality, sex ratios, and occurrence of hermaphroditism. Machinery is comprised of gonad structure, including special endocrine and exocrine glands of the testis and sperm duct, secondary sexual dimorphism, behavioral organization, and neuroendocrine control of reproduction, although the ethology and endocrinology of reproduction are not considered here in detail. As dynamics, the temporal pattern of energy and material deployment for reproduction is examined under the topics of reproductive effort, developmental phasing, frequency, bestowal, timing, and consequences for the reproducer. The adaptiveness of reproductive strategies, for maximizing fitness, is discussed with special reference to ecotopic predictability and also in relation to resource factors and intrinsic influence of body size.

**Moiseyeva, Y.B. 1983. The development of the gonads of the round goby, *Neogobius melanostomus* (Gobiidae), during the embryonic period. J. Ichthyol. 23:64-74.**
Segregation, migration, and concentration of the primary sex cells of *N. melanostomus* take place in the embryonic period, as does the formation of its gonads. Significant changes were found in the primary sex cells during their migration and concentration periods. The morphology of cell nuclei changed, as did the total number of cells and the number of gonocytes with polymorphic nuclei and inclusions in cytoplasm. A definite increase in primary sex cell size and number was determined with respect to embryo age. Mitoses of the sexual glands were not discovered. Apparently, the formation of sexual glands in the embryonal period was connected with the absence of the larval development stage in *N. melanostomus*, as well as with its relatively short life span.

**Moiseyeva, Y.B. 1984. Gonadal development during the indifferent period after hatching and sex differentiation in the round goby, *Neogobius melanostomus* (Gobiidae). J. Ichthyol. 24:83-95.**
A cytomorphological and quantitative study was conducted with *N. melanostomus* in the early ontogenetic stages after hatching. The morphological features of the primary sex cells and gonia of various generations were determined, as were their quantitative interrelations before the onset of sex differentiation. The indifferent period of

gonad development after hatching lasted from the 1st to the 15th day of goby life. Sex differentiation occurred between the 15th and 20th day. The anatomic differentiation of the ovary took place at the end of the first month of life. The total number of sex cells in the gonad increased due to mitotic division of primary sex cells and gonia. The decrease in the number of primary sex cells during sex gland development, and the increase in the number of gonia point to the interrelationship between these processes and make it possible to assume that in *N. melanostomus* there exists a single line of sex cells that started from the primary sex cell of embryos.

**Moiseyeva, Y.B. 1985. On functional identification of hypophyseal thyrotropic cells in the juvenile goby, *Neogobius melanostomus*. Zh. Evol. Biokhim. Fiziol. 21:171-176.**
Language: RUSSIAN
Experimental identification of hypophyseal thyrotropic cells in the young goby, *Neogobius melanostomus*, has been made by thiourea and metallibure treatment. It was shown that only thiourea significantly affects morphological properties of the basophils in the pituitary and thyroid glands, which may be taken as evidence of the increase in thyrotropic function of the hypophysis and compensatory intensification in the thyroid gland. The data obtained allowed us to identify the basophilic cells located between pro- and mesoadenohypophysis as the thyrotropic elements. The thyrotropic function of the hypophysis is differentiated in ontogenesis of the goby much earlier than the gonadotropic function.

**Moiseyeva, Y.B., and V.I. Rudenko. 1978. Spawning of the round goby *Gobius* ([*sic*] *Neogobius) melanostomus* Pallas in aquaria during winter. Vopr. Ikhtiol. 4:777-779.**
Language: RUSSIAN
Round gobies were induced to spawn in winter by increasing temperature. They spawned on clay plates and sides of aquaria; induction was very successful. (translated by S. Rudnicka)

**Moskal'kova, K.I. 1967. Morpho-ecological specifics of development of the round goby, *Neogobius melanostomus* (Pallas). Pages 48-75 *in* Morphological and ecological analysis of fish development. Nauka, Moskow.**
Language: RUSSIAN
Provides excellent taxonomic descriptions of eggs, developing fry, and juveniles. (translated by S. Rudnicka)

**Moskal'kova, K.I. 1971. Formation of eyes of the round goby, *Gobius* ([*sic*] *Neogobius) melanostomus* (Pallas), as connected with their ecology. Vopr. Ikhtiol. 5:840-859.**
Language: RUSSIAN
Includes description of eye with illustrations. (translated by S. Rudnicka)

**Moskal'kova, K.I. 1978. The influence of radioactive carbon $C^{14}$ on the development of the eggs of the round goby (*Neogobius melanostomus*). J. Ichthyol. 18:157-161.**
The effect of $C^{14}$ dissolved in water on the development of the eggs of *N. melanostomus*, unique in its ecological and ontogenetic characteristics, was studied. Low $C^{14}$ concentration [10-9 ci/L) had no negative effects on egg development, while incubation in a solution of 10-7 ci/L produced significant death of eggs in developmental stage VI (when the embryos form their caudal section). At a concentration of 10-5 ci/L, one-third of the individuals died before hatching without any visible signs of morphological impairment. There was a direct proportion between the $C^{14}$ concentration and death, while the number of birth anomalies was low and did not vary in different concentrations.

**Moskal'kova, K.I. 1989. Anatomical-histological and functional peculiarities of development of the intestine in the**

**round goby, *Neogobius melanostomus*, a species with direct type of development. J. Ichthyol. 29:108-122.**
Structural and functional features of the digestive system in early ontogeny are described in *Neogobius melanostomus*. The embryos were characterized by early anatomical and histological differentiation and functional maturity of the digestive organs. The intestine participated in endogenous food assimilation. Unusual embryonal "coprophagy," as a mechanism providing the assimilation of the protein component of yolk, was observed in the embryos.

**Moskal'kova, K.I. 1996. Ecological and morphophysiological prerequisites to range extension in the round goby *Neogobius melanostomus* under conditions of anthropogenic pollution. J. Ichthyol. 36:584-590.**
Based on both new data and previously published data, this study shows that the round goby, *Neogobius melanostomus*, lives under a remarkably wide range of conditions and is able to survive, breed, and develop within this wide range of environments. The unique morphophysiological traits providing the high efficiency of spawning and viability of juveniles in the early periods of the ontogeny are considered. These characters allow the species to survive the anthropogenic pollution of the seas and to settle in new reservoirs.

**Opalatenko, L.K. 1979. Feeding and food relationships of the monkey goby and southern harvest fish in the northern Caspian Sea, USSR. Gidrobiol. Zh. 15:84-85.**
Language: RUSSIAN
In the summer-fall of 1972-1973, 1,130 fish stomachs of *Neogobius fluviatilis* (Pallas) (Berg) and *N. melanostomus affinis* (Eichw.) from the northern part of the Caspian Sea were analyzed. During June-Aug. 1972, 42% of the weight of food found in the monkey gobies consisted of crustaceans (Gammaridae, Corophiidae, Cumacea). *Knipowitschia longicaudata* (Kessler) and *Hyrcanogobius bergi* Iljin were also found. *Abra ovata* and *Didacna* sp. accounted for 53.3% of rations of southern harvest fish. *Rhithropanopeus harrisii* were also present. In 1973, mollusks no longer predominated in the rations of the southern harvest fish and its food spectrum approached that of monkey goby.

**Pinchuk, V.I. 1970. An unusual goby specimen from the bay of Taman. J. Ichthyol. 5:689-691.**
This paper compares characteristics of the round goby, *Neogobius melanostomus*, and *N. fluviatilis*, including head, fins, and coloration. The paper also discusses a hybrid goby between these two species. (translated by S. Rudnicka).

**Pinchuk, V.I. 1991. Species groupings in the genus *Neogobius* (Perciformes). J. Ichthyol. 31:1-15.**
Discusses taxonomy of gobies including teeth. (translated by S. Rudnicka).

**Porumb, I.I. 1961. Contributions to the biology of gobies (*Gobius batrachocephalus, G. cephalarges, and G.* ([*sic*] *N.*) *melanostomus*) in the littoral zone of the Romanian Black Sea. Hydrobiologia 3:271-282.**
Language: ROMANIAN
Diet information for round gobies. (translated by S. Rudnicka).

**Rudneva-Titova, I.I. 1994. Correlation between the antioxidant enzyme activities and the processes of lipid peroxidation in the developing eggs of the Black Sea round goby. Ontogenez 25:13-20.**
Language: RUSSIAN
Changes in the activities of antioxidant enzymes (lipoxygenase, superoxide dismutase, catalase, peroxidase, and glutathione reductase) during the early development of the Black Sea round goby were studied with respect to the processes of lipid peroxidation. It was determined that

these activities increase by the end of embryogenesis and in larvae, accompanied by a decrease in concentration of triglycerides and an increase in concentrations of sterol and free fatty acids. The content of lipid peroxidation products (dien and trien conjugates and TBA-active substances) decreased by stage IV of development and increased by the end of embryogenesis and in larvae. At stage VI and in larvae, an increase in the lipid fluorescence was detected. The analysis of correlation between the antioxidant enzyme activities and the content of lipid fractions and lipid peroxidation products showed the average values of the correlation coefficient (r) were 0.3503 to 0.5249. The system of lipid peroxidation that largely depends on environmental factors proved to be the least stable (r = 0.3503), whereas lipids and lipids + lipid peroxidation were more stable systems (r = 0.5249 and 0.5124, respectively).

**Skazkina, E.P. 1966. On ecological differences in gobies from the Azov Sea (round and syrman gobies). Sci. Papers of AzCherNIRO 24:35-38.**
Language: RUSSIAN
Round gobies migrate from regions where dissolved oxygen is less than 50-60% of saturation, while *N. syrman* stays in areas where dissolved oxygen saturation is 20% because they can decrease their metabolism. A table for oxygen consumption of "hungry," immobile fish at a salinity of 10-11 ppt and 14°C is given. (translated by S. Rudnicka)

**Skazkina, E.P. 1972. On active metabolism of gobies from the Azov Sea. Tr. UNIRO 85:138-143.**
Language: RUSSIAN
Standard length of fish was 75-110 mm; standard metabolism was measured at different flow rates. Fish were measured over 24 hr; the maximum speed of round gobies was 34 cm/s for 3-4 min; after that they tried to keep close to the bottom. Fish were active 28.6% of the time (over 24 hr). Oxygen debt after 8-10 min of activity was paid after about 1 hour; therefore swimming correction for oxygen insufficiency should be about 15-20% of active metabolism (Qa). The mean metabolic rate was calculated to be 140% of standard metabolic rate and 50% of active metabolism. These figures were used to calculate food consumption of the round goby in the Azov Sea. (translated by S. Rudnicka)

**Skazkina, E.P., and V.A. Kostyuchenko. 1968. Food of *N. melanostomus* in the Azov Sea. Vop. Ikhtiol. 8:303-311.**
The paper presents the results of a study of food consumption of the kruglyak goby (a principal consumer of benthos in the Sea of Azov) by the respiration method. The amount of food consumed varies in the course of the year from 0.001 to 10% of its weight. The mean long-term annual food consumption of the kruglyak is 23 times its weight. In the course of a year the kruglyak population consumes 13% of the benthos in the Sea of Azov.

**Sokolov, L.I., and E.A. Tsepkin. 1992. The changes of ichthyofauna in the river systems of the Russian central region as the result of anthropogenic factors. Vestn Mosk Univ Ser Xvi Biol 0:33-39.**
Language: RUSSIAN
Changes of the species composition and relative numbers of the fishes in the Moscow River basin for the last 50 years have been revealed. *Rutilus rutilus* and *Alburnus alburnus* were shown to have become the dominating species at present. The numbers of *Abramis brama* as well as of *Perca fluviatilis* and *Stizostedion lucioperca* fry are appreciably higher than they were before. The numbers of the rheophilic fishes (*Chondrostoma nasus, Leuciscus leuciscus, Aspius aspius, Gobio gobio, Cottus gobio, Lota lota*) have sharply declined. Recently *Neogobius melanostomus* and *Proterorhinus marmoratus* have accidentally invaded the

**Soldatov, A.A. 1989a. Oxygen-binding blood function of *Neogobius melanostomus* during adaptation to temperature conditions of the environment. Gidrobiol. Zh. 25:58-62.**
Language: RUSSIAN
Restoration of blood affinity to oxygen in *Neogobius melanostomus* adapted to new environmental temperatures depends on an increase in the erythropoiesis intensity and entry of erythrocytes with changed intracellular ATP concentration into blood.

**Soldatov, A.A. 1989b. The activity of NADH-dependent methemoglobin reductase in the erythrocytes of the goby *Neogobius melanostomus* during cold adaptation. Zh. Evol. Biokhim. Fiziol. 25:772-774.**
Language: RUSSIAN
The level of hemoglobin oxidation during adaptation of fish to low temperatures is controlled by NADH2-dependent methemoglobin reductase of the erythrocytes. Recovery of the enzymic activity after prolonged acclimation of fish to new thermal conditions is realized at the level of the blood-forming tissue in a quantitative pattern.

**Soldatov, A.A. 1993a. Comparative investigation of oxygen-binding capacity of the blood in gobies from the Black Sea (genus *Gobius*). Zh. Evol. Biokhim. Fiziol. 29:327-330.**
Language: RUSSIAN
Studies have been made on three species of the gobies from the Black Sea: *Neogobius melanostomus*, *Gobius batrachocephalus*, and *Gobius ophiocephalus*. It was demonstrated that the blood of the most abundant species, *N. melanostomus*, exhibits high oxygen affinity (P-50 is equal to $12.6 \pm 0.5$ mm Hg), pronounced Bohr effect ($r = -0.31 \pm 0.02$), and low oxygenation heat ($\Delta H = -8.4 \pm 0.3$ kcal mol $O_2$). These features account for high viability and wide distribution of this species.

**Soldatov, A.A. 1993b. Experimental studies on the distribution of oxygen tension in muscles of marine fishes. Zh. Evol. Biokhim. Fiziol. 29:656-659.**
Language: RUSSIAN
Polarographic studies have been made on the distribution of oxygen tension in muscle tissue (P-$MO_2$) from six species of fishes with different natural activity. It was shown that P-$MO_2$ distribution in white and red muscles was not even. Zones with a high local P-$MO_2$ (close to venous one, i.e., 37.5-45.0 mm Hg), zones with extremely low P-$MO_2$ (less than 6.0 mm Hg), and absolutely anoxic regions were found. Mean values of P-$MO_2$ in red muscles of active fish ranged from 21.2 to 25.1 mm Hg, and in white muscles 5.6-6.3 mm Hg. Sedentary species exhibited ranges of 8.5-12.5 and 3.5-3.8 mm Hg, respectively. The observed differences are presumably due to the pattern of capillarization of muscle tissue.

**Sozer, F. 1941. Les Gobiides de la turque. Revue de la Faculté Sciences de L' Université D. Istanbul, Serie B, Vol. 6, Fasciele 1/2, Pa. 128-169.**
Language: FRENCH
Comparative paper on sizes of many species of gobies (including round gobies) in the Black Sea and adjoining Turkish inland lakes. (translated by S. Rudnicka).

**Trifonov, G.P. 1955. On reproductive biology of gobies from the Azov Sea. Tr. Karadagskoi Biol. Stantsii 13:5-46.**
Language: RUSSIAN
Describes distribution, spawning places, use of hypural plates for aging of fish, description of eggs, and fecundity. (translated by S. Rudnicka).

**Tsepkin, E.A., L.I. Sokolov, and A.V. Rusalimchik. 1992. The ecology of the round goby *(Neogobius melanostomus* [Pallas]) - a case of accidental acclimatization in reservoirs of the Moscow River**

**basin. Biol. Nauki. 0:46-51.**
Language: RUSSIAN
An investigation of the ecology of the round goby, *Neogobius melanostomus* (Pallas), was conducted after it penetrated the Moscow river basin. We established that the round goby became acclimatized and successfully spawned under new conditions. Data are presented on the size and age group, growth rate, feeding, and fecundity. The means by which this fish penetrated the basin of the Moscow River are considered.

**Tsyplakov, E.P. 1974. Expansion of the ranges of some fishes in connection with hydraulic engineering works on the Volga and acclimatization operations. J. Ichthyol. 14:343-351.**
The fish fauna of the Kubyshev Reservoir has been supplemented by the penetration of northern and southern forms. Some of them (Baltic lake smelt, Lake Beloye cisco, eel, and kilka) have penetrated naturally. Some (*Coreogonus peled*) have been introduced, and others (black-striped pipefish, round goby, and *Benthophilus* sp.) have been brought in accidentally from the Don estuary and Tsimlyansk Reservoir along with introduced forage organisms.

**Tul'chinskaya, V.P., I.I. Fal'kova, A.P. Kuvarzina, and V.V. Gubanov. 1978. Interaction of halophilic vibrio isolated from a sea medium with cells of tissue cultures. Microbial. Zh. 40:51-57.**
Language: RUSSIAN
Data on interaction of halophic *Vibrio parahaemolyticus* and *V. alginolyticus*, isolated from sea water, and mollusks with cell cultures of warm-blooded and cold-blooded organisms are presented. Parahaemolytic vibrio do not reproduce in tissue culture cells but have a pronounced cytotoxic effect. Primarily trypsinized cultures of the chicken embryo fibroblasts and *Neogobius melanostomus* gonad cells proved to be more sensitive to the vibrio effects than the transplanted RH (human kidney) cell line.

**Vinogradov, A.K. 1975. Anthropogenic influence on reproduction of Black Sea gobies. J. Rybnoe Hozjaistvo 5:24.**
Language: RUSSIAN
Discusses reasons for decline of round gobies, especially human-induced effects. (translated by S. Rudnicka).

**Wallis G.P., and J.A. Beardmore. 1984a. Genetic variation and environmental heterogeneity in some closely related goby species. Genetica 62:223-238.**
An electrophoretic study of genetic variation at three loci was made in nine species of gobiid fish (*Pomatoschistus minutus, P. lozanoi, P. norvegicus, P. pictus, P. microps, P. marmoratus, P. canestrinii, Knipowitschia caucasica* and *Neogobius melanostomus*). Rank order estimates of the degree of environmental heterogeneity experienced by each of the species examined were made and correlations between genetic variation (measured as He) and this rank order were calculated. The most conservative rank correlation coefficient is 0.88 ($P < 0.01$). The large difference in values of He between estuarine/shore (He = 0.094) and neritic/offshore (He = 0.044) species seems unlikely to be accounted for by differences in parameters such as population size or mutation rate. More variable environments are probably conducive to the maintenance of higher levels of genetic variation at enzyme loci in these goby populations. These results parallel findings made in numerous comparisons of laboratory populations.

**Wallis G.P., and J.A. Beardmore. 1984b. An electrophoretic study of the systematic relationships of some closely related goby species (Pisces, Gobiidae). Biol. J. Linn. Soc. 22:107-124.**
An electrophoretic study of genetic variation at 31 loci in each of 9 closely related gobiid species was carried out in order to assess their systematic relationships. The species used were *Pomatoschistus canestrinii, P. lozanoi, P. marmoratus, P. microps, P. minutus, P.*

*norvegicus*, *P. pictus*, *Knipowitschia caucasica* and *Neogobius melanostomus*. Genetic distances (D) and identities (I) were calculated by Nei's method for all 36 pairwise comparisons and dendrograms were constructed. The very similar and cross-fertile species pair, *P. lozanoi* and *P. minutus*, have the highest I value; *P. norvegicus* has high I values with both species. *P. marmoratus* and *P. microps* also display high genetic similarity with each other. The remaining *Pomatoschistus* spp. and *K. caucasica* are broadly and moderately equidistant from each other and from the five species referred to above; *N. melanostomus* is considerably more distant from all other species. These findings essentially agree with the pattern of relationships established using classical taxonomic approaches. The observation that *K. caucasica* is as similar to *Pomatoschistus* spp. as the latter are to each other suggests that the generic distinction of *Knipowitschia* could usefully be reconsidered.

**Yablonskaya, E.A. 1979. Studies of trophic relationships in bottom communities in the southern seas of the USSR. *In* M. J. Dunbar, ed. International Biological Programme. Marine production mechanisms. Cambridge University Press. New York. 338 pp.**
The Azov, Caspian, and Aral seas have long been famous for heavy catches of such valuable species of fish as white sturgeon, bream, carp, roach, etc. The extensive areas of productive spawning grounds on flood plains and in deltas of rivers, together with the rich feeding grounds in the seas, ensure the reproduction of abundant stocks of these species. Most valuable species of fish from these water bodies (Acipenseridae, Cyprinidae) feed on bottom and off-bottom invertebrates. The same food species are used by the Gobiidae and by other benthic fishes which although unimportant for fisheries (except for *Neogobius melanostomus* in the Azov Sea), are favorite food species of many predators, for example, *Huso huso*, *Lucioperca lucioperca*, *Acipenser stellatus*, *Aspius aspius*, and others. In recent decades, due to unfavorable climatic conditions and some anthropogenic factors, fish production in the Azov, Aral, and Caspian seas has decreased. It has now become necessary to take certain practical measures aimed at restoring the fish and invertebrate faunas in these bodies of water. At the same time, along with studies of the feeding habits of the fish, it is also necessary to investigate the feeding habits and food relations of the benthic organisms associated with them.

**Yusupov, O.Y., and A.N. Urazbaev. 1980. Parasitic ciliates, *Peritricha urceolariidae*, of fishes from the Aral Sea, USSR. Parazitologiya 14:504-510.**
Language: RUSSIAN
Fish (395) belonging to 11 species from the Aral Sea and low reaches of the Amu-Darja were investigated. These species were *Esox lucius*, *Rutilus rutilus*, *Leuciscus idus oxianus*, *Ctenopharyngodon idella*, *Barbus brachycephalus*, *Cyprinus carpio*, *Lucioperca lucioperca*, *Ophiocephalus argus warpachowskii*, *Neogobius melanostomus affinis*, *N. fluviatilis pallasi* and *Pomatoschistus caucasicus*. Nine species of urceolariids of the genera *Tripartiella* (1), *Trichodina* (6), and *Trichodinella* (2) were found. *T. nigra luciopercae* Lom, 1970, was recorded for the first time from waters of the USSR, as were *Tripartiella (Paratrichodina) incisa* Lom, 1959, *Trichodina acuta* Lom, 1970, from Central Asia and *Trichodina domerguei* (Wallengren, 1897) from the Aral Sea and low reaches of the Amu-Darja. Data on the infection rate, size, and original photos of some species of urceolariids are given.

**Zambriborshch, F.C., and B. Lai. 1978. Effect of hexachlorane on oxygen consumption of *Neogobius melanostomus* and *Neogobius fluviatilis*. Sov. J. Mar. Biol. 4:526-529.**

The effect of 12% powdered hexachlorane on the $O_2$ consumption in *Neogobius melanostomus* and *N. fluviatilis* was studied. Hexachlorane in concentrations lower than the maximum allowable concentrations (0.006-0.012 mg/L) had a negative effect on consumption of $O_2$ by *N. fluviatilis* and *N. melanostomus*. In fishes poisoned by hexachlorane, the intensity of respiration changed and was not restored to normal after placing them in hexachlorane-free sea water. At all concentrations of hexachlorane, the consumption of $O_2$ by an individual fish appeared to be higher than that by the fish in groups. This pesticide makes the group effect stronger.

# APPENDIX I
# ABSTRACTS FROM THE ROUND GOBY CONFERENCE, CHICAGO, 1996

## Introduction: Is the Goby a Bogy?

*J. Ellen Marsden*, Illinois Natural History Survey, Lake Michigan Biological Station, 400 17th St., Zion, IL 60099

*Bogy n. (1) An evil or mischievous spirit; a hobgoblin. (2) A cause of annoyance or harassment.*

The arrival of the round goby in North America, in marked contrast to the arrival of the zebra mussel, initially met with surprising disinterest. In part, this was due to the fact that the goby had not already acquired a reputation as a pest, as had the zebra mussel, because round gobies have not previously spread outside their native range. The gobies also remained quiescent in the area of the St. Clair River for almost three years after their arrival, and thus provided a false sense of security. Since 1993, however, the round goby has spread to four of the Great Lakes, including the western and easternmost points of the basin. Few exotic species are likely to ever achieve the pest status of the zebra mussel; nevertheless, gobies have already had negative impacts on sculpins and other benthic species, and have the potential to cause additional ecological problems. The purpose of this conference is to present and discuss current information about the goby with particular reference to its activities in North America. We will examine the evidence and evaluate whether the goby has the potential to be a "bogy." If so, the species deserves further intensive study to determine what impacts it is likely to have, and what control methods could be implemented.

## The Role of the U.S. Fish and Wildlife Service in Aquatic Nuisance Species Issues

*Sandra M. Keppner*, U.S. Fish and Wildlife Service, Lower Great Lakes Fishery Resources Office, 405 North French Road, Amherst, NY 14228, and *Thomas R. Busiahn*, U.S. Fish and Wildlife Service, Ashland Fishery Resources Office, 2800 Lake Shore Drive East, Suite B, Ashland, WI 54806

Enacted in 1990, the Nonindigenous Aquatic Nuisance Prevention and Control Act (Act) mandated a legal responsibility to the Fish and Wildlife Service, in cooperation with other agencies, to develop and carry out monitoring, prevention, and control strategies inhibiting the introduction and dispersal of nonindigenous aquatic nuisance species (ANS). The service co-chairs the Aquatic Nuisance Species Task Force, established by the Act, and funds ANS activities nationwide, with a focus on the Great Lakes. The rapid expansion of the round goby (*Neogobius melanostomus*) in the Great Lakes was recently brought to the attention of the task force by the Minnesota Sea Grant College Program, which recommended that the goby be considered for nuisance status, and that prevention and control initiatives be developed. To date only the ruffe (*Gymnocephalus cernuus*) has been designated a nuisance species in addition to those specified in the Act. The task force has developed a draft Risk Analysis Review Process that may be applied to evaluate whether the round goby is likely to become established and, if so, whether it poses a threat to the environment as defined by the Act. The service has begun to compile information needed to conduct a risk assessment, and hopes that this conference will provide information and expertise to advance these efforts.

## The Round Goby in the Central Basin of Lake Erie: Range Expansion and Size-Selective Predation on Zebra Mussels

*Carey Knight*, Fairport Fisheries Research Station, Ohio Department of Natural Resources, 421 High St., Fairport Harbor, OH 44077

Round gobies, *Neogobius melanostomus*, were first collected by anglers and Ohio EPA personnel in the Grand River and its estuary in 1993. In August of 1994, round gobies were collected for the first time in the central basin of Lake Erie by Ohio Division of Wildlife (ODW) bottom trawl surveys. These fish were collected from a small area west of the Grand River estuary in 7 to 11 meters of water. Since the initial discovery, round goby catch rates during ODW trawl surveys have exhibited incremental increases. In 1994, catch rates increased from 2 to 11 fish/hour during August - October surveys. In 1995, catch rates increased from 22 to 209 fish/hour during May - October surveys. In both 1994 and 1995, round gobies occupied inshore (<15 meters) rocky areas during the spring and summer months, then migrated offshore (>15 meters) following lake turnover in October. Since their initial discovery in the mouth of the Grand River in 1993, round gobies have expanded their range 20 km west, 41 km east, and 11 km north into the central basin of Lake Erie.

In 1994, goby diets consisted of 97% zebra mussels, *Dreissena polymorpha*, at 100% frequency of occurrence. The remaining diet item consisted of chironomidae larvae (3%) at 4% frequency of occurrence. Size-selective predation of gobies on zebra mussels was evident from the positive correlation between round goby total length and size of zebra mussels consumed. In 1995, diets consisted primarily of zebra mussels but became diversified as invertebrates and zooplankton were consumed.

The round goby has apparently become well established in the central basin of Lake Erie. In 1994, round gobies up to 3 years old were collected, indicating the presence of at least 3 year classes. Round gobies are multiple spawners that can adapt to a variety of habitats and exhibit a rapid dispersal rate, making them a significant threat to establish throughout Lake Erie. Round gobies also appear to consume primarily zebra mussels, which have been shown to retain contaminants. Consequently, the potential exists for predators that consume round gobies to be linked to high levels of contaminants.

**Biological Characteristics of the Round and Tubenose Gobies in the St. Clair River and Lake St. Clair, Michigan**

*Mike Thomas* and *Bob Haas*, Michigan Department of Natural Resources, 33135 S. River Rd., Mt. Clemens, MI 48047

The round goby (*Neogobius melanostomus*) and tubenose goby (*Proterorhinus marmoratus*) were first found in the St. Clair River in 1990. By 1992, sport anglers reported the round goby had reached nuisance densities in the St. Clair River. By 1993, both species were found in Michigan waters of Lake St. Clair along the west and north shore. In 1995, round gobies were collected in abundance along the south shore in Ontario waters of the lake. Diet analysis of 123 fish revealed that zebra mussels (*Dreissena polymorpha*) were the most common item found in round gobies from the St. Clair River and Lake St. Clair. Zebra mussels were found in 96% of all St. Clair River round gobies and in 67% of all Lake St. Clair round gobies. Amphipods, snails, and ostracods were also important in the diet of Lake St. Clair round gobies. The only evidence of piscivory noted was a brook stickleback found in a 110-mm female from Lake St. Clair. Preliminary examination of tubenose goby stomachs from Lake St. Clair suggested that amphipods, isopods, and ostracods were common in the diet. No zebra mussels were noted in tubenose gobies. Examination of 144 round gobies and 48 tubenose gobies from the St. Clair River and Lake St. Clair revealed that 10 species of parasites infected the fish. More parasite species infected fish from Lake St. Clair than from the St. Clair River. All parasite species found have been reported from other fish species in Lake Huron and Lake Erie, suggesting that parasites from the Black Sea did not become established with the original colonizers.

**Characteristics of the Goby Population in Southwestern Lake Michigan**

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After their initial appearance in the St. Clair River in 1990, the first upstream sighting of the round goby was in the Grand Calumet River near Chicago in January 1993. Subsequently, gobies moved into Lake Michigan at Calumet

Harbor, but have not been reported downstream from their initial site in the river. By 1995, goby densities exceeded 40/m$^2$ at Calumet Harbor, and they had spread approximately 6 miles to the south and 16 miles to the north. The highest densities of juveniles were noted on sand, while adults remained mostly on cobble and rocky substrates. Spawning in the laboratory, at ambient lake temperatures, occurred in early July, but no nests were found in the wild. Differences in developmental stages among the eggs clearly suggested that several females contributed to the brood. We collected gobies at Calumet Harbor every two weeks on average. Gobies ranged from 12mm to 153mm total length. Stomach contents were not analyzed in depth, but 90-100% of the gobies in each sample contained zebra mussels. Males and females showed no sexual dimorphism in length/weight relationships. The proportion of males in the samples began to decline by late September, and gobies were not available to sampling gear by November.

**Benthic Invertebrate Community Responses to Round Gobies (*Neogobius melanostomus*) and Zebra Mussels (*Dreissena polymorpha*)**

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The round goby (*Neogobius melanostomus*) has recently become established in southwestern Lake Michigan. Because the goby is a benthivore, we wanted to investigate the effects of goby predation on invertebrates associated with zebra mussel colonies. Using a 2x3 factorial design, we examined the effects of gobies (present/absent) and zebra mussel densities (low, medium, high) on nonmussel invertebrates. Ten ceramic tiles of each zebra mussel density were colonized in the laboratory and then anchored in Calumet Harbor, IL/IN, for 10 weeks. Gobies had access to half the tiles, whereas coarse mesh screening was used to exclude gobies from the remaining tiles but did allow for invertebrate colonization. Gobies had no effect on densities of total invertebrates, Amphipoda, or Chironomidae; however, densities of Caecidotea (Isopoda) were significantly lower in the presence of gobies ($p<0.01$). Zebra mussel density had a significant effect on numbers of total invertebrates ($p<0.001$), Amphipoda ($p<0.001$), Caecidotea ($p<0.05$), and Chironomidae ($p<0.005$).

**Impacts of Gobies on Native Species**

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Round gobies, first introduced into the St. Clair River in 1990, have spread into all five Great Lakes. We have been collecting gobies from the St. Clair River near Algonac, MI. This and other pre-existing data sets clearly establish that round gobies have detrimentally impacted mottled sculpins in the St. Clair River. Trawling data showed that mottled sculpins were rare during 1993 and the remnants were forced offshore to >9-m depths. Data from pre-goby invasion times from impingement collections and video monitoring at Port Huron established that mottled sculpins were the thirdmost abundant fish. SCUBA divers with almost two decades of experience in the St. Clair River reported a drastic decline in mottled sculpins plus the unusual day behavior of mottled sculpins perched on pilings. The mechanism by which mottled sculpins are impacted is believed to be displacement of spawning adults from prime areas by round gobies, which reached densities of almost 1 fish/m$^2$. These findings were confirmed by laboratory shelter competition studies and field studies by John Janssen in the Grand Calumet River which documented recruitment failure by mottled sculpins. Recent predation on a trout-perch by a large round goby establishes another potential mechanism for how round gobies are impacting mottled sculpins.

**Consumption of Zebra Mussels and Sponges by Round Gobies**

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An evaluation of the impact of the round goby (*Neogobius melanostomus*) on the zebra mussel and freshwater sponge populations was conducted in Hammond Harbor from May to September, 1995. Samples of the zebra mussels were collected for population and length frequency information in May from sections of the revetment wall adjacent to the permanently moored ship *Milwaukee Clipper*. Exclosures were then constructed over portions of the sampled area. In September, exclosures were removed and samples were again taken for population density and length frequency. Differences in density and length frequency of the zebra mussels were not evident statistically between the exclosed and nonexclosed areas at the study site. During June, July, and August, round gobies were also collected for stomach analysis. These samples indicated that zebra mussels are ingested as a food item and are present in a majority of stomachs. Some stomach samples contained freshwater sponges, but this may be incidental ingestion by the gobies because sponges are commonly found growing epizootically on zebra mussels. The round goby population has increased in size and density in Hammond Harbor during 1995. It seems likely this expansion will continue, and the future impact on the zebra mussel as a prey item may be not only measurable but ecologically important.

**Predation of Zebra Mussels by Round Gobies**

*William J. Ray* and *Lynda D. Corkum*, Department of Biological Sciences, University of Windsor, Windsor, ONT, Canada N9B 3P4

This study investigates the ability of a recent Great Lakes fish invader, the round goby (*Neogobius melanostomus*), to use zebra mussels (*Dreissena polymorpha*) as a food source. Laboratory experiments were designed in which predator and prey sizes were manipulated. Size selectivity was determined for three size classes (standard length) of gobies: small (5.5-6.9 cm); medium (7.0-8.4 cm); and large (8.5-9.9 cm) on four different size classes of mussels (6-9 mm, 10-12 mm, 13-15 mm, 16-18 mm). All sizes of gobies ate mussels <9 mm and only large gobies ate a fraction of the 10-12 mm size class of mussels when all prey sizes were presented. The association between the total mass of mussels available and the amount consumed by gobies increased positively up to about 6.5 g of available mussels and then leveled off. Gobies consumed 1 g of mussels in 24 h. Gut analysis of gobies (7.0-8.4 cm) collected from the Detroit River showed that they ate zebra mussels (58%), snails (6%), and other invertebrates (36%) including aquatic insects (*Hexagenia*), crayfish, and zooplankton. Gobies have the potential to alter the size structure of mussels but do not have the ability to control them. Given the distribution of zebra mussels throughout North America and the voracious feeding habits of gobies, it is possible that these exotic fish will become widespread and have a negative impact on native fish that are unable to consume mussels.

**The Round Goby as a Potential Predatory Threat to Lake Trout Eggs and Fry**

*Michael A. Chotkowski* and *J. Ellen Marsden*, Illinois Natural History Survey, Lake Michigan Biological Station, 400 17th St., Zion, IL 60099

The round goby (*Neogobius melanostomus*) was accidentally introduced from eastern Europe to Lake St. Clair in 1990. In late 1993 they were found in southern Lake Michigan, and have since spread rapidly in Lakes Erie and Michigan. By the summer of 1995, round gobies achieved densities as high as 50 per $m^2$ (adults and juveniles) on rocky and sandy substrata in Calumet Harbor, Indiana. Gobies are benthic and interstitial predators, and thus are likely to be predators on lake trout eggs. This is troubling because gobies may become a new threat to long-standing efforts to rehabilitate lake trout (*Salvelinus namaycush*) populations in the Great Lakes. We conducted laboratory studies to compare the performance of round gobies and mottled sculpins (*Cottus bairdi*) at accessing lake trout eggs within porous rocky substrata. In laboratory studies, the maximal average egg consumption rate by a round goby was 3.22 eggs/day for a 113mm (SL) goby at 9°C, while maximal daily consumption rates exceeded 10 eggs for gobies larger than 97 mm SL. Gobies were equally efficient at consuming either eggs or fry in control aquaria (no gravel or cobble) and aquaria containing 10-25cm cobble; gobies were less efficient at consuming eggs or fry (except emergent fry) in aquaria containing gravel. Parallel feeding rate studies of sculpins are under way; preliminary results are similar to those obtained for gobies. These data suggest that round gobies will be effective lake trout egg predators and probably pose a threat to lake trout rehabilitation in the Great Lakes.

### Behavioural Interactions Between *Neogobius melanostomus* (Round Goby) and *Cottus bairdi* (Mottled Sculpin)

*Lynda D. Corkum* and *Derek O.L. Dubs*, Department of Biological Sciences, University of Windsor, Windsor, ONT, Canada N9B 3P4

We examined territorial behaviours between two species of benthic clingers - native mottled sculpins and exotic round gobies. Interactions were observed for 24 h using infrared video photography. Trials were conducted using either a goby or sculpin resident in a shelter. An intruder (either a sculpin or goby) was added at random. Fish (fasted for 24 h before each trial (n=5)) were used only once. Food (*Gammarus*), maintained below satiation levels (estimated from results of separate single-fish functional feeding experiments), was used to enhance interactions. Time spent in a refuge by a resident goby did not differ when intruders were present (gobies or sculpins). Time spent in a refuge by a resident sculpin was significantly reduced in the presence of a goby intruder, but not in the presence of a sculpin intruder. The mean number of approaches, chases, and bites by resident gobies was significantly greater than those of intruders. Aggressive behaviours also were observed when gobies were added as intruders. Sculpin intruders never exerted any aggressive behaviours. In cases where sculpins were resident, a goby intruder exhibited significantly more aggressive behaviours (approaches, chases, bites) compared to the resident sculpin (approaches). The aggressive habits of gobies will likely result in the displacement of sculpins from optimal to suboptimal habitats.

### Lateral Line Biology of Gobies vs. Sculpins

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Invasions are accidental, but not random; all species are not equally likely to succeed. Fishes traveling long distances in the bellies of large ships are likely to have some common characteristics that evolved in response to selective factors other than ship bellies. These characteristics should yield clues about the invaders' ecology. Gobies have been the most successful long-distance fish invaders. They tend to be nocturnal and are similar in lateral line structure to fishes that live in caves, the deep sea, and murky water. Despite being primarily marine, more species of gobies are cavefishes than any other family. Goby lateral lines have likely "preadapted" them for successful transit in artificial caves (ship bellies). It might be expected that the native fishes most impacted by gobies would be other nocturnal, benthic species, such as sculpins. The round goby is more sensitive than mottled sculpin to *Daphnia* in still water, but less sensitive in "noisy" flowing water. In the Great Lakes we may be seeing an invasion of fishes that are ecological analogs of the sculpins most adapted for operating in the dark, the deep living sculpins of Lake Baikal.

### Significance of Trophic Interactions Between Zebra Mussels and Round Gobies in Contaminant Cycling

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Previous work with zebra mussels indicated that they play a pivotal role in the trophic transfer of hydrophobic contaminants, such as PCBs. Zebra mussels have a high lipid content and can accumulate PCBs directly from water; steady-state concentrations in mussels can easily exceed 100,000 times the aqueous concentration. However, most of the contaminant residue is not contained in water but is attached to solid media, such as algae and sediment. Filtration of solids can lead to substantial bioaccumulation in zebra mussels due to high assimilation rates. The route of exposure (solid vs. aqueous) also dictates the fate of PCBs at higher trophic levels. Aqueous contaminants can result in contaminated zebra mussels. However, zebra mussels are not widely consumed by fish or other predators and trophic transfer of contaminated zebra mussels is, therefore, limited. However, if exposure to mussels takes place via contaminated solids, some part of the residue will pass through the zebra mussel and accumulate in feces. Subsequent ingestion of contaminated zebra mussel feces by invertebrates, such as gammarids and midges, can result in contaminated benthic invertebrates. Since these organisms are widely consumed by fish, the potential for food-chain contamination appears greater by the second, indirect route of contaminant transfer. The introduction of the round goby into Lake Erie provides a unique opportunity to test an ecological hypothesis. Namely, it is held that for certain persistent contaminants, there will be a magnification of 3-5-fold for each trophic link in the food-chain. Since round gobies will consume both zebra mussels directly and gammarids, which may be contaminated by zebra mussel feces, we can study the relationship between the number of trophic links in a food-chain and biomagnification. Studies of this sort will begin in the summer of 1996.

**Morphological and Karyological Characteristics of the Lake Erie Population of Round Goby**

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Phenotypic variation was examined in shoreline (OEPA) and offshore (ODNR) collections of the round goby, *Neogobius melanostomus*, from Lake Erie. A meristic profile is presented for comparison with other round goby populations in the Great Lakes region. Variation in pigmentation was found in the dorsal fin pattern of samples taken both inshore and offshore. Two color morphs are identified in our samples (N=245) based on the presence (80%) or absence (20%) of a black ocellus in the posterior membrane of the spinous dorsal fin. This variation in pigmentation does not appear to be correlated with sex, size class, or collecting location. The sex ratio, length frequency, and number of gravid females was determined for shoreline samples as well as for offshore specimens. Preliminary data were obtained on age, size at maturity, and number of eggs produced by females of two size classes. Karyotypes were prepared from chromosome spreads of Lake Erie specimens and compared to published karyotypes of the round goby from the Black Sea population (*Neogobius melanostomus*). Chromosome spreads were silver stained to reveal the location of nucleolar organizing regions (NORs). DNA from Lake Erie round goby specimens was extracted for future sequencing of variable mtDNA regions.

**Round Goby: Potential Spread and Impact on Stream and River Ecosystems**

*Daniel A. Soluk, William J. Resetarits, Jr., Cordell H. Manz*, and *Eric R. Larsen*, Illinois Natural History Survey, 607 E. Peabody Drive, Champaign, IL 61820

The spread of round gobies from the Great Lakes into tributary streams and connected watersheds (especially the Mississippi River system) should be a focus of great concern. There is hope that such a spread will not occur, since round gobies have already clearly demonstrated an ability to survive in lotic environments in the St. Clair and Detroit rivers. We discuss preliminary results of thermal tolerance and growth experiments that suggest that round gobies survive and grow in waters as warm as 33°C. This indicates a potential to occupy both cold-water and warm-water stream systems throughout most of North America. Ongoing studies suggest potential impact of round gobies on streams is high, especially for populations of other smaller benthic fishes (e.g., darters), which may be displaced or directly consumed by gobies. There is a critical need for further research that can allow accurate assessment of the potential final range and impact of gobies in areas where they may have a greater impact than they will have in the Great Lakes themselves.

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## APPENDIX II
## RESEARCH PRIORITIES
### Summary of a Roundtable Discussion at the Round Goby Conference, Chicago, 1996

**Impacts on North American Ecosystems**

- **Investigate the potential loss of biodiversity caused by competition with native species for space and food.** In particular, mottled sculpins (*Cottus bairdi*) appear to be threatened with competitive displacement by gobies.
- **Determine effect of gobies on sport and commercial fisheries.** Gobies have already negatively affected littoral sport fisheries by competing aggressively with native species for bait and lures. In addition, loss of native benthic species may result in changes in the prey base of sport fish, such as smallmouth bass. The relative value, in terms of accessibility and nutritional value, of gobies and sculpins should be investigated to determine whether gobies will provide a prey base for sport fish. Of particular concern is the possibility that gobies may accumulate toxins from zebra mussels, and transfer these to sport fish predators such as bass. Studies on contaminant levels in gobies and goby predators should be focused in highly contaminated areas, such as the St. Clair River.

**Long-term Monitoring/Range Expansion**

- **Monitor range and population expansion of round gobies.** This requires public education and outreach because the first sightings of gobies in new areas are most likely to be made by anglers. Creel surveys are a useful tool for both educating the fishing public and confirming identification of captured fish.
- **Conduct biotic surveys in littoral areas not yet occupied by gobies**. Field investigation of the effects of gobies on native communities requires quantitative data on the status of the communities prior to invasion by gobies. Unfortunately, long-term (or even short-term) datasets on benthic, littoral communities are rare.
- **Identify vectors for range expansion**. The rapid spread of gobies in 1994-1995, in "leap-frog" fashion, suggests that intra-lake ballast water transport has been an important vector for gobies within North America. Gobies also have established a minor reputation as good bait fish, so transfer via bait buckets into inland waters may become a problem. Conference participants hypothesized that intake pipes in boat hulls, or the hulls themselves, could be attractive nesting sites. Eggs therefore could be transported on the outside of ships.
- **Determine potential range limits for gobies in North America**. This requires establishing habitat requirements and environmental tolerances for temperature, salinity, current, etc. Some of this information is available from the literature; however, these published data should be treated with caution, as zebra mussels in North America have exceeded their reported temperature tolerances. Salinity tolerances of eggs and juveniles should be particularly examined, because they may be wider than those of the adults. Presence of competitors, and predators, or the absence of important dietary items may also limit their range. Information about the ability of gobies to thrive in lotic waters is particularly needed. Gobies in Lake Michigan may readily enter the Mississippi River system, and thus gain access to a large portion of the continent.
- **Determine if multiple genetic subpopulations have been introduced or created via a founder effect**. Genetic studies may reveal whether multiple introductions have occurred or are occurring from Europe, and whether genetically differentiated populations are present that may have different environmental tolerances.

**Confinement and Control - Methods to Reduce Risk of Transfer**

- **Identify potential predators, parasites, or diseases**. In particular, it would be valuable to discover what factors limit their range and population size in Europe. Predator stocking has been suggested as a method for controlling other exotic species (e.g., ruffe), and may be a useful strategy in some North American waters.

- **Determine whether dams and other navigation structures may impede movement of gobies upstream or downstream.** Electric weirs, used for lamprey control, may also be useful for inhibiting upstream or downstream movements of gobies. Restriction of goby passage from lakes into river systems and vice-versa should be investigated.
- **Investigate male triploidy as a potential control method.** The reproductive behavior of gobies, in which a single male fertilizes and incubates the eggs of several females, suggests that this strategy could be particularly effective for gobies.
- **Develop and implement state and federal legislation and state management plans to prevent spread of gobies.** Enactment of laws prohibiting possession or transport of live gobies will assist in prevention of bait bucket transfers. Public education also will be useful for reducing the spread. Current research on prevention of ballast water transfers of exotic species should include gobies, whose early life stages (e.g., eggs) could be resistant to some forms of control, such as saltwater exchange.

**Biological Data**

As stated earlier, while much information is available from the European literature, some is lacking and some is open to question.

- **Develop a life table for round gobies**. Among its other uses, a life table may identify critical or vulnerable stages in the life cycle.
- **Determine if hermaphrodites exist**. Hermaphrodites are common in many goby species, and the presence of hermaphrodites has obvious implications for the ability of gobies to expand their range.
- **Confirm if males invariably die after spawning.**
- **Identify optimal methods for aging gobies**. Scales are reported to be unreliable; several scales must be examined to reach a "consensus" age. Otoliths have been used effectively, and age can be determined by placing the whole otolith in front of a bright light source (Rudnicka, pers. comm). It may be possible to use age data to back-calculate the date of arrival at each site.
- **Examine and compare age and growth rate data from stable versus expanding populations.**
- **Describe the winter habitat and behavior of round gobies.** Although gobies are reported to migrate into deeper water in winter, they have been observed in shallow water in December and February in the St. Clair River area (D. Jude, unpubl. data).
- **Describe seasonal and annual movements of gobies.** Movement data are needed to understand the potential for unassisted range expansion. If gobies move into deep water in fall and return to shallow water in spring along a different trajectory, they could move hundreds of miles in the Great Lakes within a year.
- **Describe territoriality of gobies.** Male gobies clearly are territorial while they are guarding a nest, but the territoriality of females and nonbreeding males is apparently unknown. In some locations juveniles are primarily found on sand and males are found on cobble; this may be due to different habitat requirements, or displacement of juveniles from preferred habitats by adults.

**Research Methods Needed**

**Sampling techniques.** Sampling techniques are needed for early detection of range expansions, and to study population composition and abundance. Methods are needed that will adequately sample all size classes and permit determination of goby densities. Different methods may be needed for different habitats (e.g., cobble vs. sand). The inherent variance and bias in the sampling techniques must be determined so that the number of samples needed for population estimation can be determined. Possible methods suggested during the discussion were as follows:

- **Rotenone** - may be suspended in solution and injected into an enclosed area. Fish may jump when they detect the chemical. Rotenone or other anesthetics could be used in combination with an airlift to collect fish. Chemical techniques could provide excellent density and population composition data; however, their use is highly restricted and requires specialized permits.
- **Electrofishing** - Roger Thoma (Ohio EPA) reported using a boat shocker with 500-600 amps DC in shallow water during the daytime to obtain a relative abundance of gobies between 30 and 115 mm (SL). The gobies emerged from cobble substrate at a maximum depth of 12-15 cm and rolled over or froze.
- **Transects with scuba** - may be used for density estimates. Small fish are hard to see, and all fish may be undersampled on cobble substrates with interstitial spaces. Scuba transects may yield abundance estimates one or two orders of magnitude higher than electroshocking (Thoma, pers. comm.). Ultraviolet light may be useful for detecting gobies by their iridiphores (primarily on juveniles).
- **Minnow traps** - particularly useful for mark-recapture studies, but may not be useful for collecting data on density or size class.
- **Electrical grid** - kills fish in a known area and, therefore, could yield good density and population composition estimates.
- **Benthic sled** with air pump - effectiveness unclear.
- **Underwater sampling** - nets could be set, filled with cobbles, and lifted after an interval of time. Gobies could be herded into a funnel trap, or kick-seined into a net. Surveys of nests and breeding males can only be done effectively using scuba. Juveniles up to about 25 mm (TL) can be readily sampled with a hand-net.
- **Trawls** - small shore trawls have been used effectively for sampling gobies between 25 and 155 mm (TL)
- **Seines** - a 75-m beach seine with a 15-m bag, 6-mm mesh in the cod end, 35-mm stretch mesh in the body, is effective. Seines are usable on cobble substrates, particularly when used with foot rope rollers. A modified net with large bag can by used on cobble in currents. Kick-seining with a 0.25-in (6.3-mm) mesh seine provides good samples of young-of-the-year.
- **Angling** - gobies can be caught at a rate of one per minute at a site of high density, using light tackle and worms or maggots for bait. Adults are most readily sampled, but fish as small as 46-mm (TL) have been collected by angling. Angling may be gender biased during the spawning season. A fishing rod could be used underwater to target particular fish, such as spawning males.
- **Artificial breeding habitats** - may be useful in areas of suboptimum habitat for detecting the presence of gobies, or censusing spawning males.
- **Other methods** - trot lines, baited traps, or crab traps may be effective, but have not been fully investigated. A search of the literature on stream invertebrate sampling may suggest additional methods.

**Tagging methods.** Tagging methods are needed to conduct studies of goby movements, migration, territoriality, and possibly to estimate population abundance in local areas.

- **Injected marks** include latex dye and fluorescent paint (Northwest Marine Inc.). Injected marks have been used effectively on sculpins, and can provide a lifetime mark with low mortality of tagged animals. Dyes can be injected subcutaneously along fin rays, at the base of the fins, into cheek tissue, or on various parts of the body.
- **Fin ray clips** can last up to 6 years. A binary key is used to identify individual animals.
- **External tags** are available in a variety of forms, but have the disadvantage that they may inhibit movement of benthic species, such as gobies, or may be torn off during contact with the substratum.

**Rearing methods.** Rearing methods need to be established so that gobies can be maintained for experiments in the laboratory. Fortunately, the literature contains several suggestions for breeding gobies in the laboratory, some of which are summarized under "Reproduction."

## General Notes

Conference attendees agreed that additional translation of Russian literature would be valuable. One or more graduate students who read Russian could be supported on a research assistantship that required a certain amount of translation to be done. It may be possible to use the Israel Program for Scientific Translation for translation of longer documents (for example, see Berg 1949 and Nikol'skii 1954). Equally important is the sharing of translated documents to reduce duplication of effort; availability of translations could be advertised on the World Wide Web (WWW).

Ability to stock small experimental lakes or ponds with gobies could prove valuable for advancing understanding of many aspects of goby biology and population dynamics. Access to confined ponds, such as the Army Corps of Engineers Confined Disposal Facilities, should be explored.

To enhance communication among researchers and reduce duplication of effort, a database of ongoing goby research should be established. The Great Lakes Panel and the Great Lakes Sea Grant Network have created similar databases for zebra mussel research. The WWW could also be used informally for this purpose.

# APPENDIX III
# INFORMATION AND EDUCATION PRIORITIES
## Summary of a Roundtable Discussion at the Round Goby Conference, Chicago, 1996

Participants of the information and education (I/E) roundtable discussion agreed that development of an I/E strategy to prevent the spread of the round goby was needed. I/E efforts should be directed to audiences who currently are affected or potentially will be affected by the round goby. These audiences include potential human vectors for accidental introduction and spread (e.g, individual anglers, sportfishing organizations, baitfish industry, and maritime industry), resource management agencies, and the research community. The I/E strategy also should be interrelated with research, management, and control strategies for the round goby. Participants also agreed that individuals and industries that are potential vectors for accidental spread should be involved in development of spread prevention strategies.

## GOAL OF ROUND GOBY INFORMATION/EDUCATION STRATEGY

Use public information and education to prevent or delay further spread of the round goby in the Great Lakes, and prevent spread to inland watersheds.

## INFORMATION NEEDS OF TARGET AUDIENCES

### 1. ANGLER AND SPORTFISHING ORGANIZATIONS

*Background*

Anglers play an important role in management strategies for preventing introduction and spread of nonindigenous species. Anglers easily catch round gobies, and therefore are often the first to see and report round gobies from a new area. Anglers may help prevent round goby introductions through effective communication and cooperation with the bait industry, and by appropriate use and disposal of bait.

Anglers, however, may unknowingly facilitate the spread of the round goby through bait bucket transfer. Every angler, including the occasional angler, needs to be aware of this possibility, and should know how to identify, report, and properly dispose of the round goby. I/E strategies should target potential bait bucket transfers, stress that the round goby should not be used as bait, and have general application for both government agencies and nongovernmental organizations. Resource managers also need to inform anglers of regulations regarding the transport of the round goby, and of the potential consequences of regulation violations.

Participants discussed existing mechanisms that could be used to facilitate I/E programs. One mechanism that reaches all licensed anglers is the annual publication of state fishing, boating, and hunting regulations. Also, nongovernmental organizations including angling associations may provide an effective means of sharing information. Anglers should be encouraged to inform others in the sportfishing community of the threats posed by and regulations regarding the round goby.

Participants discussed the potential effectiveness of a public education program to keep anglers from using round gobies as bait. It was noted that some anglers may decide that round gobies are good bait for smallmouth bass, perch, crappie, and walleye. It would be difficult to prevent an angler from using gobies as bait, especially in states where this use is not illegal. One roundtable participant maintained that a high percentage of bass anglers in Ontario do not use live bait because they have been educated about problems related to live bait release.

*Objective*: Develop and promote public I/E programs that teach identification of the round goby to aid in preventing accidental introduction. These programs would ensure that this species will not accidentally be transported alive, but will be reported and killed when caught.

*Actions*

- Inventory existing I/E products.
- Link agencies and organizations to disseminate I/E products.
- Disseminate I/E products to:
  -bait shops and marinas
  -charter fishing industry captains and representatives
  -anglers who harvest wild bait for personal use
  -conservation clubs
  -shoreland property associations
  -wild baitfish harvest industry
- Provide information through:
  -media outlets including television, newspapers, and radio public service announcements and through signage at boat landings and billboards
  -sport and outdoor trade shows
  -tourism and visitor bureaus to reach nonresident boaters and anglers
  -species ID cards, pamphlets, field guides, and other printed materials at licensing outlets
  -Web sites, including Sea Grant Nonindigenous Species (SGNIS) and the Great Lakes Information Network (GLIN)
- Conduct workshops for members of charter fishing associations, sportfishing clubs, shoreline interest groups, and other target audiences.

## 2. WILD BAITFISH HARVESTERS

*Background*

Collection, transport, and sale of wild baitfish by commercial harvesters threaten the success of strategies to prevent the spread of nonindigenous species. Wild baitfish collected from round goby-infested waters incidentally may contain round gobies. This bait may then be transported to other ecosystems or drainage basins for sale and use in waters not yet invaded by the round goby.

The bait industry includes harvesters, wholesalers, retailers, and anglers. Although the angler represents the final purchaser and user of the bait, prevention strategies should not target only the angler. A proactive management strategy would include steps to minimize the risk of spread at each level of the bait industry. For example, harvesters need to know how to recognize round gobies, be aware of infested waters, and understand their role in prevention. Implementing prevention at each level of the bait industry should provide additional insurance to minimize the risk of bait bucket transfers.

*Objective*: Prevent the introduction of round gobies (and other nonindigenous fish) to uninfested waters via commercial sale or through private bait use.

*Actions*

- Develop information and education programs in the form of workshops to teach baitfish harvesters how to identify the round goby so that it will not be transported alive.
- Encourage research and development of methods or technologies to harvest selectively or separate round gobies from target species.
- Encourage voluntary action by wild baitfish harvesters to inspect their catch and use harvest methods that are selective for target species.
- If voluntary actions by the baitfish industry are not effective, then jurisdictions will need to enact regulations and statutes that provide the same level of prevention.

## 3. RESOURCE MANAGEMENT AGENCIES

*Background*

Participants noted that standard rules and regulations need to be established in all states, and that these rules need to have universal application across the region. Most roundtable participants suggested that these rules encourage strong citizen participation in prevention strategies (e.g., monitoring), by allowing for the transport of dead gobies for identification. There are many experts—law enforcement agents, resource managers, and outreach professionals—who could work to develop effective regulations. It was noted that it is unlawful to possess a dead specimen in Ontario unless the specimen was provided from the

U.S. This applies even if the specimen is used for educational purposes.

*Objective 1*: Develop and promote consistent regulations on possession and transportation of dead specimens for positive identification.

*Actions*

- Encourage state and federal agencies to enact regulations/statutes that are consistent across affected or potentially affected jurisdictions.
- Promote statutes that support citizen activity in reporting new sightings.
- Enact regulations that allow permitted use of preserved specimens for I/E activities.
- Disseminate results of I/E and research strategies to regional fisheries management agencies, especially the Council of Lake Committees, the Upper Mississippi Basin Research Association, the Upper Mississippi River Conservation Committee, and other natural resources and research outlets adjacent to the Great Lakes area.
- Promote regulations that allow transport of dead specimens but do not allow transport of live individuals.
- Initiate dialogue with natural resource managers from different jurisdictions regarding the content of regulations restricting possession of the round goby.
- Develop high-quality identification guides or field guides.

*Objective 2*: Develop appropriate advisories regarding the consumption of the round goby.

*Action*

- If it is determined that round gobies are unhealthy to eat due to bioaccumulation of contaminants, then appropriate fish consumption education should follow.

*Objective 3*: Facilitate exchange of information between resource managers and researchers.

*Actions*

- Identify resource managers' scientific data needs. Establish effective communication among researchers and managers at early stages of project development, realizing that managers cannot always wait for peer-reviewed literature when developing their management plans.
- Use both the Great Lakes Information Network created by the Great Lakes Commission and the Nonindigenous Species Web site, SGNIS, developed by the Great Lakes Sea Grant Network to facilitate information exchange between scientists and resource managers.

4. RESEARCH COMMUNITY

*Background*

Development and implementation of prevention and control strategies are highly dependent on effective communication and information exchange between resource managers and researchers. Resource managers require an understanding of an invading species' life history features, behavioral characteristics, environmental tolerances, role in the ecosystem, and possible vectors of spread.

Communication among researchers is also important to avoid duplication of effort. Resource managers can facilitate research efforts by providing specimens, collection equipment, and personnel. Both resource managers and researchers need to maintain open and frequent information exchange, recognize each other's limitations, and coordinate efforts to advance prevention and control technology.

*Objective*: Facilitate effective information exchange among researchers and resource managers so that research needs are clearly identified.

*Actions*

- Share information at early stages of project development through workshops and conferences.
  - conduct conference calls to discuss current research projects and identify research gaps.

- Designate one person in each state or agency to be the contact person for research information. Establish or use existing points of contact for round goby research and I/E information.
- Disseminate significant research findings to regional fisheries management agencies, especially the Council of Lake Committees, the Upper Mississippi Basin Research Association, the Upper Mississippi River Conservation Committee, and other natural resources and research outlets adjacent to the Great Lakes area.

## 5. MARITIME INDUSTRY

*Background*

Although the U.S. and Canada have enacted laws to prevent new introductions into the Great Lakes via ballast water exchange, organisms already established are being spread within the Great Lakes by interlake and intralake shipping activities. Ballast water transfer is likely responsible for the spread of round gobies from the St. Clair River to the central basin of Lake Erie, southern Lake Michigan, and western Lake Superior. The shipping industry has been extraordinarily cooperative in preventing the spread of the ruffe within the Great Lakes, and must be included in future prevention planning. Therefore, resource managers and the shipping industry need to continue effective communication and cooperation.

*Objective:* Educate ship masters and port authority agents about the distribution, potential spread via ballast water, and potential ecological effects of the round goby.

*Actions*

- Provide information sessions to ship masters and port authority agents via conferences such as the annual maritime shipping meetings.
- Distribute round goby I/E products to ship masters and port authority agents.

## APPENDIX IV
## EXTENSION RESOURCES

**Round Goby Watch Card** - wallet-sized card featuring a color photo of the round goby and descriptions of its morphology and biology. This card also describes procedures to follow if a goby is found or caught.
Available from: Great Lakes Sea Grant Network Programs

**Have You Caught This Fish?** - an 11" x 11" water-resistant poster describing the biology of the round goby, and illustrating how the round goby is distinguished from native sculpins. This poster is designed for use in fishing tackle stores, bait shops, marina offices, etc.
Available from: Illinois Natural History Survey, Publications Office, 172 Natural Resources Building, 607 E. Peabody Dr., Champaign, IL 61820 (see page 65)

**Round Gobies Invade North America** - two-page fact sheet with information on distribution, identification, habitat, and potential impacts of the round goby (1995).
Available from: Great Lakes Sea Grant Network Programs (see page 66)

**Gobies in the Great Lakes** - two-page fact sheet on general information about round gobies, including methods for preventing their spread (1996).
Available from: Ontario Ministry of Natural Resources (1-800-563-7711). (see page 68)

**Gobies: Cyberfish of the 90s** - two-page fact sheet on general information about round and tubenose gobies.
Available from: D. Jude, University of Michigan, Center for Great Lakes and Aquatic Sciences, 3107 Institute of Science & Technology, Ann Arbor, MI 48109 (see page 70)

**Preventing the Spread of Round Gobies in the Illinois Waterways** - two-page fact sheet on current distribution and potential spread of the round goby in the Illinois waterways (1997).
Available from: Illinois-Indian Sea Grant Program (see page 72)

**ANS Task Force/Minnesota Sea Grant Correspondence** - letter regarding the listing of the round goby as an Aquatic Nuisance Species. (see page 74)

**Nonindigenous Species Database Voluntary Reporting Form**
Available from: Southeastern Biological Service Center, Gainesville, Fl 32653, ph-(352) 378-8181 (see page 75)

**SGNIS (Sea Grant Nonindigenous Species Site)** - a WWW site containing a searchable collection of research publications and education materials on nonindigenous species including the round goby.
http://www.ansc.purdue.edu/sgnis/

**USGS Nonindigenous Aquatic Species Database** - a WWW site established as a central repository for accurate and spatially referenced biogeographic accounts of nonindigenous aquatic species. Scientific reports, online/realtime queries, spatial data sets, regional contact lists, and general information are provided.
http://www.nfrcg.gov/nas/nas.htm

**Great Lakes Sea Grant Network Exotic Species Graphics Library** - contains graphics of round and tubenose gobies.
Available from: Michigan Sea Grant College Program

<u>Slides</u>

— round goby protecting nest
— round goby in gloved hand
— round goby (extreme close-up)
— black male goby
— goby cut open with zebra mussel in stomach
— round goby eggs
— close-up of round goby in fish tank

<u>Illustrations</u>

— tubenose goby
— round goby

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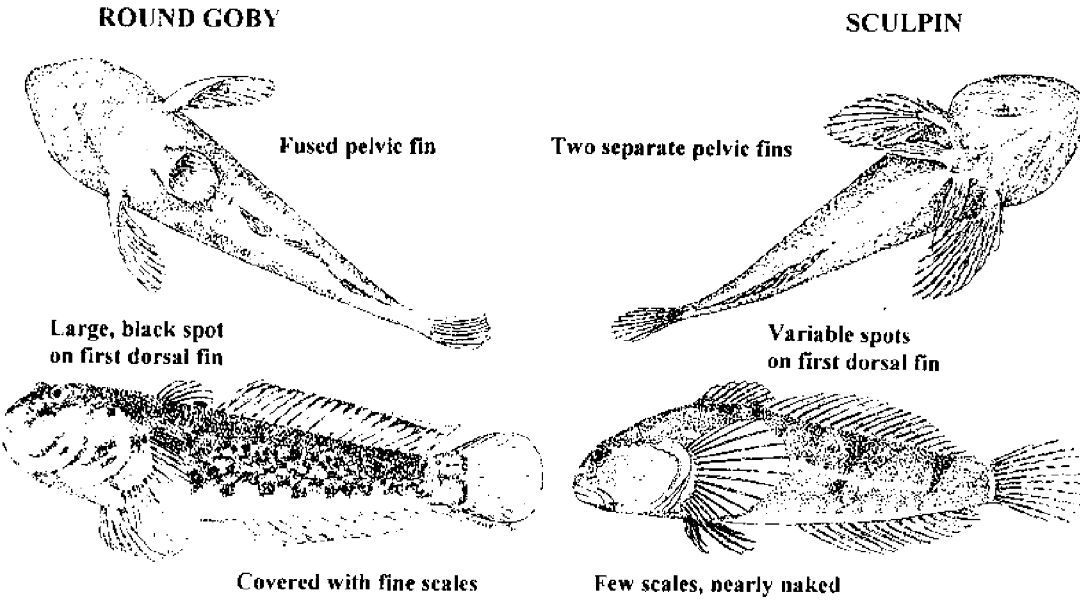
# HAVE YOU CAUGHT THIS FISH ?

ILLINOIS NATURAL HISTORY SURVEY

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

The round goby, a new invader from Europe, is in Lake Michigan. This small, bottom-living fish readily takes bait and small lures, and is abundant at Calumet Harbor and Hammond Harbor. Scientists are trying to predict what problems gobies are likely to cause in the Great Lakes. **Your help is needed.** Gobies are easily confused with native sculpins. Distinguishing features are pointed out below. If you find a goby anywhere other than Calumet or Hammond harbors, please **save** the fish (on ice or in rubbing alcohol) and contact:

**Goby Watch**
Illinois Natural History Survey
400 17th St., Zion IL 60099
tel 708-872-8677 or fax 708-872-8679
or contact your local DNR or Sea Grant office




## Biology

The round goby (*Neogobius melanostomus*) was accidentally introduced from eastern Europe to the St. Clair River in 1990. Their native range is in the Black and Caspian seas. In 1993 they spread to Lake Michigan and Lake Erie, and in 1995 they were found at Duluth in Lake Superior. Round gobies prefer a rocky or gravel habitat in which they can hide in crevices or actively burrow into gravel. Females can spawn every 18-20 days from April through September. Each female produces 300-5000 eggs which are deposited in nests among rocks and are guarded by the male. They generally inhabit the nearshore area, though they will migrate to deeper water (up to 195 ft depth) in winter. They are also found in rivers and in slightly brackish water. They eat clams and mussels (including zebra mussels), large invertebrates, fish eggs (including lake trout eggs), small fish, and insect larvae. Gobies are a robust, aggressive fish, and they are likely to compete with native fish such as sculpins and darters.

# Round gobies invade North America

Produced by the Illinois-Indiana Sea Grant Program in cooperation with the Michigan and Ohio Sea Grant College Programs as IL-IN-SG-95-10.

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Sea Grant

The Great Lakes Sea Grant Network is a cooperative program of the Illinois-Indiana, Michigan, Minnesota, New York, Ohio, and Wisconsin Sea Grant programs. Sea Grant is a university-based program within the National Oceanic and Atmospheric Administration (NOAA) that is designed to support greater knowledge and well-informed, responsible decisions about the resources of the Great Lakes, inland waters, and oceans.

Through its network of advisory agents, researchers, educators, and communicators, the Great Lakes Sea Grant Network supplies the region with usable solutions to pressing problems and provides basic information needed to better manage the Great Lakes and inland waters for both present and future generations.



In the last decade, considerable public and scientific attention has been focused on the zebra mussel, an aquatic invader in the Great Lakes. The zebra mussel actually is a recent addition in a long history of invaders, ranging from rainbow smelt, alewife, and lamprey to the recently introduced ruffe and spiny water flea. Now another foreign species has begun to spread throughout the inland waterways. The round goby (*Neogobius melanostomus*) was discovered in the St. Clair River, the channel connecting Lake Huron and Lake St. Clair, in 1990. This species comes from the same area of the world as the zebra mussel (around the Black and Caspian Seas). Presumably, they arrived the same way as zebra mussels: in ballast water discharged by transoceanic vessels.

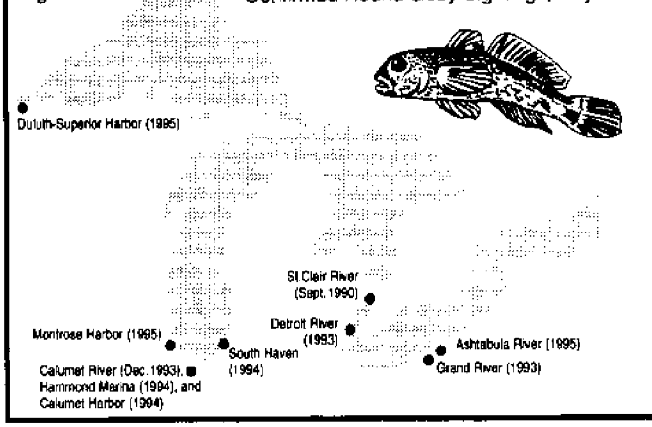



**Figure 1** Confirmed Round Goby Sightings, July 1995

Although gobies belong to a family of fish with a worldwide distribution in both salt and freshwater, they had not been found in the Great Lakes prior to 1990. A second species, the tubenose goby (*Proterorhinus marmoratus*), also appeared in the St. Clair River in 1990; but this species, which is endangered in its native habitat, has remained uncommon. The more aggressive, robust round goby underwent a rapid dispersal and population expansion in the St. Clair River and Lake St. Clair. In 1993 it began to spread to other waterways, and the likelihood of its spreading to watersheds such as the Mississippi River drainage system has raised concerns over its potential effects on North American native species and ecosystems.

Exotic species, such as the round goby, have destroyed and disrupted aquatic communities across the nation. The entry of another foreign invader to the already abused Great Lakes environment is an unwelcome addition to the plethora of other problems, including habitat destruction, overfishing, pollution, and loss of native species.

## Range and Spread

From 1990 to 1992 round gobies were found only in the areas adjacent to the St. Clair River: Lake St. Clair and in the first 2 km of the upper Detroit River. By 1993 round gobies were found in the Grand River near Cleveland, Ohio (Lake Erie) and in the Grand Calumet River near Chicago, Illinois (Lake Michigan). In August 1994, gobies became well established in the Central Basin of Lake Erie. Also in 1994, gobies were found 12 miles east of the Grand Calumet River at Hammond Marina and at South Haven, Michigan, on the east shore of Lake Michigan. Because the Grand Calumet River is connected to the Mississippi River, round gobies now have access to America's largest watershed. By 1995, they had spread to Duluth-Superior Harbor, in Duluth, Minnesota (Lake Superior), Montrose Harbor north of Chicago (Lake Michigan), and Ashtabula River in Ohio (Lake Erie).

After they reach a new area, gobies are capable of rapid population growth. Densities of gobies in rocky areas at Calumet Harbor already exceed 20 per square meter—equivalent to 20 fish in a space the size of a bathtub. The fish in this harbor range from 12 to 140 mm (0.5 to 5.5 inches) in length, and likely represent two age groups.

## Identification

Round gobies are bottom-dwelling fish that perch on rocks and other substrate. They can grow to 250 mm (10 inches) as adults. Gobies have large heads, soft bodies, and dorsal fins lacking spines; they slightly resemble large tadpoles (Figure 1). The gobies' unique feature is their fused pelvic (bottom) fins, which form a suctorial disk. In flowing water habitats, this suction disk aids in anchoring the fish to the substrate. Young round gobies are a solid slate gray; larger individuals have blotches of black and brown over their bodies, and their dorsal fin may be tinged with green.

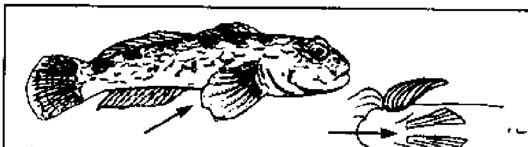
Round gobies look similar to sculpins, a native, bottom-dwelling fish occasionally caught by anglers. Sculpins (*Cottus bairdi* and *C. cognatus*), also called muddlers or Miller's thumb, are usually solid brown or mottled. Both sculpins and goby males can appear almost solid black during spawning. Round gobies have a distinctive large black spot on the front dorsal fin; and sculpins often have a dark spot in the same location. Sculpins can most easily be distinguished from gobies by their separate pelvic fins (Figure 2).

## Characteristics and Habitat

Round gobies possess four characteristics that make them effective invaders.

1. Round gobies are aggressive, pugnacious fish. They feed voraciously and may eat the eggs and fry of native fish such as sculpins, darters, and logperch. They will aggressively defend spawning sites in rocky habitats, thereby restricting access of native species to prime spawning areas.
2. They have a well-developed sensory system that enhances their ability to detect water movement. This allows them to feed in complete darkness, and gives them a major competitive advantage over native fish in the same habitat.
3. They are robust and are able to survive under degraded water quality conditions. This ability and their propensity to swim into holes and other crevices probably allowed round gobies to enter and survive in the ballast water of ships.
4. Round gobies spawn over a long period during the summer months so they can take advantage of optimal temperature and food conditions. Females mature at 1 to 2 years and males mature at 3 to 4 years. Spawning can occur frequently from April through September. Each female produces from 300 to 5,000 large (4 x 2.2 mm [0.16 x 0.09 inch]) eggs; these eggs are deposited in nests on the tops or undersides of rocks, logs, or cans; they subsequently are guarded by the males.

Round gobies prefer a rocky or gravel habitat; they hide in crevices or actively burrow into gravel when startled. In the Black and Caspian Seas, gobies generally inhabit the nearshore area, although they will migrate to deeper water (up to 60 m [197 feet] depth) in winter. They also are found in rivers and in slightly brackish water. In Europe, the diet of round gobies consists primarily of bivalves (clams and mussels) and large invertebrates, but they also eat fish eggs, small fish, and insect larvae. In the United States, studies have revealed that the diet of round gobies includes insect larvae and zebra mussels.



Sculpin — Sculpins have separate pelvic (bottom) fins. A dark spot on the dorsal fin is common.

**Figure 2**

Round Goby — The distinctive feature of the round goby is its fused pelvic (bottom) fins. This fish can grow up to 10 inches in length, although 3- to 6-inch fish are more common. The smaller tubenose goby has two, rather distinct, tube-like projections from its head.

## Potential Impacts

Gobies may compete successfully with native benthic fish such as sculpins and darters. Substantial reductions in local populations of sculpins already have been reported from areas in which gobies have become established. Gobies may compete with sculpins for food or drive them from their preferred habitat and spawning area. In laboratory experiments, gobies will eat darters and other small fish. Of perhaps more concern is their predation on the eggs and fry of lake trout, which has been observed in laboratory experiments. The reproduction of the lake trout in the Great Lakes is extremely limited.

On the positive side, round gobies eat large quantities of zebra mussels, an invader that is causing an increasingly large number of problems because of its huge reproductive output. Zebra mussels are an important component of the gobies' diet in their native range; and, in laboratory studies in North America, a single round goby can eat up to 78 zebra mussels a day. However, it is unlikely that gobies alone will have a detectable impact on zebra mussels. The round goby is expected to be one of several species (including ducks, crayfish, diseases, and other fish species) that eventually will reduce the abundance of zebra mussels. Gobies are preyed upon by several sport fish species (e.g., smallmouth and rock bass, walleyes, yellow perch, and brown trout). Because the diet of round gobies consists predominately of zebra mussels, there may be a direct transfer of contaminants from gobies to sport fish.

Gobies affect anglers in several ways. These fish aggressively take bait from hooks. Anglers in the Detroit area have reported that, at times, they can catch only gobies when they are fishing for walleye.

## What can be done?

Unfortunately, eliminating a species after it has become established usually is impossible. However, it may be possible to slow the spread of these unwanted species into our waterways. Ballast water exchange is one method of reducing additional introductions of foreign organisms. Ballast dumping regulations within North American waterways may help to prevent the spread of exotic species. Anglers and others can avoid accidentally spreading these species by dumping bait buckets only in areas where they were filled, and by not taking unusual animals home to add to an aquarium. Note: there may be a temptation to take gobies for a home aquarium or home fish pond; however, transportation of gobies or other exotic species across state lines is illegal.

## What can you do?

Learn to identify gobies (see illustration that indicates fused pelvic [bottom] fins). To enable biologists to track the spread of round gobies, up-to-date information on new sightings is needed. Your assistance is extremely important. If you catch a round goby outside the areas noted on the map indicating goby range, preserve the fish either in alcohol (grocery store rubbing alcohol is fine) or by freezing it. Then contact your state Sea Grant office, fisheries management agency, or the Illinois Natural History Survey (708/872-8677). Be prepared to describe when and where you caught the fish (the name of the lake or stream, and the nearest town). New sightings can be confirmed only by identification of a captured fish. Verbal reports cannot be used because sculpins can be easily

For other publications, newsletter, conference, and workshop announcements, or for advice from local experts, contact the Sea Grant program or state natural resources management office nearest you. Phone numbers for the Great Lakes Sea Grant programs follow.

| | |
|---|---|
| Illinois-Indiana | 217/333-9448 |
| Michigan | 517/353-9748 |
| Minnesota | 218/726-8106 |
| New York | 800/285-2285 |
| Ohio | 614/292-8949 |
| Wisconsin | 608/263-3259 |

Other Sea Grant programs and other agencies also have information available on this issue.

Publishers and authors can be contacted at the addresses listed here.

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1159 Forestry Building
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*Administration*
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For large orders of this publication, contact Ohio Sea Grant. Request OHSU-FS-065.

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Lake St. Clair/Thames River Fact Sheet January 1996

Ministry of Natural Resources Ontario

# Gobies in the Great Lakes

## What Are They?

Gobies belong to a large family of fish represented by many species throughout the world. Two species from eastern Europe, the round goby and the tubenose goby, were introduced to the St. Clair River in the late 1980s. It is believed that both species arrived in North America after being transported in the ballast water of ships originating from eastern Europe.

Both gobies are relatively small fishes that live near the bottom. They are mottled brown in colour, and bear a resemblance to our native sculpins. The front fins of gobies are joined underneath the body to form a suctorial disk which allows them to stay on the bottom in fast current. Gobies are the only fish that have this feature.

The round goby is the larger of the two species. It can reach lengths of 25 cm, and has a prominent black spot on its first dorsal fin. Round gobies prefer gravel and sandy bottoms. They occupy a broad range of depths, but are most abundant nearshore. The tubenose goby only reaches a size of 10 cm. It prefers shallow areas with aquatic vegetation.

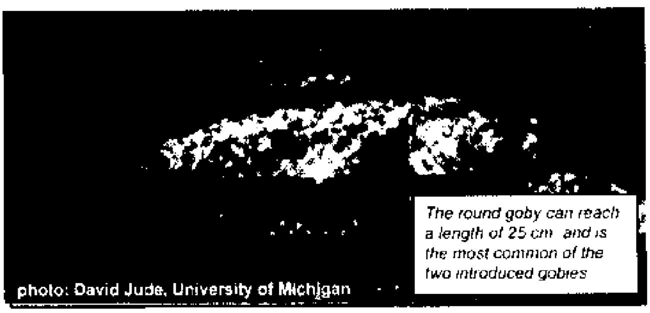


photo: David Jude, University of Michigan

*The round goby can reach a length of 25 cm and is the most common of the two introduced gobies*

## Where Are They?

After being discovered in the St. Clair River in 1990, gobies have been found in Lake St. Clair and in the Detroit River near Windsor. Round gobies have also been found in eastern Lake Erie (Welland Canal), southern Lake Erie, southern Lake Huron (Goderich), southern Lake Michigan, and western Lake Superior (Duluth). It is believed that these isolated populations were transported by ships from the St. Clair River area.

## What Do They Eat?

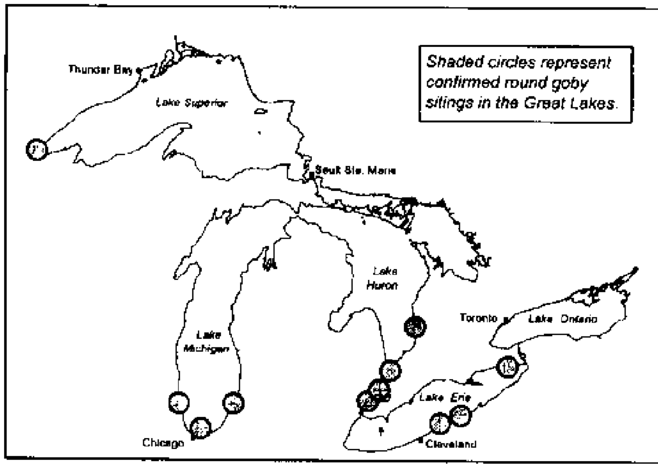
Both species of gobies feed largely on insects and other small organisms found on the bottom. As round gobies grow larger, they feed heavily on zebra mussels. Unfortunately, **it is unlikely that gobies will be successful in controlling zebra mussel numbers.**

## What Are The Impacts of The Introduced Gobies?

Round gobies have become very abundant in the St. Clair River and in other areas where they have been introduced. In the St. Clair River they have become an annoyance to anglers due to their habit of stealing bait. The round goby is an aggressive fish that can spawn several times in each season. These characteristics combined with its abundance and relatively large size, mean that the round goby will probably have an impact on native fish species. The smaller tubenose goby is not as abundant and widespread as the round goby, and should not have as much of an impact.

Although it is too early to tell exactly what impact the round goby will have in the Great Lakes, changes have already occurred in the St. Clair River. As round gobies have flourished, the abundance of the native mottled sculpin (a small bottom-dwelling fish) has declined dramatically in the river. Numbers of the native logperch (a small relative of the yellow perch) have also decreased. Similar changes are expected to occur where the round goby has been introduced in Lakes Erie and

Michigan. It appears that gobies have the ability to out-compete some of our small, native bottom-dwelling fishes. It is not clear what this will mean for larger fish species, but it could affect their feeding habits. Walleye and other predators in the St. Clair River are feeding on gobies. Goby populations have continued to expand despite this predation.




## What Can Be Done?

Although anglers and boaters can help to prevent the spread of gobies to inland waterways, there are no known ways of eliminating gobies from a large, open system such as the Great Lakes. Gobies, like many other exotic species are probably here to stay. Although some predators are feeding on gobies, it is unlikely that they will significantly reduce goby numbers. The proliferation of zebra and quagga mussels in the Great Lakes provides an ample food supply for the round goby, and they will continue to expand their range in the Great Lakes.

Gobies and many other exotic species have been introduced to the Great Lakes through the ballast water of ships. The zebra mussel, spiny water flea, and ruffe were all transported from Europe in this manner. The United States enacted legislation in 1993 requiring ships entering the Great Lakes to exchange their ballast water at sea. This should help to prevent additional introductions of unwanted exotic species. Further research is required to find effective ways of treating ballast water so that organisms will not be transported within the Great Lakes.

## Boaters and Anglers - You Can Help!

Now that gobies are firmly established in parts of the Great Lakes, it is important to prevent or slow their spread into our inland waters and other areas of the Great Lakes. Please take the following precautions to help prevent the spread of gobies and other exotic species:

✓ **Inspect** your boat, trailer and boating equipment and **remove** any visible plants or animals before leaving any waterbody.

✓ **Drain** water from the motor, live well, bilge and transom wells while on land before leaving the waterbody.

✓ **Empty** your bait bucket on land before leaving the waterbody. **Do not** collect baitfish from the Great Lakes for use in inland waters. **It is illegal** to use gobies as bait. **It is also illegal** to release baitfish from one waterbody into another.

✓ **Wash/Dry** your boat and equipment to kill harmful species that were not seen at the boat launch. Some species can survive for several days out of water, so it is important to:

- **rinse** your boat and equipment with hot tap water (> 40 °C); **or**
- **spray** your boat and equipment with high pressure water (250 psi); **or**
- **dry** your boat and equipment for at least five days, before transporting to another waterbody.

A toll-free Invading Species Hotline has been set up by the Ontario Federation of Anglers and Hunters, The Ontario Ministry of Natural Resources, and the Canadian Coast Guard. Members of the public can phone this Hotline to get information and report sightings of gobies and other exotic species. If you catch a round goby in an area not shown on the map, preserve the fish in alcohol or by freezing it. Then call the toll-free **Invading Species Hotline at 1-800-563-7711**, or contact the **Lake Erie Management Unit** at **(519)661-2730.**

The round goby *Neogobious melanostomus* along with its small cousin the tubenose goby *Proterorhinus marmoratus* are our latest uninvited piscine immigrants joining Great Lakes fish communities. First discovered in 1990 in the St. Clair River, the round goby has now spread throughout the St. Clair River system into Lake St. Clair, the head of the Detroit River, Lake Erie, southern Lake Michigan, southern Lake Huron, Lake Superior, and there are recent reports of their capture in Lake Ontario, completing their dispersal throughout the five Great Lakes in 5 years, dispersal almost as fast as the zebra mussel. How did a fish species move that fast into all the Great Lakes and what impacts is it having on native species?

First, a little about the life history of these fish. The tubenose goby is a small fish reaching lengths up to 110 mm (3 in), lives to about 5 years, and once the males spawn they die. They defend nests under rocks, shells, logs, and produce young that resemble adults. The diet consists of aquatic insects; some specimens we collected ate round goby fry in the St. Clair River. The tubenose goby has only been found in the St. Clair River, Lake St. Clair, and within the first 1 km of the Detroit River. It has not spread as far or as fast as the round goby. Population abundances would be considered low and they appear to have had negligible impact on fish communities to date. Ironically, because of habitat destruction, the tubenose goby is endangered in its native habitat of the Black and Caspian Seas in Russia.

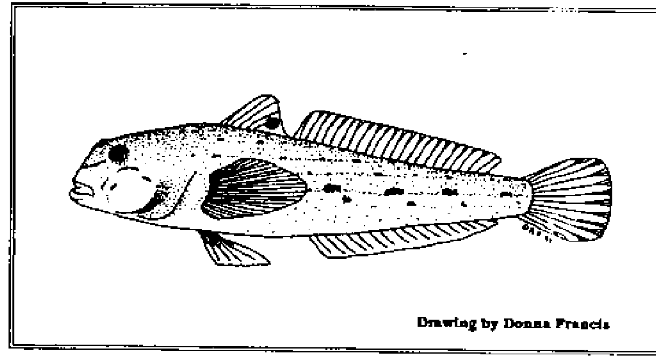
The round goby attains a much larger size, up to 250 mm or 10 in. After attaining a large size, males spawn once, then die. Females, however, do not die after spawning, and can spawn up to six times during the spring and summer, every 20 days conveying a great competitive advantage over native species that usually spawn once during spring. The round goby is robust, aggressive, and can withstand very low levels of dissolved oxygen and apparently defends the type of rocky and cobble habitat it prefers vigorously to the exclusion of some native species. Round gobies are adapted to be primarily mollusk eaters, which their well-developed, molariform teeth attest. The studies we have conducted so far indicate that at small sizes they eat benthos and benthic zooplankton while an increasing proportion of their diet as they grow older is zebra mussels, fingernail clams, and snails. Gerry Smith has recorded the consumption of over 100 zebra mussels per day in laboratory studies. We have only found one incidence of round gobies eating fish and that was a 41-mm adult trout-perch found inside a 139-mm round goby. This opens up another avenue of potential impact on native species, since round gobies can prey on fairly large, co-habitating benthic fishes. In our and other laboratories, round gobies have been documented killing and eating other species of fish, especially darters. However, this may be an aquarium, territorial effect rather than true predation. Round goby larvae also resemble the adults at hatching and appear to be benthic, since they have no swim bladder.

Our research in the St. Clair River has indicated that round gobies have seriously impacted mottled sculpin populations there causing a large decline and forcing remnants of the population into deeper water. Apparently the round goby does not compete as well with the mottled sculpin in deep water, as it obviously does in shallow water. The mechanism of this competitive advantage appears to be the aggressive nature of the round goby which drives mottled sculpin from prime feeding, shelter, and spawning areas. We think that spawning has been disrupted causing almost total year class failure of the mottled sculpin in areas where round gobies are abundant. This hypothesis is supported by evidence that shows that round gobies would drive mottled sculpin from one shared shelter in aquarium studies. In addition, field studies conducted by John Janssen indicate that mottled sculpins in the Grand Calumet River, southern Lake Michigan apparently suffered year class failure during 1994-1995, probably due to this mechanism.

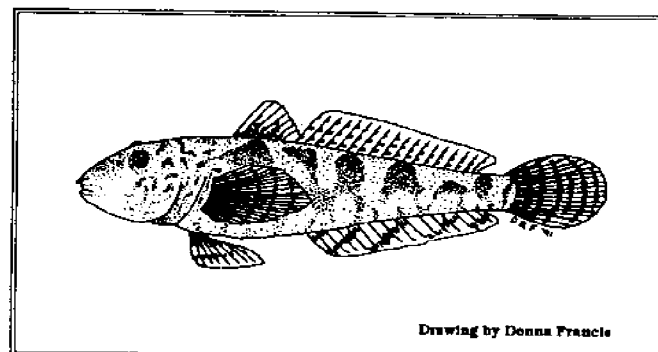
Round gobies are well adapted for transport in the ballast water of transoceanic ships and also freighters in the Great Lakes, which is probably how they got here in the first place and probably why they have been able to spread so far so fast. There are many incidences of freighter transport of other species of gobies into other water bodies across the world, so our experiences are not new. Round gobies are very cryptic species; they occupy holes, crevices, and cracks and may have occupied these places on ships. They may also have laid eggs on the undersides of ships or in suitable holes thereby allowing the eggs to be transported long distances before they hatched. The Family Gobiidae contains many species of cavefishes which are adapted for living in complete darkness. Round gobies have a lateral line system which is very well adapted for feeding in the dark. Studies performed by John Janssen on round goby have shown that round gobies can feed in complete darkness and can detect prey at a shorter distance than can mottled sculpin, giving them a competitive advantage in this area as well. These two creature features along with the round gobies tolerance for degraded water quality has probably pre-adapted round gobies for transport in ships and their ballast water.

Predators have shown an interest in round gobies in the St. Clair River, probably because they are so abundant in that system. Predators we found to have preyed on round gobies included rock bass, smallmouth bass, stonecat, tubenose goby, brown trout, walleye, yellow perch, and even mottled sculpin.

# GOBIES: CYBERFISH OF THE 90s




**round goby**
(*Neogobius melanostomus*)




**tubenose goby**
(*Proterorhinus marmoratus*)

There are two possibly damaging scenarios we are concerned about that may come to pass in the future. The first of these is food chain bioaccumulation of PCBs. Since zebra mussels are known to accumulate large concentrations of PCBs, and round gobies eat large numbers of zebra mussels, and now we have sport fish eating round gobies, the potential for contamination of important sport fish is of obvious concern. Secondly, another species of goby, the black goby, has been documented to cause the demise of a species of sculpin, which is a congener of our Great Lakes deepwater sculpin. The deepwater sculpin is very abundant in the deep abyss of the upper three Great Lakes. The potential exists for the round goby to have a negative impact on these populations. The literature states that round gobies will overwinter in water up to 50 m deep in the Black Sea. Deepwater sculpin usually reside in water 50 m or deeper. To date we have evidence that in the Great Lakes, round gobies have been found in 18 m (60 feet) of water in Lake Erie, 15 m (50 feet) of water in Lake Michigan and in 10 m of water in the St. Clair River. Therefore, the potential definitely exists for this species to occupy deeper water and affect deepwater sculpin. In addition, since the invasion of the quagga mussel, which has a cooler and deeper water tolerance, another source of mussels may be available for round gobies in the deeper areas of the Great Lakes, especially Erie and Ontario.

Appearance and dispersal of round gobies is another symptom of our damaged ecosystems in the Great Lakes, since entry of exotic species are favored when fish community integrity is severely destabilized. Exotic species, including the introduced salmon and rainbow and brown trout, alewives, rainbow smelt, and the infamous sea lamprey have irrevocably changed ecosystem form and function in the Great Lakes. The round goby is just another addition to our growing list of exotic species of not only fish, but of other groups, including invertebrates, well represented by the zebra mussel, and plants, including the notorious purple loosestrife, which is destroying our wetlands. These organisms are wreaking more havoc with ecosystem health than toxic substances or nutrients, since with the latter we at least have done something about controlling the problem. Once in, most successful exotic species establish permanent populations which are irrevocably detrimental to fish community stability and cause serious loss of irreplaceable genetic material and biodiversity. Like a broken heart, it is something that we just can't fix!

David J. Jude, Research Scientist
Center for Great Lakes and Aquatic Sciences
The University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109-2099

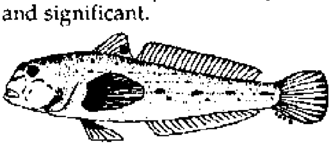
1-96

# Preventing the Spread of Round Gobies in the Illinois Waterways

## ISSUES

• **Aquatic Nuisance Species:** The introduction of aquatic nonindigenous nuisance species is a global problem. The establishment of some nonindigenous species may harm native species, including sportfish, by disturbing the balance of native ecosystems. Also, public use of aquatic resources for recreation and industry may be adversely impacted.

• **Illinois Waterways:** The Illinois Waterway System serves as a direct connection between the Great Lakes and the Mississippi River basin. Through the installation of a series of man-made canals and channels originally designed to advance the transport of cargo and people from the Great Lakes to the Mississippi River, water flows within the Chicago and Calumet Rivers were reversed (Figure1). This connection has provided many nonindigenous species the route to invade both basins. Zebra mussels are one of the most recent invaders of the Great Lakes to have spread into the Mississippi River through this pathway. The Great Lakes and Mississippi River basins include over 30 states, therefore potential impacts could be widespread and significant.



• **Round Goby:** The round goby (*Neogobius melanostomus*), a soft bodied fish species native to the Black and Caspian Seas, may be the next introduced species to expand its range to most of North America via the Illinois Waterway System. The round goby is poised for expansion through the Calumet River system. It is unlikely that the river system possesses any long-term natural barriers to prevent expansion.

## BACKGROUND

• **Round Goby Distribution:** The round goby was first collected in North American waters in 1990 in the St. Clair River, Michigan. It is believed to have been introduced in ballast water discharged by trans-atlantic ships. This recent invader was first reported in the Calumet River, southern Lake Michigan in 1993 (Figure 2). Recent surveillance efforts led by the U.S. Fish and Wildlife Service in the fall of 1996 have shown the round goby inhabiting downstream areas of the Little Calumet River approximately 12 miles from Lake Michigan. The round goby is therefore poised for further expansion into the Mississippi River basin via the Calumet Sag Channel and the Sanitary and Ship Canal.

• **Round Goby Biology:** The round goby is a benthic (bottom dwelling) fish species, noted for its aggressive feeding and defensive behavior. Concerns have been raised regarding its potential to outcompete species native to the Great Lakes for both food and space. Impacts to mottled sculpin populations are already apparent in the St. Clair River. Other species that might be affected include logperch and lake sturgeon. Also, if round gobies invade the Mississippi River basin, impacts to darters and other benthic species may be significant. Because the round goby is a benthivore (bottom feeder), concerns have arisen regarding its potential to accumulate contaminants and to contribute to increased contaminant levels in sportfish and other predator species through food web processes.

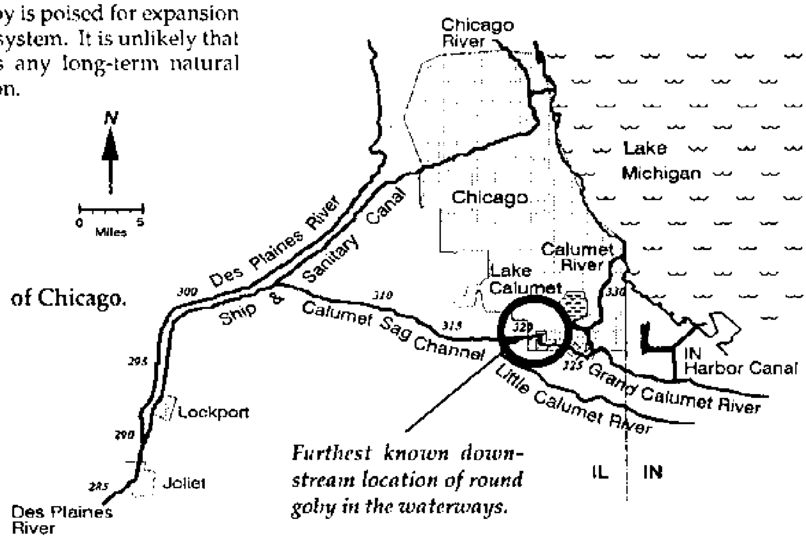



**Figure 1.**
**Illinois Waterway System of Chicago.**
**(Source: USFWS)**

• **Opportunity for Control:** Several factors lead natural resource managers to believe that a narrow window of opportunity may remain to implement control strategies to prevent the expansion of round gobies into downstream sections of the Illinois Waterway System. Since 1993, round goby populations have only expanded about 12 miles downstream indicating a relatively slow rate of spread within the waterway. Also, based on the surveys conducted in the fall of 1996, a short reach of river downstream of the round goby's current distribution is likely unsuitable habitat (because rocky substrate appears to be less common). This may provide a short-term natural barrier until population densities expand or gobies are transferred through bait use or other actions.

## ACTIONS UNDERWAY

• A national Aquatic Nuisance Species Task Force (Task Force) was established through mandates of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Act) to coordinate all federal activities involving nonindigenous aquatic species with those of the private, or non-governmental sector. The Task Force is chaired by the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration. Membership includes five other federal agencies and 10 non-governmental agencies as ex officio members.

• In August 1995, Minnesota Sea Grant recommended to the Task Force that the round goby be considered for nuisance status, as defined by law, and that control alternatives be investigated. A resource document examining risk assessment and control feasibility is currently being developed to assist the Task Force in its decision-making process. The U.S. Fish and Wildlife Service is leading this activity.

• In October 1996, Congress reauthorized the Act, recognizing the national and global significance of this issue through many new mandates. One of the provisions requires the Assistant Secretary of the Army (Civil Works), in consultation with the Task Force, to investigate and identify environmentally sound methods for preventing and reducing the dispersal of nonindigenous aquatic nuisance species between the Great Lakes and Mississippi River drainages, via the Illinois Waterway System.

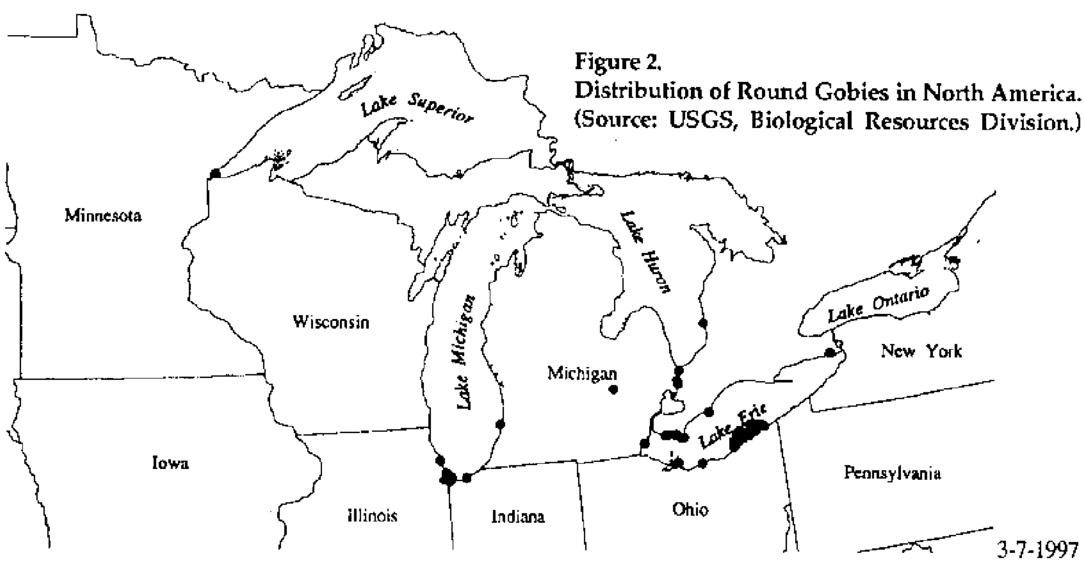
• In November 1996, the Task Force charged the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to develop and recommend specific control strategies that could be implemented immediately to prevent the spread of round gobies in the Illinois Waterway System. Recommendations, developed through a series of meetings, shall be formally presented to the Task Force in spring of 1997.

### For more information contact:

| | |
|---|---|
| Edwin Theriot - USACE, Vicksburg, MS | (601) 634-2678 |
| Phil Moy - USACE, Chicago, IL | (312) 353-6400 |
| Sanda Keppner - USFWS, Amherst, NY | (716) 691-5456 |
| Pam Thiel - USFWS, Onalaska, WI | (608) 783-8431 |
| Jay Rendall - MN DNR, St. Paul, MN | (612) 297-1464 |
| Patrice Charlebois - IL/IN SG, Zion, IL | (847) 872-0140 |

*Note: The information included within this fact sheet was compiled and prepared by the U.S. Fish and Wildlife Service, Minnesota Department of Natural Resources, and the Illinois/Indiana Sea Grant Program.*

**Figure 2.**
**Distribution of Round Gobies in North America. (Source: USGS, Biological Resources Division.)**



United States Department of the Interior

FISH AND WILDLIFE SERVICE
Washington, D.C. 20240

IN REPLY REFER TO:

FWS/MA

Michael E. McDonald, Ph.D
Director, Minnesota Sea Grant
2305 East 5th Street
Duluth, Minnesota 55812-1445

Dear Dr McDonald:

This responds to your letter of August 22, 1995, requesting the Aquatic Nuisance Species Task Force (Task Force) to designate the round goby (*Neogobius melanostomus*) as an aquatic nuisance species

Prior to determining whether a control program is warranted, the Task Force will evaluate the following factors

1. need for control, including the projected consequences of no control and less than full control;
2. the technical and biological feasibility and cost-effectiveness of alternative control strategies and actions,
3. whether the benefits of control, including cost avoided, exceed the costs of the program, and
4. the risk of harm to non-target organisms and ecosystems, public health and welfare; and such other appropriate considerations

In addition, the Task Force shall determine what constitutes feasible and desirable control mechanisms. If warranted, the Task Force will develop a control program that achieves the desired target level of control

We would appreciate receiving any pertinent biological, ecological, and economic information that you may have available that would assist us in evaluating the need for a control program. Please forward all information to the attention of Jay Troxel, U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, Suite 840, Arlington, Virginia 22203, (703-358-1718), or Herb Kirch, National Oceanic and Atmospheric Administration, Herbert C. Hoover Building, Room 6117, 14th and Constitution Avenue, N.W., Washington, D.C. 20230, (202-482-5181).

The Task Force is concerned about emerging nuisance species issues and problems surfacing around the nation We greatly appreciate the views and concern expressed by your organization regarding invasive species.

Sincerely,

Gary B. Edwards
USFWS
Co-Chair, ANS Task Force

Katharine W. Kimball
NOAA
Co-Chair, ANS Task Force

Southeastern Biological Science Center
7920 N.W. 71st Street
Gainesville, Florida 32653
Telephone (352) 378-8181 FAX (352) 378-4956

# NONINDIGENOUS SPECIES DATA BASE VOLUNTARY REPORTING FORM

**Common Name**______________________________

Genus______________________ Species______________________

Subspecies______________________ **Date Collected**______________________

**State**________ **County**____________ Drainage Basin______________________

**Location**______________________________
(please be as specific as possible, e.g. distance and direction to nearest town)

______________________________

______________________________

______________________________

Habitat Type: River/Stream____ Natural Lake/Pond____ Marsh/Swamp____
Canal/Ditch____ Man Made Reservoir____ Estuary/Bay____

Other Habitat______________________________

Water Temperature________ Salinity______ DO______ pH______ Depth______

Water Velocity__________ Substrate______________________

Vegetation______________________________
(presence, absence, type, species if known)

Identified By______________________________
(name, address, and phone number)

**Collected By**______________________________
(name, address, and phone number)

Method of Collection______________________________
(cast net, electrofishing, gill net, hook/line, rotenone,seine,trammel net, trall, trot line,?)

Number Collected________ Age________ Class__________ Size__________
(larvae, juvenile, adult)

Method of Disposal______________________________
(discarded, ethanol, formalin, frozen, mounted, released, tagged and released, ?)

Specimen Storage______________________________
(museum or agencies name and collection number)

Comments______________________________

______________________________

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*At minimum, please provide the name or description of what you have observed, where it was observed, the date it was observed, your name and how you may be reached.