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Letter to the Editor

The invasive round goby may attach its eggs to ships or boats – but there is no evidence

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The round goby *Neogobius melanostomus* is an invasive vertebrate species that is currently on the agenda of many environmental managers. In Europe, it is considered one of the "100 worst" invasive species (Vilà et al. 2009). The species is reported to alter the properties of aquatic ecosystems from contaminant recirculation to community restructuring to species extinctions (Hirsch et al. 2016a). Based on the common assumption that invasive goby eggs could be translocated attached to ship or boat hulls (Janáč et al. 2012; Roche et al. 2015; Kotta et al. 2016), hull cleaning approaches are increasingly being considered as a preventive management option to protect certain water bodies from round goby invasion.

To support a management initiative in Switzerland, we searched Web of Knowledge, Google Scholar, and PubMed for papers on round goby spread, round goby egg attachment, or round goby dispersal, and screened them for mention of boats, ships, hulls, eggs, or clutches. Russian publications were professionally translated. We identified several scientific, peer-reviewed publications which report that the eggs of invasive Ponto-Caspian goby species travel attached to ship hulls, or which cite such reports. However, we could not identify any evidence on the matter. Ultimately, all reports were based on anecdotal reports, or on circumstantial evidence from goby behaviour (Figure 1, Table 1).

We agree with the commonly proposed assumption that invasive Ponto-Caspian goby species could be travelling with ships. Indirect evidence supports this assumption. Both spread patterns and population genetics correlate with shipping routes (Wiesner 2005; Adrian-Kalchhauser et al. 2016). Invasive gobies have been observed close to boats, and they thrive in harbours (Vélez-Espino et al. 2010). Since invasive gobies accept artificial spawning substrates (Corkum et al. 1998; Hirsch et al. 2016b), and goby eggs are able to withstand the harsh conditions expected during ship travel or boat transport (Rubinoff and Rubinoff 1969; Hirsch et al. 2016b), it is possible that egg attachment plays a role in Ponto-Caspian goby translocations. Ballast water and bilge water constitute additional possible vectors. Preventive management approaches targeting boats and ships as vectors are therefore justified. Indirect support for a spread mode should suffice as an argument for preventive measures in the management of invasive species. By definition such measures must be installed at the point of risk perception and before the risk has become real to such an extent that it can be empirically tested. Nonetheless, the concept that Ponto-Caspian goby species attach their clutches to aquatic vessels is currently not supported by evidence and thus remains an untested hypothesis. We therefore urge that the hypothesis should be communicated as untested, and that evidence is presented if it exists.

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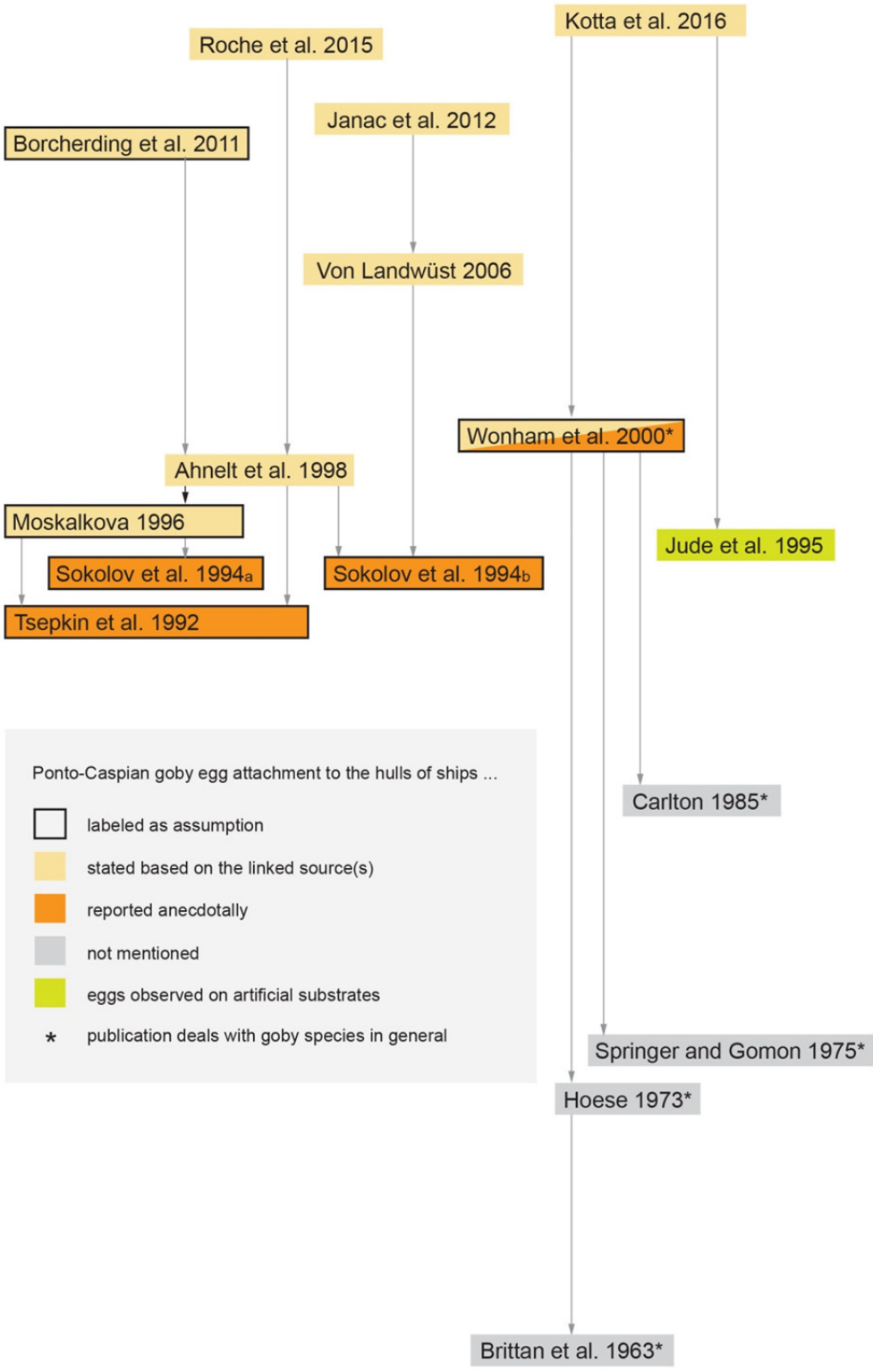

Figure 1. Scientific literature containing statements on goby egg attachment to ship or boat hulls. See Table 1 for the associated statements from these papers.

Table 1. Text passages from Figure 1.

Figure 1, left	Roche et al. 2015	It is now generally accepted that initial introductions have been through international shipping at major ports (Wiesner 2005) through accidental transport of juveniles/eggs in ballast water or as eggs attached to the ship's hull (Ahnelt et al. 1998; Hayden and Miner 2009), followed by natural spreading from the point(s) of introduction (Roche et al. 2013).
	Borcherding et al. 2011	Whichever route was taken, the round goby was probably introduced via ballast water released from ships (Ricciardi and Rasmussen 1998; Neilson and Stepien, 2009) or from eggs attached to ship hulls which in turn hatched at the new location (Ahnelt et al. 1998) and spread into nearby areas.
	Hayden and Miner 2009	[discuss larval transport with ballast water]
	Ahnelt et al. 1998	The transport of egg clutches of *N. melanostomus* and *P. marmoratus* on the hull of ships travelling along the Volga and its tributaries has recently been reported (Tsepkin et al. 1992; Sokolov et al. 1994b). A long incubation period (about two to three weeks) and the fact that freshly hatched *N. melanostomus* juveniles stay among the egg membranes for several additional days allow them to be moved considerable distances with a ship during that time (Moskal'kova 1996).
	Moskal'kova 1996	In light of the aforementioned characteristic of the round goby, the penetration of the sedentarian round goby from the Volga into the Moskva River by means of the passive dispersion of egg clutches attached to the fouling on the bottoms of barges travelling along the Volga and its tributaries is probable, as suggested by several authors (Tsepkin et al. 1992; Sokolov et al. 1994a). Thus, if the eggs were laid during the mooring in the harbor, further moving by the ship provides conditions analogous to those provided by males when guarding the eggs. Ventilation of the clutch, its cleaning, and to some extent its protection from predation are provided during the boat motion.
	Sokolov et al. 1994a (Russian)	At the same time, two new invading species were spotted for the first time in the Moscow river fish fauna – the round goby *Neogobius melanostomus* and the tubenose goby *Preterorhinus marmoratus* – whose egg batches "swam up" from the Southern seas, apparently on the bottom of motor ships and barges, which were overgrown with coquina.
	Sokolov et al. 1994b	At that time, two new immigrant species were found for the first time in the Moscow River, the round goby, *Neogobius melanostomus*, and the tubenose goby, *Proterorhinus marmoratus*, whose eggs evidently were transported on the bottoms of boats and barges.
	Tsepkin et al. 1992 (Russian)	It is hard to believe that this slow-moving groundfish is capable of travelling several hundred kilometres against the stream, even surmounting cascades of dams, without assistance. In this case, we are most likely dealing with passive settling, when batches of goby eggs are transported attached to coquina growing on the bottom of motor ships and barges which go up the Volga and the Moscow canal.
Figure 1, center	Janáč et al. 2012	In recent decades, this and other gobiid species have invaded new regions facilitated and accelerated by transport in the ballast water of ships, by transport of eggs on ships, by accidental stocking with other fish species, by release of bait fish and through their ability to colonize riprap structures along inland waterways (Von Landwüst 2006).
	Von Landwüst 2006	In recent decades it showed a rapid expansion of its range, facilitated and accelerated by transport in the ballast water of ships (Ahnelt et al. 1998; Wonham et al. 2000), by transport of egg clutches on ship hulls (Sokolov et al. 1994b), by accidental stocking together with other fish species (Friedl & Sampl 2000), release of bait fish (Prášek and Jurajda 2005), and through its ability to colonize riprap structures along inland waterways (Jude 1996; Ahnelt et al. 1998).
	Sokolov et al. 1994b	At that time, two new immigrant species were found for the first time in the Moscow River, the round goby, *Neogobius melanostomus*, and the tubenose goby, *Proterorhinus marmoratus*, whose eggs evidently were transported on the bottoms of boats and barges.

Table 1 (continued). Text passages from Figure 1.

Figure 1, right	Kotta et al. 2016	The larvae and early juveniles of the round goby, similar to several demersal fish species, undergo diel vertical migration and therefore nocturnal ballasting can result in the transport of larval and young round gobies (Hensler and Jude 2007; Hayden and Miner 2009). Moreover, the gobiidae are known to lay eggs on hulls or within sea-chests (Wonham et al. 2000; Jude et al. 1995) and their pelvic fins reduce maintenance costs while carried within ships' ballast water (French and Jude 2001).
	Wonham et al. 2000	The invasive success of gobies and blennies may be explained in part by their crevicolous nature: both groups seek refuge and lay eggs in small holes, and may take advantage of the ballast-intake holes on ship hulls. [...] The crevicolous nature of gobies when seeking refuge and laying eggs may predispose them to ballast-water transport, particularly if the ballast-intake grates on ship hulls present appealing crevices (Carlton 1985; Hoese 1973; Springer and Gomon 1975).
	Jude et al. 1995	In this case spawning occurred on the upper surfaces of a hollowed out oak log. One round goby was observed guarding eggs in a beer can on the bottom of the St. Clair River in June (K. Johnson and Greg Lashbrook, personal communication, Clyde, MI), and we collected newly hatched larval round gobies from Lake St. Clair Chara beds, where spawning presumably occurred.
	Carlton 1985	Herdman, Thompson and Scott (1897) described the composition of plankton samples pumped aboard a steamer into a deck tank as the vessel crossed the north Atlantic Ocean. Taxa passing through the pumps into and through the ship's seawater system included numerous species of protists (diatoms, dinoflagellates, radiolarians, foraminiferans), and of adult and larval animals (hydromedusae, polychaetes, cladocerans, ostracods, barnacle cyprids, harpacticoid, cyclopoid and calanoid copepods, hyperiid amphipods, mysids, isopods, shrimp and crab larvae, euphausiids, bivalve and gastropod larvae, pteropods, chaetognaths, and fish the last including eggs, embryos, and larvae). Of the remaining "possible" cases, four species of blennies and gobies may have been transported either on or in vessel fouling or in ballast water. McCosker and Dawson (1975) have demonstrated that *Lupinoblennius*, *Hypleurochilus*, and *Lophogobius* are all euryhaline and could survive transport through the freshwater sections of the Canal, while Rubinoff and Rubinoff (1969) experimentally determined that the eggs of the stenohaline, *Gobiosoma*, can survive in freshwater portions of the Canal and still remain viable.
	Hoese 1973	Brittan et al. (1963) have suggested that the eggs [of *Acanthogobius flavimanus* and *Tridentiger trigonocephalus*] may have been transported attached to fouling organisms in the sea water system. *Acanthogobius flavimanus* lays eggs in burrows constructed in mud, while *Tridentiger* deposits its eggs on oyster shells. *Acanthogobius* is known to lay eggs in earthen pipes and might conceivably spawn in sea water intake pipes or in a sheltered space under the hull of a ship.
	Brittan et al. 1963	Newman (1963, pp. 128-9) feels *Palaemon* larvae may have been carried in a ship 's sea water system which was partially clogged with fouling organisms, such as tubeworms and barnacles. *A. flavimanus* could have been introduced in a similar manner.
	Springer and Gomon 1975	Dutt and Visveswara Rao (1961) reported *O. zebra* (as *Petroscirtes bipunctata*) nesting in holes in mangrove stems in the Godavari River estuary (16º28′N, 82º03′E) in India.

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