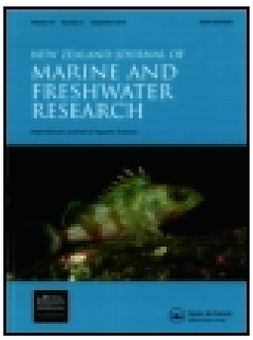

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Short communication

Invasion of the Asian goby, *Acentrogobius pflaumii*, into New Zealand, with new locality records of the introduced bridled goby, *Arenigobius bifrenatus*

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Abstract The Asian goby, *Acentrogobius pflaumii* (Bleeker, 1853), is reported from New Zealand waters for the first time. It was collected by beach seine in 2001–02 from muddy substrata in the upper reaches of the Waitemata and Whangapoua Harbours. We suggest that *A. pflaumii* has been introduced to New Zealand, probably in ship ballast water. It may have arrived directly from its native range in the north-west Pacific Ocean, or indirectly via Australia, which it invaded before 1996. The Australian bridled goby, *Arenigobius bifrenatus* (Kner, 1865), which is also thought to have invaded New Zealand via ballast water, is here recorded from three new locations, extending its known New Zealand range to five different harbours spanning c. 150 km of coastline. This species is more widespread than previously thought and appears well established. Both gobies have been found only on the east coast of the North Island.

Keywords *Acentrogobius pflaumii*; *Arenigobius bifrenatus*; goby; invasion; ballast water; biosecurity

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INTRODUCTION

New Zealand is now home to at least 150 species of introduced marine organisms, most of which are invertebrates or algae. In a review of New Zealand's adventive marine species, Cranfield et al. (1998) identified only five marine fishes. Four of these had been deliberately introduced, but only one of them, the diadromous chinook salmon *Oncorhynchus tshawytscha*, became established. The fifth species, the damselfish *Abudefduf vaigiensis*, arrived in New Zealand in 1975 on a towed oil rig (Foster & Willan 1979), but it also failed to establish. Interestingly, the same species has been recorded twice recently from the north-eastern North Island in what appear to be self-introductions through oceanic larval transport from subtropical areas to the north (Francis et al. 1999; C. Worthington, Bay of Islands pers. comm.).

In 1998, the Australian bridled goby, *Arenigobius bifrenatus* (Kner, 1865), was discovered in the Waitemata and Whangateau Harbours on the north-east coast of North Island; it is thought to have been introduced by release of ballast water from passing ships (Willis et al. 1999). A small brackish water microdesmid, probably the Australian *Parioglossus marginalis* Rennis & Hoese, 1985, was recorded for the first time in 2000 from saline streams entering estuaries at North Cape and Great Barrier Island; it is not known whether this species has been introduced to New Zealand, or is a native that has previously been overlooked because of inadequate sampling (McDowall 2001).

In this paper, we report the discovery of a further small fish species, the goby *Acentrogobius pflaumii* (Bleeker, 1853), in two northern New Zealand estuaries. We suggest that it is a recently-introduced species that has been transported from its native range in the north-west Pacific via ballast water. The species may have arrived in New Zealand directly, or via Australia, which it invaded before 1996. We also report the capture of further specimens of *A. bifrenatus* in three further estuaries, showing that this introduced species is more widespread than previously thought.

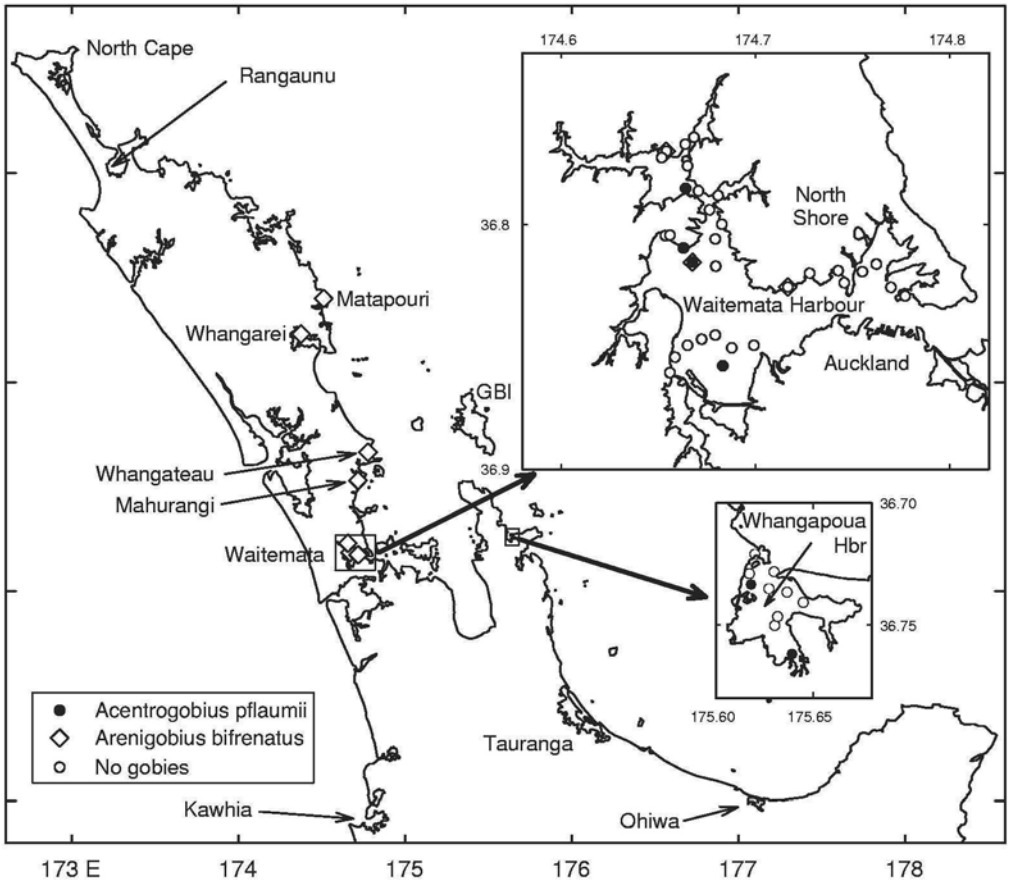

Fig. 1 New Zealand locations where *Acentrogobius pflaumii* and *Arenigobius bifrenatus* were caught by beach seine or observed by diving. Beach seine tows in Waitemata and Whangapoua Harbours that caught neither goby are also shown. (GBI, Great Barrier Island.)

OBSERVATIONS

Acentrogobius pflaumii (Bleeker, 1853)

During January–March 2001, we carried out a large-scale, small-fish survey of 25 estuaries and harbours in the northern North Island. The locations surveyed ranged from Kawhia and Ohiwa Harbours in the south to Rangaunu Harbour in the north (Fig. 1). At each location, a number of beach seine tows (5–40 per harbour, mean 12) were carried out within 2.5 h of low tide. The net was 11 m wide, had a headline height of c. 1 m, and a 4-m-long codend of 9 mm mesh. When towed at a slow walking pace, it swept a path c. 8 m wide. A total of 305 tows were made.

Acentrogobius pflaumii were caught only in Waitemata Harbour (Fig. 1), on 8–9 February 2001. Thirty-six individuals were taken from four stations scattered throughout the upper harbour. The substratum at three stations was soft mud, and the net bogged down while being towed. At the fourth station, the substratum was firm mud mixed with gravel. No vegetation (e.g., seagrass or mangroves) was present at any of the stations. Salinity measured at one station was 34.9‰, and surface water temperatures at the four stations were 21.8–22.7°C. The gobies measured 24–70 mm total length (TL), but most were 25–40 mm (Fig. 2).

No *A. pflaumii* were collected from eight beach seine tows carried out in Whangapoua Harbour on 21 February 2001 (Fig. 1). However, additional sampling between 14 March and 16 April 2002 caught 27 specimens at two Whangapoua stations:

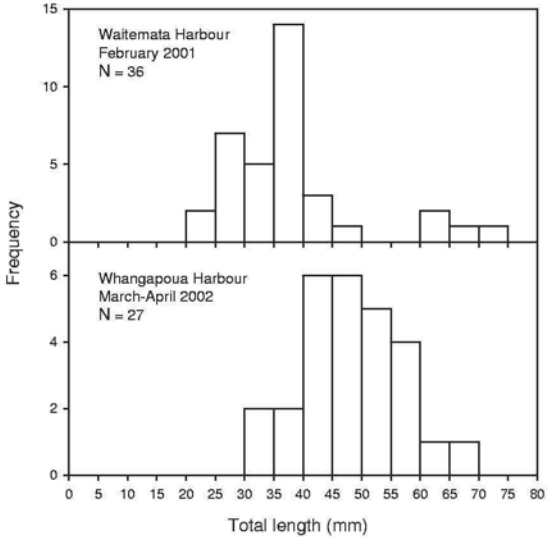

Fig. 2 Length-frequency distributions of *Acentrogobius pflaumii* caught at Waitemata and Whangapoua Harbours, New Zealand. For three Whangapoua gobies, fresh total length was calculated from total length after preservation in ethanol using a regression equation derived from our data: $TL_{fresh} = -0.536 + 1.006\ TL_{ethanol}$ ($N = 28$, $R^2 = 0.996$).

one was on soft mud in the upper reaches of the southern harbour, in a narrow channel adjacent to a seagrass (*Zostera capricorni*) bed (30 m away) and mangroves (*Avicennia marina*) (70 m); and the other was on sand in the northern harbour (where specimens were caught both in and adjacent to an extensive seagrass bed). The stations at which *A. pflaumii* were caught in 2002 were not sampled in 2001, so it is not known whether fish were present in the harbour in 2001 and missed, or whether the gobies invaded the harbour between the two sampling periods. The gobies measured 34–69 mm TL fresh (Fig. 2).

Six specimens from Whangapoua Harbour were deposited in the Museum of New Zealand (NMNZ P.38084, 14 March 2002, 5 specimens, 36–56 mm standard length (SL); NMNZ P.38118, 16 April 2002, 1 specimen, 38 mm SL). The first five specimens mentioned were identified as *A. pflaumii* by D. F. Hoese (Australian Museum, Sydney, Australia pers. comm.), who is familiar with the species from Australia (Fig. 3). Hoese is preparing a description of the New Zealand material for publication elsewhere.

Arenigobius bifrenatus (Kner, 1865)

Specimens of *A. bifrenatus* were caught while beach seining in four different harbours (out of 25 sampled): Whangateau and Mahurangi Harbours in April 2000 (one fish from each harbour); Waitemata and Whangarei Harbours in February–March 2001 (five and one fish respectively); and Mahurangi Harbour in February 2002 (three fish) (Fig. 1). These fish measured 35–115 mm TL fresh, but all except two were longer than 85 mm. Habitats occupied by the gobies were mud, in or adjacent to seagrass beds, or very soft mud adjacent to mangroves (except for Waitemata stations, with no nearby vegetation). At one of the Waitemata Harbour stations, *A. bifrenatus* and *A. pflaumii* were caught in the same tow (Fig. 1).

Underwater photographs of *A. bifrenatus* were taken by a diver in Matapouri Estuary (Fig. 1) in December 2000 (R. Armstrong, Tutukaka pers. comm.; Fig. 4). On 21 May 2002, 12 individuals were seen and photographed in the same estuary (M. P. Francis pers. obs.). These fish were found in a very restricted habitat, occupying a c. 2-m-wide strip of relatively bare sandy mud studded with mangrove pneumatophores; this strip was situated between emergent mangrove trees and a submerged vegetation band consisting mainly of unattached *Hormosira banksii* and sparse seagrass. The gobies were observed resting on the substratum in c. 50 cm of water, and they dived rapidly head-first into holes in the mud when disturbed.

The specimens from Mahurangi and Whangarei Harbours, and observations from Matapouri Estuary, represent new distributional records for this species. *A. bifrenatus* is now known from five locations in New Zealand spread over c. 150 km of coastline.

DISCUSSION

The fish fauna of New Zealand's estuaries and harbours has been poorly studied until recently. The only comprehensive study of the goby fauna focused on two native species, recently re-identified as *Favonigobius lentiginosus* and *F. exquisitus* (D. F. Hoese pers. comm.), in Whangateau Harbour in the early 1980s (McKenzie 1984). That study, and others that used beach seines to sample Whangateau Harbour (Grogan 1984; Park 1984), Manukau Harbour (Pearks 1982), and Waitemata Harbour (Saunders 1999), did not record *A. pflaumii*, though the possibility that it was caught and not recognised cannot be ruled out. Most of those studies targeted

Fig. 3 *Acentrogobius pflaumii*, Victoria Docks, Melbourne, Australia. (Photo: R. Kuiter.)

Fig. 4 *Arenigobius bifrenatus*, Matapouri Estuary, New Zealand. (Photo: R. Armstrong.)

specific species, and may have paid little attention to non-target species.

Our study of the fish faunas of estuaries in the northern North Island began in 2000, and we carried out a large-scale beach seine survey of small fish in 25 estuaries in early 2001. However, our sampling intensity in many of the harbours was low, and localised populations of *A. pflaumii* could easily have been missed. Furthermore, our sampling technique may not be the most appropriate for this species. *A. pflaumii* is most abundant in water deeper than 5 m in Port Phillip Bay, Victoria, Australia, but is apparently rare in shallow water sites sampled by beach seine (Hamer et al. 1998; Lockett & Gomon 1999, 2001). Manukau Harbour, on the west coast, is the only location where we have sampled habitats deeper than 1.5 m using gear appropriate for gobies, so it is possible that *A. pflaumii* is more widespread and abundant in New Zealand than is currently understood. It is therefore not possible to define the current distribution of the species, or to determine when the Asian goby first arrived in New Zealand.

The native distribution of *A. pflaumii* is the north-west Pacific Ocean, where it has been reported from southern Japan, Korea, Taiwan, and the Philippines (Fowler 1960; Masuda et al. 1975, 1984). A report of this species from the Nicobar Islands in the eastern Indian Ocean (Matsubara 1955, in Fowler 1960) is likely a mis-identification of another species. The taxonomy of the genus *Acentrogobius*, and related genera, is uncertain, and further study is required to determine whether *A. pflaumii* does occur throughout the north-west Pacific, or whether several closely related species have been confused.

Acentrogobius pflaumii was first discovered in Australia in 1996, at Melbourne's Victoria Docks in Port Phillip Bay, and it is thought to have been introduced in the early to mid 1990s (Lockett & Gomon 1999, 2001). Subsequent sampling throughout Port Phillip Bay in 1997–98 found that the species was the eighth most abundant fish taken by beam trawl, and that it was present in all regions of the bay except near the entrance (Hamer et al. 1998; Lockett & Gomon 1999, 2001). *A. pflaumii* also occurs in other Australian harbours, including Botany Bay and Sydney Harbour (M. M. Lockett, University of Technology, Sydney, Australia pers. comm.; D. F. Hoese pers. comm.).

The largest New Zealand *A. pflaumii* was 70 mm TL. This is similar to maximum sizes reported in Port Phillip Bay of 70 mm TL (Hamer et al. 1998) and 62 mm SL (c. 77 mm TL) (Lockett & Gomon 2001). The species is reported to reach 80 mm TL in the north-west Pacific (Fowler 1960; Masuda et al. 1975). Whangapoua Harbour fish were larger, on average, than Waitemata Harbour fish (Fig. 2). In the absence of information on the growth rate of *A. pflaumii*, it is not clear whether this difference is a result of fast growth over summer (Whangapoua was sampled 1–2 months later than Waitemata), or different growth rates or age compositions in the two populations.

How *A. pflaumii* arrived in New Zealand is uncertain. It is possible that it is self-introduced from Australia. New tropical and subtropical fish species are regularly recorded from north-eastern North Island waters, and are thought to arrive in New Zealand as planktonic larvae or pelagic juveniles that have been transported by ocean currents from upstream sources such as Norfolk Island (Francis & Evans 1993; Francis et al. 1999). However, eggs and larvae of fish species that inhabit harbours and estuaries are less likely to be transported across oceans because they are spawned away from major current systems. Furthermore, ocean transport of temperate fish species from Australia to New Zealand has not previously been documented; tropical and subtropical species have a distinct advantage over temperate species because they can "island-hop" from Australia to New Zealand via Lord Howe and Norfolk Islands in the north Tasman Sea.

However, *A. pflaumii* meets the following four of nine criteria proposed by Chapman & Carlton (1994) for assessing the likelihood that a species is invasive: (1) the species' distribution is associated with human mechanisms of dispersal (shipping—see below); (2) the species' distribution is restricted compared with that of native species (*Favonigobius lentiginosus* and *F. exquisitus* are found in many estuaries, the former mainly in the north-eastern North Island, and the latter in both the north-eastern and north-western North Island); (3) the species has a disjunctive worldwide distribution; (4) natural dispersal mechanisms are inadequate for dispersal from Asia to New Zealand.

We suggest that *A. pflaumii* arrived in New Zealand in ship ballast water. Most adventive species are robust cryptic fishes that inhabit shallow coastal environments and are usually abundant in ports. They have long spawning seasons and produce large numbers of free swimming pelagic larvae that have the potential for being taken up in ballast water (Lockett & Gomon 1999). They can also tolerate temperature and salinity fluctuations, and low oxygen concentrations, and are hardy enough to survive ocean crossings in ballast tanks (Hoese 1973; Carlton 1985). Live fishes have been collected from ballast water in ships operating between Japan and Australia (Williams et al. 1988) and Japan and the United States (Carlton & Gellar 1993).

The potential for ship-mediated introduction of small marine fishes from Australian harbours and estuaries to New Zealand is considered high because both countries share significant international shipping trade, and both span common latitudes and have similar environmental conditions in harbours and estuaries. Support for this route for invasion of *A. pflaumii* is provided by the successful introduction of the Australian *A. bifrenatus* to northern New Zealand (Willis et al. 1999), and the reciprocal introduction of New Zealand triplefins into Australia (Clements et al. 2000; Lockett & Gomon 2001). However, direct introduction of *A. pflaumii* from the north-west Pacific is also possible. Although most of New Zealand's shipping trade is with Australia, most ballast water released in New Zealand originates from Asia (Nelson 1995). Support for this route is provided by the observation that most goby introductions worldwide have originated from Japan (Carlton 1985). Also, *A. pflaumii* established itself in Australian waters, presumably from an Asian source, and the distance and travel time between Asia and Australia is practically the same as between Asia and New Zealand.

The stations where *A. pflaumii* were caught in the Waitemata Harbour are only 7–12 km from the port of Auckland (Fig. 1), which is the busiest international shipping port in New Zealand (Nelson 1995). By contrast, Whangapoua Harbour is a relatively pristine

estuary that has no large shipping. However, Whangapoua is adjacent to the route taken by vessels steaming between North Cape and Tauranga (Fig. 1), which is the second busiest international shipping port in New Zealand (Nelson 1995), and considerable volumes of logs and wood chips are transported between there and Asia. The Whangapoua population of *A. pflaumii* may have originated from ballast water discharged off the coast by a passing vessel. Willis et al. (1999) proposed the same scenario for the arrival of *A. bifrenatus* in Whangateau Harbour. Alternatively, the Whangapoua population of *A. pflaumii* may have originated from another New Zealand population (such as that in the Waitemata Harbour) by secondary translocation via coastal shipping, or by natural dispersal.

It is not known whether *A. pflaumii* has established self-sustaining populations in New Zealand. The populations in Waitemata and Whangapoua Harbours span the full size range of the species except for an absence of fish <20 mm TL (Fig. 2). Their absence may be a result of escapement through the meshes of the beach seine, or non-availability to the fishing gear for behavioural or habitat reasons. Future research should attempt to locate newly settled juveniles and gravid females. The presence of these elements would add support to, though not prove, successful breeding in New Zealand.

The extent to which newly introduced marine fishes will impact on native species or the physical environment is unknown. Some introductions have obscured the biogeography of native fishes and profoundly affected the community structure of coastal ecosystems (Baltz 1991). *Tridentiger bifasciatus*, a goby from Japan and China that was discovered in San Francisco Bay in 1985, preys on and competes with the native goby *Eucyclogobius newberryi* (Matern & Fleming 1995). The spread of the introduced Japanese goby *Acanthogobius flavimanus* in the same waters was described as "explosive" (Brittan et al. 1970), but in New South Wales it has had only limited success (Middleton 1982). Many introduced species probably fail to establish at all.

Acentrogobius pflaumii has become abundant and widely distributed in Port Phillip Bay and elsewhere in Australia in less than a decade (Lockett & Gomon 1999, 2001), but its impact on local marine life and the environment is unknown. Environmental conditions in New Zealand estuaries are presumably conducive to the expansion of the range *of A. pflaumii*, but we are unable to predict whether this will affect native fauna or flora. In Japan, *A. pflaumii* inhabits sandy flats and *Zostera* beds in the inner parts of bays, and may make seasonal migrations between these habitats (Matsumiya et al. 1980). The species spawns in summer, feeds mainly on copepods when <50 mm TL, and thereafter on gammarid amphipods (Matsumiya et al. 1980). In Port Phillip Bay, Australia, the largest *A. pflaumii* were caught in the central, deeper part of the bay, and the size composition of samples varied seasonally, possibly through growth of cohorts of fish (Hamer et al. 1998). The potential impact might therefore vary spatially and temporally.

The possible ecological impact of *A. bifrenatus*, which is more widespread than previously thought, is also unknown. Studies on the ecology of this species in New Zealand are underway, and will hopefully shed light on its ecological role (T. Willis, University of Auckland pers. comm.).

Both *A. pflaumii* and *A. bifrenatus* overlap in range and habitat with two abundant New Zealand native gobies, *Favonigobius lentiginosus* and *F. exquisitus* (authors' unpubl. data). Both introduced species grow substantially larger than the two native species (which rarely exceed 50 mm TL), but further research is required to determine whether inter-specific competition will occur.

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