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The Oriental Goby, *Acanthogobius flavimanus*, Colonizes a Third Estuary in New South Wales, Australia

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The oriental goby, *Acanthogobius flavimanus*, is native to estuarine and brackish waters of Japan, the Korean Peninsula and China (Masuda et al., 1984), but it has spread elsewhere. In 1963 *A. flavimanus* was collected in San Francisco Bay, and was common there by 1970 (Brittan et al., 1970). Individuals from San Francisco Bay reach sexual maturity within a year and grow to 270 mm total length (TL) (Baker, 1975). The oriental goby is thought to have been introduced to San Francisco via ballast water discharged from cargo ships (Brittan et al., 1963).

Acanthogobius flavimanus has also been introduced to Australia, presumably in ballast water (Hoese, 1973). Between 1971 and 1981, 107 specimens, comprising mostly adults, were collected from Sydney Harbour and Botany Bay, 20 km to the south. Except for two specimens from the Hunter River, a major port 120 km north of Sydney, there are no records of the goby from other Australian estuaries (Middleton, 1982; J. Paxton, pers. comm.). This is in contrast to the distribution of another introduced goby, *Tridentiger trigonocephalus*, in Australia: it has been recorded from Sydney Harbour, Port Kembla, Melbourne and Perth (Paxton and Hoese, 1985; R. Talbot, unpublished data).

Ninety-six of the specimens of *A. flavimanus* from Sydney Harbour and Botany Bay were examined by Middleton (1982). Although the specimens included sexually mature females, Middleton was not sure whether the gobies were spawning or whether catches represented individuals from continual introductions in ballast water. However, a collection of running ripe individuals from Sydney Harbour in 1983 (P. Gibbs, pers. comm.) indicates that *A. flavimanus* is spawning there.

Here we report data from an estuary that is not a port for ocean-going vessels, the Hawkesbury River system, ~30 km north of Sydney Harbour. These data were taken mostly from a study of fishes associated with seagrass habitats (Bell, 1986) and they indicate that *A. flavimanus* is reproducing in the Hawkesbury system.

Methods

In June (winter) and December (summer) 1984 all fish were collected from a 36 m^2 plot within each of 24 beds of the seagrass *Zostera capricorni*, and in 30 of the 7 m^2 artificial seagrass units (ASUs) described by Bell et al. (1985), distributed throughout the Pittwater and Cowan Creek arms of the Hawkesbury system (Fig. 1). We sampled fish from *Zostera* plots by surrounding them with a wall net of 1 mm mesh and then applying rotenone, after Gray and Bell (1986). We collected fish from an ASU by completely encasing it with a net of 1 mm mesh and then applying rotenone (Bell et al. 1985). ASUs were submerged for six weeks prior to collection.

On 8 May 1985, we collected all oriental gobies from the catch of a small (10 m L.O.A.) commercial prawn trawler, operating further up the Hawkesbury River from our sites (Fig. 1). The trawl used had a minimum mesh size of 38 mm, and so was only capable of catching adult gobies.

All oriental gobies collected were preserved in 10% formalin and later measured to the nearest millimetre TL.

Results and discussion

No oriental gobies were collected in June 1984. In contrast, we collected 72 gobies in December 1984; 50 from nine *Zostera* sites and 22 from six ASUs (Fig. 1). All of these gobies came from sites in Cowan Creek. Specimens ranged in length from 38–73 mm; their mean length was 58.4 mm± 7.6 S.D. Individuals of this length in San Francisco Bay are in the 0+ age class (Baker, 1975).

The 16 specimens from the prawn trawler ranged in length from 118–200 mm and had a mean length of 167.4 mm±22.4 S.D. Individuals of this size are sexually mature (Baker, 1975; Middleton, 1982).

Three events could explain absence of oriental gobies in Cowan Creek during June and the relative abundance of 0+ aged individuals the following December. First, as larvae of *A. flavimanus*

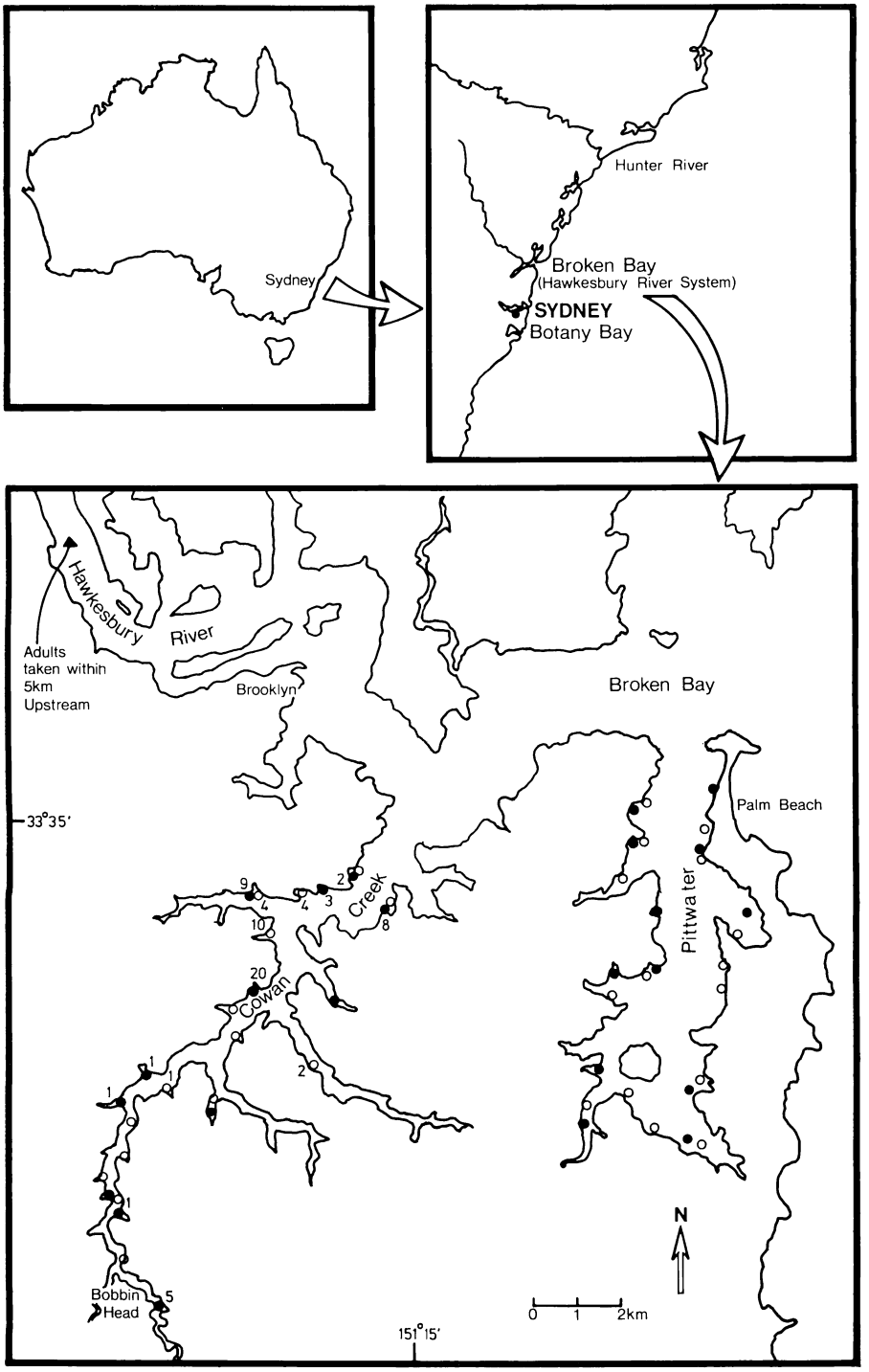

Fig. 1. Map showing location of *Zostera* sites (●) and artificial seagrass units (○) in Pittwater and Cowan Creek. Also shown is the general area where adult gobies were collected within the Hawkesbury River itself. Numbers are abundances of 0+ aged oriental gobies collected at that site.

are pelagic (Dotu and Mito, 1955), larval recruits could have arrived in ballast water dumped in Sydney Harbour or Botany Bay between June and December. Second, as *A. flavimanus* is a winter spawner (Dotu and Mito, 1955), larvae spawned in Sydney Harbour or Botany Bay could have dispersed northwards to colonise the Hawkesbury system by December. Third, adults are already established and spawning in the Hawkesbury system, with juveniles recruiting to habitats in the lower reaches during December and then moving from these to the more brackish spawning habitat up the river before the end of their first year (i.e. June).

Larval gobies recruiting from sites for disposal of ballast water, or from spawning sites in Sydney Harbour and Botany Bay, should settle in Pittwater, as well as in Cowan Creek because both areas receive oceanic water during flood tide (A. Nielsen, pers. comm.). Since no gobies occurred in Pittwater during our comprehensive collections, the first and second propositions are unlikely to explain the appearance of relatively high numbers of 0+ individuals in the Hawkesbury system.

The presence of fish of breeding size upcurrent from Cowan Creek suggests that the gobies we collected were spawned the previous winter within the Hawkesbury system. *A. flavimanus* of 0+ age were absent from Pittwater presumably because water that has ebbed from the Hawkesbury River proper does not flow into Pittwater when the tide floods, whereas it does enter Cowan Creek (A. Nielsen, pers. comm.). Thus there is little scope for larvae from the Hawkesbury River to reach Pittwater.

The occurrence of 0+ oriental gobies in the Hawkesbury system is significant because it shows that *A. flavimanus* can spread from a point source of introduction (ports) to adjacent estuaries. We do not know how the gobies first arrived in the Hawkesbury system. It seems reasonable to assume, however, that spawning fish in Sydney Harbour now provide a greater source of larvae to disperse to the Hawkesbury system than does ballast water. But larval dispersal may not be the only means by which larvae reached the Hawkesbury system. For example, larval *A. flavimanus* may settle on the hulls of pleasure craft in Sydney Harbour, occupy outlet pipes in the hull, and then be transported to the Hawkesbury system. A specimen of the other goby introduced to Australia, *Tridentiger trigonocephalus*, was living in the water intake pipe of a local trawler moored in Sydney Harbour (Paxton and Hoese, 1985).

It took 13 years, from the first record of *A. flavimanus* in Sydney Harbour in 1971 (Hoese, 1973) to the apparent establishment of a breeding population in an estuary ~30 km to the north. It is possible that the spawning biology and patterns of water discharge from estuaries in N.S.W. may slow the rate of further larval dispersal of *A. flavimanus*. The adult specimens from the Hawkesbury River, and the ripe fish collected from Sydney Harbour by P. Gibbs, were taken 15–20 km from the sea. Spawning during winter in such locations, and the demersal nature of the eggs (Dotu and Mito, 1955), places larvae well inside estuaries when river flow rates are at a minimum (Bureau of Meteorology, 1979). Thus, larvae of *A. flavimanus* have a high probability of being retained within their natal estuary. Nevertheless, we believe the oriental goby will colonize other estuaries on the coast of N.S.W. in a slow and stepwise manner. This will happen at a faster rate to the north of Sydney because surface currents within 1 km of the coast usually move in that direction (A. Nielsen and J. Padman, pers. comm.). Colonization of estuaries in northern N.S.W. may be limited by water temperature because *A. flavimanus* spawns in winter. However, all that is known of the temperature tolerances of reproduction in this species is that eggs can be incubated at temperatures as great as 13°C (Dotu and Mito, 1955).

There is no evidence that *A. flavimanus* will dominate local estuarine and brackish-freshwater fish assemblages, as reported for San Francisco Bay (see references in Middleton, 1982). Population densities of estuarine gobies in N.S.W. can be highly variable, due to the vagaries of larval life (Bell, 1986; D. Hoese, pers. comm.). It remains to be seen whether populations of *A. flavimanus* will display such variability or whether their spawning habits, combined with local hydrological conditions, will confer an advantage permitting them to reach, and maintain, great abundance in the Australian estuaries they colonize.

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オーストラリアにおけるマハゼの新産地

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オーストラリア，ニューサウスウェールズ州のHawkesbury河川水系が同国におけるマハゼの第3番目の産地であることが確認された．採集標本は1984年12月の72個体（全長 38–73 mm）と1985年5月の16個体(全長 118–200 mm) である．これらの大きさ，出現時期およびこの水系が港湾でないことから，既に他所からの侵入定着があり，水系内に補給源がある可能性が示唆された．