# An Overview of Goby-Fry Fisheries

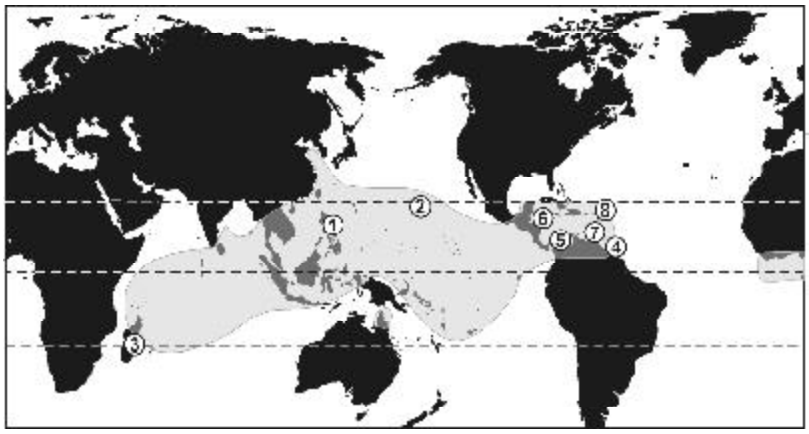
**K.N.I. Bell** (this copy modified from Galleys) <kbell@mun.ca>

## Abstract

A number of diadromous gobies, notably *Sicydium* spp. and *Sicyopterus* spp., support fisheries based on return migrations of postlarvae (fry) to rivers. Most species are tropical, although close relatives occur in Japan. The life-history of this group has often been incorrectly described as catadromous (spawning in the sea or estuary), whereas anadromous (spawning in rivers) would be more accurate. Among species, postlarvae range in length from 12 to 30 mm. Postlarvae have often been mistakenly described as new species because adult characters are absent. Most fisheries are in areas of volcanic habitat with high rainfall, torrential streams and high rates of disturbance. Even though some fisheries have been large, almost no historical information on yields exists and, at present, catch data are not regularly collected anywhere. This is a major obstacle in monitoring these fisheries, assessing reports of declining yields and relating them to trends in other variables.

## Introduction

Goby-fry fisheries, based on return migrations of postlarvae of sicydiine (Nelson 1994) gobies, exist in many locations worldwide (Fig. 1 and Table 1). Most fisheries are in areas of volcanic habitat with high rainfall, torrential streams and high rates of disturbance. Most are tropical. Although the postlarvae are small (12-25 mm) when fished, the harvests can be large, e.g., nearly 20 000 t year$^{-1}$ in northern Luzon in the Philippines (Manacop 1953). Genera which support postlarval fisheries are represented virtually throughout the Indo-Pacific, with the possible exception of Australia. Sicydiine goby fisheries are known from the Pacific, the Caribbean and Central America, and the Indian Ocean (Fig. 1). Species are also known from other areas where fisheries may exist but have not been documented, e.g., the Gulf of Guinea (Risch and Thys van den Audenaerde 1979) and the Ivory Coast (Risch 1980).




**1** Philippines: great known fisheries, most species, most complex gear; information on fisheries economics and social structure, some basic biology
**2** Hawaii: 'hinana' historic yields, traditional use some age-at-recruitment data and biology
**3** Réunion: 'bichiques' (best time-series)
**4** Dominica: 'tri-tri' earliest mention, most detail on life-history
**5** Jamaica: 'ticky-ticky' brief but lucrative fishery
**6** Central America: 'tismiche'?
**7** Venezuela 'titi'
**8** Puerto Rico: 'seti' traditional fishery
Other places: scanty information

***Fig. 1. Distribution of sicydiine diadromous gobies and goby-fry fisheries.***

The fishery is both lunar and seasonally periodic (Manacop 1953; Bell 1994; Bell et al. 1995; Bell 1997). Lunar phasing seems to be similar within regions but may differ between regions. Manacop (1953) reported migrations from the second to the ninth day following the full moon with some variation from place to place in the Philippines. In Dominica, West Indies, the migration initiates on the fourth day following the last lunar quarter. Advantages of pulsed migrations (vs. continuous migrations) can include predator swamping. The reason for any particular lunar recruitment timing is not known but it has been suggested that it may be related to maximum tides (Manacop 1953). In both regions the migrations include several species and in Dominica a number of species of decapod shrimps also migrate at the same time.

Data on goby-fry fisheries are difficult to find and are rarely reported in the literature. The fishery in Dominica had not been documented since its first mention 200 years ago by Atwood (1791). This may be because the fishery is episodic and participants in it are part-time and difficult to track, and because much of the product is consumed within the local community or sold informally. It may also

be that fisheries based on fish only 2 cm in length tend to be dismissed as curiosities. Even in the Philippines, where the largest recorded yields have occurred, there is no available data on long-term yield variations and the limited data that do exist are inadequate for serious analysis. (The author would be pleased to hear about any goby-fry fisheries not mentioned here.)

Because of the lack of data, the examples below cannot be considered exhaustive and accounts cited are often less authoritative than similar accounts for other fisheries.

## Fishing Methods

The fishing methods are summarized in Table 1. The methods in the Philippines are intensive, diverse and ingenious: nets operated from boats near river mouths, several varieties of traps and fixed barriers used to herd fish into the traps on their upriver migrations. These are often associated with complex traditional social arrangements. In the Philippines there are also traditional methods of preservation (Manacop 1953). The fishery methods in other locations are simpler. In Dominica, beach seines are used at the mouth of rivers where the bottom is sandy. Where the bottom is stony, traps are improvised from mesh fertilizer bags weighted with stones. Fish migrating through the stones are trapped by the bag. The bag is lifted at intervals and the fish remain after the stones are individually picked out (Bell 1994). Interestingly, the fishery in Dominica is gender-segregated, the beach seine fishery is operated by men in sandy rivers and the traps by women in stony rivers.

## A Perspective on Fishery Declines

There are references of a decline in goby-fry fisheries. Ego 1956, Erdman 1986 and Aiken 1988 attribute this to human alteration of natural habitats while Montilla (1931), Acosta (1952), Manacop (1953) and Blanco (1956) cite overexploitation. It is not possible to assess the degree to which these and other factors are responsible because no systematic yield data exist and little is known about the life history and ecology of the sicydiines.

The data on goby-fry fisheries in Réunion (Aboussouan 1969), brief as they are, are the best time-series available. These data (Table 2) show a rise and a fall rather than a monotonic decline and suggest the possibility that recruitment variation of a factor of 7 over a number of years might be a natural feature of fisheries for goby postlarvae. Thus, even if we accept that all reported declines are real, they may be the descending part of oscillations and may not always indicate long-term trends.

There are several plausible causes for the decline. Habitat degradation could compromise adult population levels, larval production or survival rates, and could reduce recruitment. If changes reduce the growth rate of postlarvae in the marine environment, then age-at-recruitment (AAR) and overall exposure to prevailing mortality factors would increase and recruitment would suffer (Houde 1987). If AAR is a periodic function of time as it is for *Sicydium punctatum* in Dominica (Bell et al. 1995), and if mean AAR increases (i.e., if the AAR curve is scaled upward), then recruitment will decrease while seasonal variation in recruitment will increase (Bell 1997). The density-stratified nearshore marine environment, where mixing of river runoff is slow so that salinities are lower at the surface than at a depth, appears to be the larval habitat of *S. punctatum* for about 10 days (Bell and Brown 1995). If so, changes affecting this system could affect time-specific mortality. For example, weather patterns which change over time could affect the mixing rates in stratified nearshore environments and could be a natural source of early survival variability. Adult *S. punctatum* appear to be long-lived (maximum length well over 100 mm, yet healthy breeding individuals for 8 years in aquaria attained only 60 mm) and to have a very high reproductive output (K. Bell, unpubl.). So, unless a fishery is very efficient and allows very little escapement for replacement of adult mortalities, it is unlikely that overfishing of postlarvae is alone responsible for fishery declines in this group.

## Life History - State of Knowledge

The life-history of *Sicydium* spp. and allied genera has often been misunderstood. There is some published work on this, e.g., Manacop's (1953) work on Philippine goby-fry fisheries and the life history of *Sicyopterus* spp., emphasizing *S. extraneus*, and recent work by Bell (1994, Bell and Brown 1995, Bell et al. 1995 and Bell 1997) on *Sicydium punctatum* and *S. antillarum* in Dominica, West Indies. Aspects of biology have been published by many other authors (Dotu and Mito 1955, Ego 1956, Erdman 1961, Fukui 1979, Erdman 1984, Erdman 1986, Katsura and Hamada 1986, Nishimoto and Fitzsimons 1986, Aiken 1988, Kinzie 1988, Radtke et al. 1988, Fitzsimons and Nishimoto 1990, Fitzsimons et al. 1990, Iguchi and Mizuno 1990, Iguchi and Mizuno 1991, Mochizuki et al. 1991, Kinzie 1993).

The life cycle (Fig. 2) determined for *Sicydium* spp. in Dominica is consistent with observations in previous work on the life history of related species and is probably applicable to sicydiines in general.

In Dominica, *S. punctatum* adults spawn in rivers with suitable (coarse, not silty) substrate, building nests under stones. Larvae hatch in about 24 hours and adopt a vertical swimming/sinking habit

***Table 1. Summary of information pertaining to goby-fry fisheries worldwide.***

| Place | Fishery | Declines | Periodicity | Fishing method/Area | Remarks |
|---|---|---|---|---|---|
| **Pacific:** Very many genera (Koumans 1953; Manacop 1953). Unreported goby-fry fisheries probably present in much of the Indo-Pacific. | | | | | |
| Philippines | Postlarvae sometimes called *ipon, hipon,* and made into *bagoong* (fermented product with long storage life). Fishery for *ipon* in river, river mouth, nearshore areas. Fishery for adults in some rivers. Fishery widespread. Yields approaching 20,000 t in N. Luzon alone (estimated from Manacop 1953); fishery in Cagayan R. alone (Mindanao) landed approx. 65 t annually, where the dominant species was *Sicyopterus extraneus*. A number of species and genera are commercially important in other areas of the Philippines (Manacop 1953). | Yes (Montilla 1931, Manacop 1953). Inadequate escapement of postlarvae and harvest of adults cited as factor (Manacop 1953). | Recruitment is lunar-phased (2nd to 9th day after full moon in Mindanao, may vary slightly from place to place), and fishery is pan-seasonal but with a high near Dec. (Manacop 1953). | Large and sophisticated weirs and traps in rivers, boats used nearshore. Gears described in various papers (Montilla 1931; Manacop 1953; Blanco 1956). | Conservation of *ipon* fishery motivated the first monograph on the region's gobies (Herre 1927). Generally insufficient data to meet requirements for management, data should be collected (Blanco 1956). The life-cycle was only poorly understood, and Manacop's work apparently not accepted (e.g., Herre 1958). |
| Hawaii | Fishery for goby postlarvae (species not certain) generally called *hinana*, and adults of several gobies called *o'opu* (Titcomb 1977). Commercial harvest in 1900 given as ~2 t, but subsistence fishery may be greater (Jordan and Evermann 1905). Adult *Awaous guamensis* fished commercially and for sport, and before *Hinana* fishing was banned, "considerable quantities of the larval [sic] fish caught and sold in gallon lots" (Ego 1956). Apparently no continuing fishery for postlarvae in Hawaii. | Yes; fishery now nonexistent and not mentioned in recent work (Kinzie 1988; Radtke et al. 1988; Fitzsimons and Nishimoto 1990; Kinzie 1993). | | Weirs and nets; *hinana* apparently sometimes stocked in ponds (Titcomb 1977). Poisons (including bleach) and torches used (Jordan and Evermann 1905; Ego 1956). | |
| **Caribbean:** Fisheries heaviest in the late months of the year, migrations near day of the last lunar quarter (Erdman 1961; Erdman 1984; Aiken 1985; Erdman 1986; Silva Melo and Acero 1989-1990), and virtually dominated by *Sicydium* spp. Sicydium and other gobies well-represented in Central America and may support possible unreported fisheries there; for example, "tismiche" at Tortuguero, Costa Rica (Nordlie 1979) seems to consist of eleotrids under 10 mm in length, associated with shrimps; not known whether this is a fished item. | | | | | |
| Dominica | Earliest mention (Atwood 1791) of goby-fry fishery: "vast quantities" taken using cloth, baskets, stones; postlarvae called *trez-trez* (now *tritri*). Lunar-monthly fishery yield at Layou >900 kg in late 1989. Fishery >95% *Sicydium punctatum*, 0-<5% *S. antillarum* and *Eleotris pisonis*. *Awaous taiasica* postlarvae very rarely seen (3 seen), and *Philypnus dormitor* postlarvae not seen by the author 1989-1991. *Tritri* a delicacy, by weight the most expensive fish retailed in Dominica. Natural (*nivwe*, probably *Clibadium sylvestre*) and synthetic poisons have been used to catch adults. | Yes: interviews suggest that decline has been severe, that current harvests are a fraction of previous (K. Bell, unpubl. data). | Recruitment is lunar-phased (4th day after last lunar quarter), and fishery is pan-seasonal but with a high (Aug-Dec) and low (Jan-Apr) (Bell 1994; Bell et al. 1995). | 2-man seine near river mouth, over sandy bottom; trap using cloth and stones used (by women) when base is stony (Bell 1994). Boats not used. | Declines more likely associated with environmental changes (including land-use changes: industry, forest clearing, reduction in adult habitat, pollution) than with overfishing. Age-at-recruitment shows seasonal cycles (Bell et al. 1995), and this is shown to be capable of generating a seasonal pattern in recruitment (Bell 1997). |

| Place | Fishery | Declines | Periodicity | Fishing method/Area | Remarks |
|---|---|---|---|---|---|
| Puerto Rico | Erdman (1984) reported the catch in one river, during one postlarval migration, of 1360 kg. Wholesale values at the time in Puerto Rico ranged from US$4.40 to $11.00/kg. Identity of species in Puerto Rico is unclear: while some authors acknowledge only one species of *Sicydium*, Brockmann (1965) reports several spp. in one sample. | Erdman (1986) reported that populations of adult *Sicydium* spp. in rivers (e.g., the Humatas R.) had declined considerably. | Lunar periodic recruitment on last quarter day or during the last quarter; migrations largest between August to December (1986). | Dipnets made from burlap bags with wooden hoops or nylon mosquito netting. | Preliminary work in Puerto Rico (I. Mateo, Mayaguez lab, U. Puerto Rico, pers. comm.) showed age-at-recruitment similar to values previously obtained (Bell 1994; Bell et al. 1995) from Dominica in the same season. |
| Jamaica | Aiken (1988) reported that "brief but lucrative" fisheries still existed for postlarval *Sicydium* spp. on the northeast coast. Watershed alteration cited as threat to *Sicydium* spp. | Aiken (1988) reported that migrations were "nowhere as impressive as in former years". Aiken (1985) mentions stream dewatering as one cause of decline. | Lunar periodic near last quarter (can be 1 or 2 days before or after the 3rd quarter day). Peak recruitment: Nov-Jan rainy season, "but no significant migration in secondary rainy season in May" (Aiken 1985). | Not reported. | |
| **Indian Ocean:** *Sicyopterus* or *Sicydium* spp. (genera sometimes considered synonymous) is reported in the Comores (Fourmanoir 1954; Starmühlner 1976, 1979; Thys van den Audenaerde and Teugels 1984; Teugels et al. 1985), but fisheries for postlarvae are either small or unreported. Related species exist in Sri Lanka (Klausewitz and Henrich 1986). | | | | | |
| Reunion | Fisheries for "bichiques" and "sans culottes" reported by Aboussouan (1969), who gives Réunion's catch broken down by location for 1966, showing that the highest catches are on the windward, NE coast; he also gives the total harvest for the years 1954 to 1966: mean 39.9, lowest 12.8 t, highest 78. Species (Catala 1982): *Sicydium acutipinnis, S. laticeps, S. lagocephalum* ["bichiques"], *S. fasciatum*. | Aboussouan (1969) catch data for 1954 to 1966 show large year-to-year increases and decreases. These data do not cover recent times; recent status of the fishery is unknown. | Fishery limited to a few days around the full moon and (maximum recruitment ) coincides with rainy, warm season, i.e., Oct to Mar (Aboussouan 1969). | At river mouths. | |
| Madagascar | Fisheries are mentioned by Catala (1982): the postlarval gobies play a smaller role in the diet and fishing of Madagascar than in Réunion, being restricted to the east coast. Species: *Sicydium acutipinnis, S. laticeps, S. lagocephalum, S. fasciatum*, plus *S. franouxi*. | No data. | Probably similar to Réunion. | Generally caught in estuaries or sand banks at river mouth by women, by hand using nets improvised from cloth or burlap (Catala 1982). | |
| Mauritius | Catala (1982) states *Sicydium lagocephalum* common in fresh waters of Mauritius and Réunion, and postlarvae known as "bichiques" which are a delicacy in Réunion; *Sicydium fasciatum, S. laticeps* also present. | Uncertain; fishery not detected by recent visitor (J.M. Green, Memorial Univ., pers. comm.), suspected to have ceased. | Probably similar to Réunion. | | |
| **Other regions** | *Sicydium* spp. known from: islands (Fernando Poo, Annobon) in Gulf of Guinea, Cameroon and Ivory Coast (Blanc et al. 1968; Thys van den Audenaerde and Tortonese 1974; Risch and Thys van den Audenaerde 1979; Risch 1980). No information on fisheries. | | | | |

***Table 2. Catch data of Goby-fry fishery for Réunion, Indian Ocean.***

| Yr | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yield (t) | 14.5 | 12.8 | 13 | 33 | 62 | 53 | 78 | 47 | 42 | 32 | 26 | ? | 65.9 |

Source: Aboussouan 1969.

which keeps them in the water column and enables them to be carried by the river to the sea. Some time is spent at sea as postlarvae — 50 to 150 days being approximately the extremes (Bell et al. 1995) — and then the fish re-enter the river. During the first ten days following hatching, there is a pronounced behavioral choice of salinity in a stratified system (Bell and Brown 1995). This has implications for exposure to terrigenous river-borne pollutants. Virtually nothing is known directly about the marine postlarval phase. On entry to rivers they are transparent, schooling and pelagic; on reaching suitable stony substrate they settle and become pigmented, benthic and relatively solitary (Bell 1994). Rheotaxis is strong and upstream migrations distribute fish up to 14 km from the sea (in Dominica, that is near the maximum river length) and over 300 m in altitude.

The sole credible account of anything similar to catadromy is a report by Ego (1956) of downstream movement of adult Hawaiian *Awaous guamensis* followed by downstream spawning. However, he notes that there is no evidence for this occurring other than after a freshet, so there is some doubt as to whether the downstream spawning is deliberate or an accidental event associated with floods. Available evidence supports anadromy in the sense of upriver spawning and early growth in saline, nearshore habitats.

For several decades after Manacop (1953) reported finding eggs from river nests and larvae from river plankton in the Philippines, no newly hatched larvae of river gobies were found anywhere else in the world until 1989. Aquarium spawnings had produced larvae of three species: *S. punctatum* (Bell 1994), *Dormitator latifrons* (Todd 1975) and *Evorthodus lyricus* (Foster and Fuiman 1987). In 1989 larvae were found in streams in Dominica (Bell 1994; Bell and Brown 1995; Bell et al. 1995). The larvae from these sources and the larvae reported by Manacop were morphologically and behaviorally very similar. In Dominica, five types of larvae were recognizable on the basis of pigments and minor structural features. It was concluded that these types probably represent the[5] species. This is supported by the uniformity of larvae within batches known to be *S. punctatum*. Several larval types have also been recognized in Japan (Iguchi and Mizuno 1990). Identification of larval types provides an opportunity for investigating recruitment on a species-by-species basis.

Postlarvae (the marine stage following the freshwater larval stage) lack many of the adult features and are often unidentifiable when caught, but become readily identifiable after one to three days' captivity in an aquarium with a suitable pebbly substrate. Postlarvae usually have little pigment or scalation and have fairly soft bones and transparent flesh (scalation begins at the caudal peduncle, and *Sicydium* spp. postlarvae recruiting to freshwater in Dominica have only a few cycloid scales posterior to the second dorsal). The dentition and mouth structure also change. Postlarvae are terminally mouthed and during recruitment the mouth becomes subterminal and then inferior in adults. After the freshwater-recruitment metamorphosis, juveniles and adults have a mobile upper lip armed with rows of curved labial teeth. During feeding the mobile upper lip is raked across stones to harvest the epilithic community. During feeding the ventral sucker anchors the fish so that by pressing down with both the tail and the mouth a greater scraping force can be exerted by the upper lip. Because developmental changes occur over the time during which the fish are migrating upstream, there tends to be some correlation of appearance (stage) and distance from the river mouth. This may explain why the different stages are sometimes, incorrectly, thought to be different species. It has also meant that postlarvae have been regarded

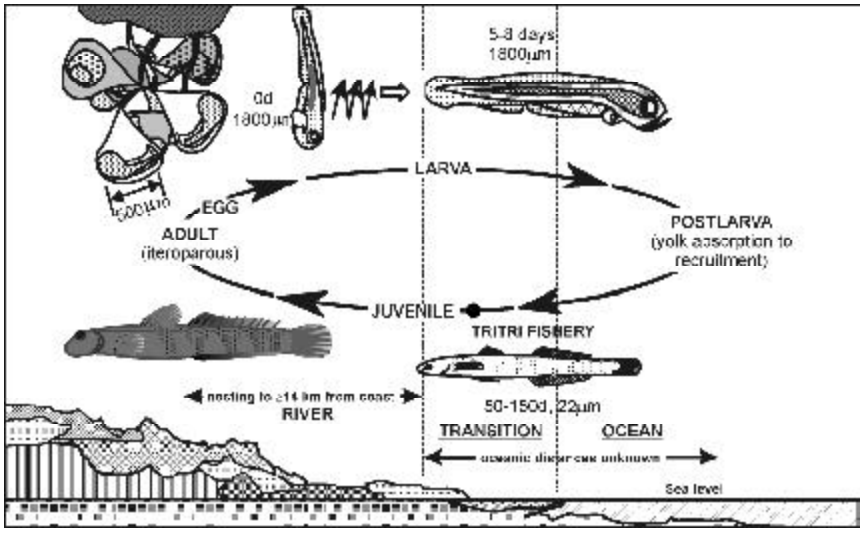



***Fig. 2. Life cycle of* Sicydium punctatum *in Dominica.***

as a product of the sea alone. The most common question I was asked while conducting my fieldwork in Dominica: "where do the *tritri* come from?".

The age-at-recruitment (AAR) of *S. punctatum* and *S. antillarum* varies on a seasonal basis (Bell 1994; Bell et al. 1995), which means that single-date samples may oversimplify the relationship between length and age of recruits leading to incorrect interpretation of samples at other times of the year (generally, length-age keys can only be applied within samples, or samples at the same seasonal phase as those from which they were derived). The seasonal pattern in AAR is also capable of being transformed in a complex way to a seasonal pattern in the number of recruits (Bell 1994; Bell 1997; Bell et al. 1997). The pattern induced in recruiting numbers is potentially large (several-fold), counter-intuitive, and capable of either canceling or increasing variation otherwise contributed by seasonal variation in spawning intensity. The phenomenon was shown to be analogous to the Doppler effect. Two methods for predicting recruitment can be used with observed values to generate residuals, which in turn may be an indirect indication of variations in survival.

## Conclusion

Probing the health of goby-fry fisheries and developing methods to improve them, requires both long-term data and a thorough exploration of the life-history. Without such information it is difficult to suggest appropriate management practices.

The taxonomy of gobies and eleotrids is not simple, and it is very easy to misidentify species. The value of any ecological work is greatly diminished if there is any doubt about what species the observations apply to. If a misidentification can be corrected later, a published work can retain its value. It is, therefore, important to preserve samples and deposit them with a reputable museum (e.g., the U.S. National Museum) that will archive them and make them available for further study.

For analyzing the causes of recruitment variation, field data should include larval production, fishery yields, recruitment and ages (from representative subsamples of otoliths). Samples should, if possible, include samples of individual length and weight, and whole recruits, both formaldehyde-preserved for identification and buffered-alcohol preserved or dried for subsequent otolith analysis. Collateral data (basic weather, river outflow volumes, river and sea temperatures) sources should be noted and basic collateral data should be collected if not otherwise available.

The author welcomes questions, discussion and information about goby-fry fisheries.

## References


Aboussouan, A. 1969. Note sur les "Bichiques" de l'ile de la Réunion. Rec. Trav. Sta. Mar. Endoume, Fasc. hors série suppl. 1969(9):25-31.

Acosta, P.A. 1952. Inland fisheries of the Philippines, p. 91-99. *In* Philippine fisheries. Bureau of Fisheries, Manila.

Aiken, K.A. 1985. *Sicydium plumieri* (Bloch) a migratory fish from Jamaica rivers. Nat. Hist. Notes, Nat. Hist. Soc. Jamaica 1(10):35-39.

Aiken, K.A. 1988. Notes on the ecology of fishes of some rivers in Portland. Nat. Hist. Notes, Nat. Hist. Soc. Jamaica 2(2):9-19.

Atwood, T. 1791. The history of the island of Dominica. (Orig. publ.: J. Johnson, No. 72, St. Paul's Churchyard, London, MDCCXCI.) Reprint facsimile edition 1971. (Cass Library of West Indian Studies, no. 27. Ed.). Frank Cass and Co. Ltd., London. viii + 285 p.

Bell, K.N.I. 1994. Life cycle, early life history, fisheries and recruitment dynamics of diadromous gobies of Dominica, W.I., emphasising *Sicydium punctatum* Perugia. Ph.D. thesis, Memorial University of Newfoundland, Canada. xviii + 275 p.

Bell, K.N.I. 1997. Complex recruitment dynamics with Doppler-like effects caused by shifts and cycles in age-at-recruitment. Can. J. Fish. Aquat. Sci. 54:1668-1681.

Bell, K.N.I. and J.A. Brown. 1995. Active salinity choice and enhanced swimming endurance in 0 to 8-d-old larvae of diadromous gobies, with emphasis on *Sicydium punctatum* (Pisces), in Dominica, West Indies. Mar. Biol. 121:409-417.

Bell, K.N.I., P. Pepin and J.A. Brown. 1995. Seasonal, inverse cycling of length- and age-at-recruitment in the diadromous gobies *Sicydium punctatum* and *Sicydium antillarum* (Pisces) in Dominica, West Indies. Can. J. Fish. Aquat. Sci. 52:1535-1545.

Bell, K.N.I., P. Pepin and J.A. Brown. 1997. Variation in age-at-recruitment can drive recruitment dynamics: the example of *Sicydium* spp. (Pisces: Gobiidae) in Dominica, West Indies. Micronesia 30:25.

Blanc, M., J. Cadenat and A. Stauch. 1968. Contribution a l'etude de l'ichthyofaune de l'ile Annobon. Bull. I.F.A.N. 30:239-256.

Blanco, G.J. 1956. Assay of the goby fry (*ipon*) fisheries of the Laoag River and its adjacent marine shores, Ilocos Norte Province. Philipp J. Fish. 4:31-80.

Brockmann, F.W. 1965. A taxonomic study of the Panamanian freshwater gobies of the genera *Awaous* and *Sicydium*. M.S. thesis, Florida State University, Tallahassee. v + 73 p.

Catala, R. 1982. Poissons d'eau douce de Madagascar (suite et fin): Familledes *Gobiidés* (suite). Rev. fr. Aquariol. 9(2):57-64.

Dotu, Y. and S. Mito. 1955. Life history of a gobioid fish, *Sicydium japonicum* Tanaka. Sci. Bull. Fac. Agric. Kyushu Univ. 15:213-221.

Ego, K. 1956. Life history of freshwater gobies. Proj. No. 4-4-R. Freshwater Game Fish Management Research, Department of Lands and Natural Resources, Honolulu, Hawaii. 23 p.

Erdman, D.S. 1961. Notes on the biology of the gobiid fish *Sicydium plumieri* in Puerto Rico. Bull. Mar. Sci. Gulf Carib. 11:448-456.

Erdman, D.S. 1984. The freshwater goby, *Sicydium plumieri*, and the

goby fry fishery in Puerto Rico. Fishbyte 2(1):19.

Erdman, D.S. 1986. The green stream goby, *Sicydium plumieri*, in Puerto Rico. Trop. Fish Hobbyist (Feb):70-74.

Fitzsimons, J.M. and R.T. Nishimoto. 1990. Territories and site tenacity in males of the Hawaiian stream goby *Lentipes concolor* (Pisces: Gobiidae). Ichthyol. Explor. Freshwat. 1:185-189.

Fitzsimons, J.M., R.M. Zink and R.T. Nishimoto. 1990. Genetic variation in the Hawaiian stream goby, *Lentipes concolor*. Biochem. Syst. Ecol. 18:81-83.

Foster, N.R. and L.A. Fuiman. 1987. Notes on the behaviour and early life history of *Evorthodus lyricus*. Bull. Mar. Sci. 41: 27-35.

Fourmanoir, P. 1954. Ichthyologie et péche aux Comores. Mém. Inst. Sci. Madagascar A:187-239.

Fukui, S. 1979. On the rock-climbing behaviour of the goby, *Sicyopterus japonicus*. Jap. J. Ichthyol. 26:84-88.

Herre, A.W. 1927. Gobies of the Philippines and the China Sea. *In* W.H. Brown, R.C. McGregor and A.B. Banyea (eds.) Monographs of the Bureau of Science, No. 23. Philippine Bureau of Science, Manila. 352 p.

Herre, A.W.C.T. 1958. Marine fishes in Philippine rivers and lakes. Philipp. J. Sci. 87:65-88.

Houde, E.D. 1987. Fish early life dynamics and recruitment variability. Am. Fish. Soc. Symp. No. 2:17-29.

Iguchi, K. and N. Mizuno. 1990. Diel changes in larval drift among amphidromous gobies in Japan, especially *Rhinogobius brunneus*. J. Fish Biol. 37:255-264.

Iguchi, K. and N. Mizuno. 1991. Mechanisms of embryonic drift in the amphidromous goby *Rhinogobius brunneus*. Environ. Biol. Fish. 31:295-300.

Jordan, D.S. and B.W. Evermann. 1905. The aquatic resources of the Hawaiian Islands. Bull. U.S. Fish Comm. for 1903. Part I. The shore fishes. Vol. 23. U.S. Fish Commission, Washington.

Katsura, K. and K. Hamada. 1986. Appearance and disappearance of chloride cells throughout the embryonic and postembryonic development of the goby, *Chaenogobius urotaenia*. Bull. Fac. Fish. Hokkaido Univ. 37:95-100.

Kinzie, R.A. 1988. Habitat utilization by Hawaiian stream fishes with reference to community structure in oceanic island streams. Environ. Biol. Fish. 22:179-192.

Kinzie, R.A. 1993. Reproductive biology of an endemic, amphidromous goby *Lentipes concolor* in Hawaiian streams. Environ. Biol. Fish. 37:257-268.

Klausewitz, W. and S. Henrich. 1986. *Sicyopus jonklaasi*, n. sp., a new freshwater goby from Sri Lanka (Pisces, Perciformes, Gobioidei, Gobiidae, Sicydiaphiinae). Rev. Fr. Aquariol. 12:117-122.

Koumans, F.P. 1953. Gobioidea. *In* M. Weber and L.F. de Beaufort (eds.) Vol. 10. The fishes of the Indo-Australian archipelago. E.J. Brill, Leiden, 423 p.

Manacop, P.R. 1953.The life history and habits of the goby, *Sicyopterus extraneus* Herre (añga) Gobiidae with an account of the goby-fry fishery of Cagayan River, Oriental Misamis [Province, Mindanao, Philippines]. Philipp. J. Fish. 2:1-60.

Mochizuki, K., S. Fukui and S. Gultneh. 1991. Development and replacement of teeth on jaws and pharynx in a gobiid fish *Sicydium plumieri* from Puerto Rico, with comments on resorption of upper jaw teeth. Nat. Hist. Res. 1:41-52.

Montilla, J. 1931. The *ipon* fisheries of northern Luzon. Philipp. J. Sci. 45: 61-75.

Nelson, J.S. 1994. Fishes of the world. 3rd ed. John Wiley and Sons, Inc., New York. xvii + 600 p.

Nishimoto, R.T. and J.M. Fitzsimons. 1986. Courtship, territoriality, and coloration in the endemic Hawaiian freshwater goby, *Lentipes concolor*, p. 811-817. *In* T. Uyeno, R. Arai, T. Taniuchi and K. Matsuura (eds.) Indo-Pacific fish biology: Proceedings of the Second International Conference on Indo-Pacific Fishes, Ichthyological Society of Japan, Tokyo.

Nordlie, F.G. 1979. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. J. Fish Biol. 1981:97-110.

Radtke, R.L., R.A. Kinzie and S.D. Folsom. 1988. Age at recruitment of Hawaiian freshwater gobies. Environ. Biol. Fish. 23:205-213.

Risch, L. 1980. Description of *Parasicydium bandama*, gen. nov., sp. nov., a new gobiid fish from the Bandama River, Ivory Coast (Pisces: Gobiidae). Rev. Zool. Afr. 94:126-131.

Risch, L. and D. Thys van den Audenaerde. 1979. On the West African species of the genera *Sicydium* Cuv. and Val. and *Lentipes* Gthr. Rev. Zool. Afr. 93:882-900.

Silva Melo, L. and A.P. Acero. 1989-1990. Sistematica, biologia y ecologia del Titi *Sicydium antillarum* Grant (Pisces: Gobiidae) en la region de Santa Marta, Colombia. An. Inst. Invest. Mar. Punta de Betin 19-20:153-172.

Starmühlner, F. 1976. Contribution to the knowledge of the freshwater fauna of the Isle of Anjouan (Comores). Cah. ORSTOM. ser. Hydrobiol 10:255-265.

Starmühlner, F. 1979. Results of the Austrian hydrobiological mission 1974, to the Seychelles, Comores and Mascarene Archipelagos: Part 1: preliminary report. Ann. Naturhist. Mus. Wien 82:621-742.

Teugels, G.G., L.J.M. Janssens, J. Boggaert and M. Dumalin. 1985. Sur une collectionde poissons de riviere des Comores 9:41-56.

Thys van den Audenaerde, D. and G.G. Teugels. 1984. De zoetwatervissen vande Comoren, een merkwaardige groep. Afr.-Terv. 30:58-67.

Thys van den Audenaerde, D.F.E. and E. Tortonese. 1974. Description of a new Eleotris from Annobon Island (Pisces: Gobiidae). Ann. Mus. Civ. Stor. Nat. Genova 157-161.

Titcomb, M. 1977. Native use of fish in Hawaii. 2nd ed. University Press of Hawaii, Hawaii.

Todd, E.S. 1975. Vertical movements and development of the prolarvae of the eleotrid fish, *Dormitator latifrons*. Copeia 1975:564-568.

**K.N.I. BELL** *is from the J.L.B. Smith Institute of Ichthyology, Private Bag 1015, Grahamstown, 6140 South Africa. <k.bell@ru.ac.za>*