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Distribution and Status of Introduced Cichlid Fishes of the Genera *Oreochromis* and *Tilapia* in the Islands of the South Pacific and Micronesia

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Abstract

Fishes of the genera *Tilapia* and *Oreochromis* have become established in a variety of habitats on numerous islands of the South Pacific and Micronesia. Reproductive populations of tilapias can be found in lakes, reservoirs, streams, rivers, mangroves and shallow lagoons. The reasons for the introductions include mosquito control, aquatic weed control, culture, stock enhancement and accidental release. Consequences of the introduction of tilapias have ranged from dramatic improvements of inland fisheries and the significant development of subsistence and commercial aquaculture to detrimental effects both on indigenous species and on traditional fish culture systems.

Introduction

The natural distribution of cichlid fishes of the genera *Tilapia* and *Oreochromis,* hereafter referred to by their common name of tilapia, is limited to Africa and the Near East (Philippart and Ruwet 1982). However, because of their usefulness as agents of biological control and their suitability for culture in a wide variety of situations, several of these species have been spread, both purposefully and accidentally, throughout the world, including to many of the islands in the tropical Pacific. As a result, tilapia have become established

outside of their natural range in a variety of inland-water and coastal habitats resulting in effects ranging from severe ecological disturbances to dramatic improvements of local fisheries.

Over 30 years ago the first tilapia were introduced to the islands of the South Pacific and Micronesia. They have since become widely distributed throughout the region and have come to occupy a variety of habitats on both volcanic islands and atolls. The long-term value of these introductions can be assessed both in terms of their impact on island ecosystems and of their socioeconomic benefit. This work documents the current distribution of the tilapias within the Pacific islands, examines the history of transfers of the fish throughout the region and evaluates the benefits of the introductions.

History and Rationale for the Introductions

As described below, tilapia have been introduced to the Pacific islands primarily for three reasons: for aquaculture, for the control of aquatic pests and for the improvement of inland fisheries. In a recent note, Gillett (1989) speculates that tilapia were introduced to many islands through projects designed to provide rapid, tangible improvements in local fisheries and bolster support for fisheries development in general. Most of the initial introductions were carried out in the mid-1950s, but subsequent introductions have occurred sporadically in various areas. The original transfers of tilapia to the Pacific islands were from the Asian countries of Singapore, Malaysia and the Philippines. More recently, tilapia have been introduced from Taiwan and Israel. However, numerous transfers of tilapia have also been made between islands within the region. Table 1 provides a summary of the various introductions of tilapia to the Pacific islands.

The first introduction of tilapia into the Pacific islands was accomplished in Hawaii in 1951 (Brock 1960) when *Oreochromis mossambicus* were brought in from Singapore for the control of aquatic vegetation in irrigation ditches and for use as live bait in the fishery of skipjack tuna *Katsuwonus pelamis* (Uchida and King 1962; Maciolek 1984). Chimits (1955) states that the source of these fish was Malaysia, but gives 1952 as the date of the introduction. Information regarding the subsequent introductions of tilapia in the Hawaiian Islands was throughly reviewed by Maciolek (1984) and, consequently, our work focuses only on the islands of the South Pacific and Micronesia.

Table 1. Tilapia introductions in the South Pacific and Micronesia. The table indicates the species, date of introduction, reason for the introduction, the habitats where tilapia have become established and the status/impact of the introduction. Species codes are: 1 = *Oreochromis mossambicus*, 2 = *Tilapia zillii*, 3 = *O. niloticus*, 4 = *O. aureus*, 5 = *O. hornorum*, 6 = hybrid tilapia. Habitats codes are: FW = freshwater, BW = brackish or marine.

Location	Species	Source	Date	Reason	Habitats	Current status
Micronesia						
Yap, Caroline Islands	1	?	1970s	Culture	FW, BW	impact unknown
Tarawa, Gilbert Islands	1	Fiji (?)	1963	Culture	BW	impact unknown
Fanning Atoll, Line I	1	Hawaii	1958	Accidental	BW	suspected neg. impact on local fish
Washington I., Line I	1	Hawaii	1958	No purpose	FW	impact unknown
Guam, Mariana Islands	1	Philippines	1954	Culture	FW, BW	commercial production
Guam, Mariana Islands	2	Hawaii (?)	1956	Weed control	FW	small recreational fishery
Guam, Mariana Islands	6	Taiwan	1973	Culture	-	commercial production
Pagan, Mariana Islands	1	Saipan	1955	Enhance stocks	FW	island no longer inhabited
Saipan, Mariana Islands	1	Philippines	1955	Enhance stocks	FW	impact unknown
Nauru	1	?	1960s	Pest control	FW, BW	impedes traditional aquaculture
Polynesia						
Cook Islands	1	Fiji	1955	Culture	FW	impact unknown
American Samoa	1	W. Samoa	1950s	Enhance stocks	FW	fished at Aunu'u
Niue	1	?	?	?	?	impact unknown
Tahiti, Society Islands	1	?	1950s	?	?	impact unknown
Tongatapu Island, Tonga	1	Fiji	1955	Pest control	BW	impedes aquaculture development
Nomuka Island, Tonga	1	Tonagtapu	1970s	Pest control	FW	fished; reduced milkfish population
Niuafo'ou Island, Tonga	1	Tongatapu (?)	1982	Enhance stocks	FW	subsistence fishery
Vava'u Island, Tonga	1	Tongatapu (?)	?	?	FW	subsistence fishery
Funafuti Atoll, Tuvalu	1	?	?	?	BW	impedes aquaculture development
Nanumanga Island, Tuvalu	1	?	?	?	?	impact unknown
Niutao Atoll, Tuvalu	1	?	?	?	?	used as pig feed
Wallis, Wallis & Fatuna	1	?	1966	?	FW	impact unknown
Western Samoa	1	Fiji	1955	Culture	FW	small-scale culture
Melanesia						
Viti Levu, Fiji	1	Malaysia	1954	Culture	FW	subsistence culture
Vana Levu, Fiji	1	Viti Levu	?	Culture	FW	impact unknown
Fiji	2	Hawaii	1957	Culture	?	distribution and impact unknown
Viti Levu, Fiji	3	Israel	1988	Culture	FW	subsistence culture
Vana Levu, Fiji	3	Viti Levu	?	Culture	-	subsistence culture
Viti Levu, Fiji	4	?	1974	Research	-	not established
Viti Levu, Fiji	5	Taiwan	1985	Research	-	not established
New Caledonia	1	Philippines	1955	Culture	FW	impact unknown
Papua New Guinea	1	Malaysia	1954	Culture	FW, BW	fishery established
Guadacanal, Solomon Isl.	1	?	1957	Culture	FW	impact unknown
Malaita Isl. Solomon Isl.	1	Guadacanal (?)	?	?	FW (?)	impact unknown
Santa Anna Isl. Solomon Isl.	1	Guadacanal (?)	?	?	FW (?)	impact unknown
Rennell Island, Solomon Isl.	1	Guadacanal	?	Enhance stocks	FW	subsistence fishery
Efate Island, Vanuatu	1	New Caledonia	1960s	Enhance stocks	?	impact unknown
Tanna Island, Vanuatu	1	New Caledonia	1950s	Enhance stocks	?	impact unknown

The Melanesian islands of the South Pacific became the first within the region to introduce tilapia when, in 1954, *O. mossambicus* from Malaya were introduced to Fiji (Holmes 1954) and to the territories that now constitute Papua New Guinea (Devambez 1964; Glucksman et al. 1976; Coates 1987). The date of these introductions is confirmed in a note by van Pel (1955), although he states that the source of the introduced fish was Singapore. That same year (Anon. 1958), 40 *O. mossambicus* from Manila were introduced to ponds built at the Port Laguerre Farm School in New Caledonia (van Pel 1956) and, around this same time, fingerling *Tilapia zillii* from Hawaii were also released in the ponds (van Pel 1959). Around 1957 *O. mossambicus* were brought to the Solomon Islands and stocked in ponds at Guadalcanal (P. Nichols, pers. comm.). The fish were transplanted from Honiara to Lake Tenggano on the island of Rennell in the southern Solomon Islands and eventually also became established on the islands of Malaita and Santa Ana (P. Nichols, pers. comm.). By 1956 *O. mossambicus* had been brought from Noumea and released on Efate and Tanna Islands of Vanuatu (Uwate et al. 1984). The purposes of the Melanesian introductions of tilapia were for aquaculture and stock enhancement.

The Polynesian islands were not far behind in introducing tilapia as Western Samoa, Tonga and the Cook Islands received fingerlings of *O. mossambicus* from the Sigatoka Agricultural Station in Fiji in 1955 (Beddell 1956; Chimits 1957; Devambez 1964; Csava 1986; van Pel 1961). From Western Samoa, *O. mossambicus* were introduced in 1957 into the brackish swamp at Aunu'u and later into Leone Creek on Tutuila in American Samoa (van Pel 1959). In 1966 tilapia were introduced into two crater lakes on Wallis Island (Hinds 1969). Tilapia were also introduced to Niue, Tuvalu, Wallis Island and Tahiti (Uwate et al. 1984; Welcomme 1988). As in Melanesia, the purpose of most of these introductions was for aquaculture to provide an additional source of food for local populations (Holmes 1954). An exception was Tonga's request for the fish to aid in the control of mosquitoes (U. Fa'anunu, pers. comm.). However, in 1982, introductions of tilapia into Lake Ava Ano in Nomuk, H'Aapi, also in Tonga, were made to provide additional stocks for fishing (U. Fa'anunu, pers. comm.).

In the central Pacific, tilapia were introduced in the early 1960s to ponds in Nauru and to several islands of the Gilbert group in the island nation of Kiribati. On Nauru, tilapia were introduced into a natural, brackishwater pond for the control of mosquitoes

(Ranoemihardjo 1981). In the islands of Kiribati, tilapia, probably from Fiji, were introduced into some of the traditional milkfish ponds by the Department of Agriculture in 1963 (Villaluz 1972) to establish subsistence aquaculture which could provide an additional source of protein, particularly during rough weather when fishing was not possible (Terroroko 1982). An accidental introduction of *O. mossambicus* to Fanning Atoll in the Line Islands was made in 1958 from research vessels examining the potential use of tilapia as tuna bait; and some of the fish were also released in a lake on Washington Island (Lobel 1980).

In the western islands of Micronesia, tilapia introductions have occurred sporadically since the 1950s. In the Mariana Islands, tilapia have been introduced to Guam, Saipan and Pagan. In 1954, the Guam Department of Agriculture imported *O. mossambicus* from the Philippines, and these were distributed to local residents for pond culture (De Leon and Liming 1956). Brock and Yamaguchi (1955) recommended releasing *O. mossambicus* and *T. zillii* into the Fena reservoir in southern Guam to control aquatic vegetation. Also in 1955, 309 *O. mossambicus* were introduced from the Philippines to the 10-ha Lake Susupe in nearby Saipan (Anon. 1955). That same year, a US naval field trip to Pagan, an island which is now uninhabited as a result of recent volcanic activity, carried 200 *O. mossambicus* fingerlings which were released to each of the two lakes there (Brown 1955). The rationale for the introductions to Saipan and Pagan is uncertain, but presumably it was to provide a source of fish for human consumption. Brock and Takata (1956) resurveyed the reservoir in Guam, noting that *O. mossambicus* had become well established and *T. zillii* were also released in the reservoir (Edlredge 1988) based on their recommendations. Further tilapia introductions have periodically occurred in Guam since 1973 when the first red hybrids of *O. mossambicus* and *O. niloticus* were introduced from Taiwan for use in the developing commercial aquaculture industry (FitzGerald and Nelson 1979). Although the red hybrid did not prove popular in local markets, farmers in Guam still bring in juveniles of normally pigmented tilapia hybrids for commercial production.

Rota and Tinian are the only two other islands in the Mariana archipelago which have habitats suitable for tilapia. However, attempts to introduce tilapia at Tinian proved unsuccessful (Edlredge 1988), and no records of attempts to introduce tilapia to Rota could be found. Both of these islands remain free of tilapia today.

The spread of tilapia to the other islands in Micronesia has been more recent. In the mid-1970s, several aquaculture demonstration ponds were constructed adjacent to a mangrove habitat in Yap and stocked with *O. mossambicus*. We were unable to find any record of tilapia being introduced to the other islands in the Federated States of Micronesia (Pohnpei, Kosrae, Truk), in the islands of Palau or in the Marshall Islands.

Establishment in Island Ecosystems

Although many of the tilapia introductions were initially confined to ponds or reservoirs, the transplanted fish soon became established in a variety of natural bodies of water through accidental release or escapes. In other cases, the establishment of tilapia in natural ecosystems was the result of purposeful introduction. As a result, at numerous locations within the region, populations of tilapia have become established in reservoirs, lakes, streams, rivers, swamps, mangrove areas and even in marine habitats as discussed below.

Freshwater Habitats

Populations of *O. mossambicus* are now well established in freshwater habitats in the Cook Islands (N. Howard, pers. comm. 1987), the Samoas (D. Itano, pers. comm.), Wallis Island (Hinds 1969), the Mariana Islands (Best and Davidson 1981; Brock and Takata 1956; Brown 1961), Fiji (Ryan 1980; Andrews 1985), New Caledonia (van Pel 1959), Nauru (Ranoemihardjo 1981), Papua New Guinea (West and Glucksman 1976; Coates 1985, 1987), the Solomon Islands (P. Nicols, pers. comm.), Tonga (U. Fa'anunu, pers. comm.), the Line Islands (Lobel 1980) and the Caroline Islands at Yap (Nelson 1987).

Other tilapias have also become established in freshwater habitats within the region. In Guam, *T. zillii* is common in the man-made Fena reservoir and, although it was introduced to help control aquatic vegetation, the shallow areas of the reservoir remain choked with the aquatic weed *Hydrilla verticillata* (Leith et al. 1984). In Fiji, populations of *O. niloticus* have become established in local streams, but there is no record of the establishment of *T. zillii* which was also introduced into natural waters (T. Adams, pers. comm.).

Brackishwater and Marine Habitats

As a result of its salinity tolerance (Stickney 1986), *O. mossambicus* has been able to become established in brackish and marine habitats at several Pacific-island locations. In the South Pacific, tilapia, which were introduced to rivers to improve fishing (Herington 1977), have incidentally become established in the estuaries of Papua New Guinea (Glucksman et al. 1976). Tilapia are reported to have become the dominant species in the brackishwaters of the Sopu area of Tongatapu in Tonga following its establishment effected by fish escaping from a small fishpond (U. Fa'anunu, pers. comm.; Uwate et al. 1984). The fish have also become established in brackishwater at Tuvalu (Uwate et al. 1984), in the mangrove areas of Yap in the Caroline Islands (Nelson 1987) and at Fanning Atoll in the Line Islands (Lobel 1980). In the central Pacific, *O. mossambicus* has survived eradication attempts and remains firmly established in the brackishwater ponds of Nauru and in the lagoons of Tarawa in Kiribati (Uwate et al. 1984).

Most of the island groups within the region now have established populations of *O. mossambicus* and other species have become established in Guam and Fiji. Today, few island groups with suitable habitat remain free of tilapia. However, tilapia were not found in recent faunal surveys of the streams of Pohnpei (Maciolek and Ford 1987) and Palau (Bright and June 1981). Also, we could find no evidence of tilapia being introduced to the islands of Truk or Kosrae in the Federated States of Micronesia or to the Marshall Islands.

Impact of Tilapia Introductions

The impact of tilapia introductions in the South Pacific and Micronesia could be assessed in terms of environmental costs, such as the degree of disturbance of natural ecosystems; and of socioeconomic benefits, such as the control of aquatic pests, the development of aquaculture or the improvement of local fisheries.

Unfortunately, the costs associated with the introduction of tilapia in the Pacific islands are difficult to quantify since, in most cases, the impact of the exotic fish on the indigenous flora and fauna is virtually unknown. This largely results from the paucity of ecological information regarding the inland waters of the Pacific islands in general. However, in spite of the lack of quantitative data,

it is believed that, in some cases, tilapia have replaced more highly valued species as the predominant fish in shallow near-shore habitats. For instance, Lobel (1980) reported that the fishermen of Fanning Atoll claim that the establishment of tilapia resulted in decreased populations of mullet, bonefish and milkfish.

As documented in other geographic areas (Rosenthal 1980), attempts to develop aquaculture have been impeded by the impact of introduced tilapia. For example, on Tongatapu, the main island of Tonga, tilapia are considered a pest; they interfere with the cultivation of mullet and are only fished by children. On Fanafuti in Tuvalu, the stunted populations of tilapia which have become established in the lagoon hinder the development of milkfish culture (Uwate et al. 1984).

Introduced tilapia have also interfered with traditional aquaculture practices. One notable example can be found at Nauru where the impact of introduced tilapia has virtually destroyed the traditional culture of milkfish in inland ponds and lagoons (Ranoemihardjo 1981). Milkfish are highly valued on Nauru and are traditionally used there as food for special occasions and ceremonies (Petite-Skinner 1981). However, with the demise of traditional aquaculture which resulted from the introduction and establishment of tilapia, milkfish now must be imported from other areas, such as Guam or Kiribati, where they are cultured commercially. Similarly, the thousands of stunted tilapia in the milkfish ponds at Tarawa and other islands in Kiribati are competitors with the milkfish for food as well as predators on the fry (Terroroko 1982). These situations have led to attempts, thus far unsuccessful, to eradicate the introduced fish in both Kiribati and Nauru (Ranoemihardjo 1981; Terroroko 1982).

Although, in most islands tilapia were introduced in efforts to develop aquaculture, there are few sites within the region where they are currently cultured. The only significant commercial cultivation of tilapia within the region occurs in Guam where *O. mossambicus* and hybrids of *O. mossambicus* x *O. niloticus,* which are obtained from Taiwan, are raised in ponds and sold live through local market outlets (Nelson 1988). The culture of tilapia in Guam has resulted in the replacement, in domestic markets, of tilapia imported from the Philippines, and annual tilapia production on Guam has increased steadily in recent years to the current level of over 125,000 kg, nearing the point of saturating the local market. In addition, subsistence culture of tilapia has been successful in Fiji where a

program for the production of *O. niloticus* has been developed by volunteers of the US Peace Corps on the island of Viti Levu (Andrews 1985). According to Uwate et al. (1984) tilapia have also been cultured on a small scale in Western Samoa, but marketing the fish has been difficult.

Significant improvements of freshwater fisheries have resulted from the introduction of tilapia in some areas within the region (Petr 1985). The most dramatic impact on fisheries has occurred from the introduction of *O. mossambicus* into the Sepik River in Papua New Guinea where tilapia now constitutes more than 50% of the local catch (Coates 1985; 1986). Impressive harvests of *O. mossambicus,* at times in excess of 16 t per year, have been taken from Lake Tenaggano on the island of Rennell in the Solomon Islands (P. Nicols, pers. comm.).

Small-scale or subsistence fisheries for tilapia have developed in some areas. For instance, in the Kingdom of Tonga, *O. mossambicus,* which became established in Lake Vailahi constitutes the major fishery of the island of Niuafo'ou where the sea is too rough for ocean fishing most of the year ('U. Fa'anunu, pers. comm.). Tilapia are also fished on the islands of Vava'u and Nomuka in Tonga (S. Langi, pers. comm.) and in the area of American Samoa where they are known (D. Itano, pers. comm.). Tilapia have also been fished in the Cook Islands, but their recent low populations have led to the species being ignored as a food source (N. Howard, pers. comm.). Tilapia are apparently not relished in Tuvalu, but the people of Niutao Atoll there catch tilapia for use as an ingredient in pig feed (Uwate et al. 1984).

Adverse effects of introduced tilapia on indigenous organisms through competition, predation or the destruction of aquatic vegetation have been well documented in other areas (Philippart and Ruwet 1982).

Conclusions

Although the ecological and socioeconomic impacts of tilapia introductions in the South Pacific and Micronesia have varied from harmful to beneficial depending on the particular circumstances of the island sites and cultures, it is clear that once these fish are introduced to tropical island environments, it is likely that they will eventually come to inhabit most of the accessible freshwater and

brackishwater habitats and are even capable of invading marine habitats. Once established in natural bodies of water, the fish have proven to be virtually impossible to eliminate. Therefore caution and carefully planned studies should precede any further introductions of tilapia within the region. Such studies should include evaluations of the anticipated interactions between the introduced fish and the indigenous aquatic organisms as well as the expected socioeconomic benefits. No matter how well intentioned, introductions made in the absence of such background information constitute nothing less than high-risk games of ecological roulette.

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