CHAPTER 7

Flyingfish

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I. INTRODUCTION

Flyingfish represent an important resource in many parts of the world. Several Pacific islands currently have developed flyingfish fisheries and many have a history of traditional fisheries for flyingfish. Some Pacific islands do not have flyingfish fisheries, yet the abundance of the resource appears to be at least as great as other areas. As fishing pressure on limited reef resources increases, the development of alternative fisheries is needed, particularly for small- scale fishermen. Preliminary investigations suggest that flyingfish may also fall into this category.

This chapter presents information obtained from a review of available literature, discussions with fisheries workers, correspondence with flyingfish authorities, and recent flyingfish fishing trials. This provides the basis for an assessment of the potential for fisheries development for this resource in the South Pacific.

II. BIOLOGY

In the following section, aspects of the biology of flyingfish are presented with as much reference as possible to the Pacific islands situation. In many cases, however, for lack of details specific to the Pacific islands, information on studies from other parts of the world is provided.

IDENTIFICATION

In order to address fundamental questions on population dynamics and biology of flyingfish, it is important to be able to identify clearly the species involved. Flyingfishes (family Exocoetidae) are closely related to the garfishes (family Hemiramphidae), longtoms or needlefish (family Belonidae), and sauries (family Scomberosocidae). Although the adult forms vary considerably, early developmental stages of these families have many features in common. In particular, these fish typically have filaments on their eggs, develop chin barbels at juvenile stages, and share a similar appearance at early developmental stages.

The taxonomy of flyingfishes is complex. Problems in properly identifying flyingfish are due to 1) the large number of species that occur in the Pacific islands, 2) the uncertain distinction between some genera, 3) the likelihood that several species have yet to be described, and 4) juveniles that look significantly different from adults of the same species. The difficulty in obtaining adequate reference material further complicates the situation.

Parin (1960a) states that about 41 species of flyingfishes inhabit the western part of the Pacific Ocean, which includes 29 species in the Coral Sea, 27 in Indonesia-New Guinea, 19 in Marianas-Carolines-Marshalls, and 19 in Gilberts-

Table I. Flyingfish species that are likely to occur in the Pacific Islands. Adapted from Parin (1960a), Kailola (1987) and Wass (1984).

Cheilopogon		*Exocetus*	
	antoncichi		*monocirrhus*
	furcatus		*obtusirostris*
	unicolor[1]		*olitans*
	arcticeps		
	atrisignis	*Hirundichthys*	
	cyanopterus		*albimaculatus*
	intermedius		*speculiger*
	longibarbus		
	nigricans[2]	*Parexocoetus*	
	spilonotopterus		*brachypterus*
	spilopterus		*mento*
	suttoni		
		Prognichthys	
Cypselurus			*sealei*
	angusticeps		*agoo*
	oligolepis[3]		*albimaculatus*
	naresii		*brevipennis*
	pitcairnensis		
	poecilopterus		
	simus		

1. The distinctions among *Cheilopogon antoncichi, Ch. unicolor,* and *Ch. furcatus* awaits clarification and the names may have been used interchangeably by various authors.
2. Probably more than one species.
3. The distinction between *Cypselurus angusticeps* and *C. oligolepis* awaits clarification and the names may have been used interchangeably.

Samoa-Fiji-Tonga. Wass (1984), based on correspondence with Parin, indicates that 16 species of flyingfishes occur near Samoa.

Among the references listed in the attached bibliography, 14 papers contain primarily taxonomic information. Many authors indicate that six genera of flyingfish occur in the Pacific islands (see Table I). These are: *Cheilopogon, Cypselurus, Exocoetus, Hirundichthys, Parexocoetus*, and *Prognichthys*.

Two points should be noted:

(1) The genus *Oxyporhamphus* has, in the past, been included in the family Exocoetidae but more recently there is agreement that it belongs in the family Hemiramphidae;

(2) *Cheilopogon* includes species that were formerly placed in the genus *Cypselurus*.

Because the same six flyingfish genera occur in the Indian Ocean, the 1984 FAO Species Identification Sheets for the Western Indian Ocean (Appendix 2) can be used to identify Pacific islands flyingfish genera.

Identification to the species level is considerably more difficult. A revision of the taxonomy of the group has been proposed by FAO and would culminate in a comprehensive catalogue of flyingfish species found in the Pacific islands and elsewhere.

To obtain taxonomic information on the species caught in some of the Pacific island flyingfish fisheries, specimens were collected in 1989 and 1990 from the nearshore fisheries in several Pacific islands countries and sent to the National Marine Fisheries Service Systematics Laboratory in Washington, D.C. The Laboratory Director, B. Collette, kindly made tentative identifications of the species. In June 1990 the specimens were re-identified by N. Parin. The results of these examinations are given in Table II. The discrepancies between the opinions of the two taxonomists highlight the difficulty that fishery workers are likely to encounter in correctly identifying flyingfishes.

Collette indicates that the *Cheilopogon* and *Cypselurus* species listed in the table (which presumably constitute a major portion of the Pacific islands flyingfish catch) can be distinguished using the following characteristics:

A) Pigment of pectoral fins

spotted:	*atrisignis, poecilopterus, suttoni*
clear:	*unicolor*
dark:	*spilopterus*
dark with white margin:	*oligolepis, spilonotopterus*

B) Pigment of dorsal fin

clear:	*unicolor, poecilopterus, oligolepis*
with black spot:	*atrisignis, spilopterus, spilonotopterus, suttoni*

DISTRIBUTION

Flyingfish common in the tropical Pacific have limits of distribution bounded by 40° S and 40° N (Kovalevskaya 1982). Some authors partition flyingfish species into two groups, neritic (coastal) and oceanic. "Oceanic" species can be found in coastal areas; likewise, "coastal" species can also be found in oceanic areas. An oceanic species does not require coastal habitat for any stage of its life history, in particular, spawning. Coastal species on the other hand, use the coastal environment for some stage of their life cycle, typically to spawn.

Parin (1960a) states that in the Pacific islands there are about 28 species in the coastal group and 13 in the oceanic. He indicates that the proportion of coastal to oceanic species is lower in the central Pacific and increases to the west. Presumably this is related to the larger land masses in the western Pacific. All of the species listed in Table II were obtained from nearshore fisheries in the central Pacific. Seven are described by Parin (1960a) as coastal species while *Cheilopogon suttoni* is considered oceanic.

For fisheries involved in catching flyingfish at the surface at night, the depth at which the fish are found will undoubtedly affect catchability. The vertical distribution of flyingfish extends to 18 m during the night while roughly 86 per cent are found in the shallow layer from 0-2 m (Nesterov and Bazanov 1986). The brightness of the moon may affect flyingfish depth, although no studies of this phenomena are known.

Several visual survey methods have been developed to estimate the abundance and distribution of flyingfish (*e.g.* Parin, 1983; Zuyev and Nikolsky, 1980; Oxenford *et al.*, 1989). Problems with these methods include difficulties in identifying species and determining absolute abundance. Nonetheless, these methods can give some indication of the relative abundance and the suitability of flyingfish habitat. Oxenford *et al.* (1989) found that in the Caribbean, the distribution of *H. affinis* is considerably wider than the region where the current fishery operates. Such definitive studies have not been conducted in the Pacific islands region.

MIGRATION/DISPERSION

The extent of migration and/or dispersion of flyingfish will affect the degree to which they can withstand fishing pressure. As noted above, there are oceanic and coastal species of flyingfish. The oceanic group has a greater range but fewer species than the coastal group.

In the Pacific islands region, no studies have been conducted to determine the extent of flyingfish movements. In the Caribbean, tagging studies of *Hirundichthys affinis*, a species that may be similar to *H. speculiger* found in the Pacific, show that movement may be related to oceanographic conditions. These

Table II. Identification of flyingfish specimens from eight Pacific islands countries.

Origin of Samples	Collette's Identification	No. Indiv.	Parin's Identification	No. Indiv.
Tonga 1: (Jan-Apr) 1989	*P. brachypterus*	(1)	*P. brachypterus*	(1)
	C. poecilopterus	(2)	*C. poecilopterus*	(2)
	Ch. spilopterus	(1)	*Ch. spilopterus*	(1)
	Ch. suttoni	(3)	*Ch. suttoni*	(3)
	Ch. spilonotopterus	(1)	*Ch. spilonotopterus*	(1)
	Ch. atrisignis	(2)	*Ch. atrisignis*	(2)
	Ch. unicolor	(1)	*Ch. antoncichi*	(1)
	C. oligolepis	(1)	*C. sp.*	(1)
Tonga 2: (Sept 89)	*Ch. unicolor*	(3)	*Ch. antoncichi*	(3)
	Ch. spilonotopterus	(2)	*Ch. atrisignis*	(2)
Tahiti: (June 89)	*C. poecilopterus*	(6)	*C. poecilopterus*	(2)
	-		*C. pitcairnensis*	(4)
Cook Is: (Feb 89)	*C. poecilopterus*	(1)	*C. poecilopterus*	(1)
	Ch. unicolor	(2)	*Ch. antoncichi*	(2)
	Ch. atrisignis	(2)	*Ch. atrisignis*	(2)
Niue: (Sept 89)	*Ch. spilonotopterus*	(1)	*Ch. spilonotopterus*	(2)
	Ch. atrisignis	(2)	*Ch. atrisignis*	(2)
	Ch. unicolor	(2)	*Ch. antoncichi*	(1)
	C. oligolepis	(2)	*C. angusticeps*	(3)
	(Unknown Species)	(1)		
Tokelau: (Aug 89)	*Ch. atrisignis*	(1)	*Ch. atrisignis*	(1)
	Ch. unicolor	(1)	*Ch. antoncichi*	(1)
	Ch. spilonotopterus	(5)	*Ch. spilonotopterus*	(6)
	C. oligolepis	(1)	*C. angusticeps*	(2)
Tuvalu: (Aug 89)	*Ch. unicolor*	(3)	*Ch. antoncichi*	(3)
	Ch. spilonotopterus	(4)	*Ch. spilonotopterus*	(6)
	Ch. suttoni	(2)	-	
Kiribati: (March 90)	-		*Ch. spilonotopterus*	(6)
			Ch. suttoni	(3)
Papua New Guinea: (Jan-Feb 90)	-		*C. oligolepis*	(4)
	Total number specimens	53	Total number specimens	68
	Total number species	9	Total number species	11

studies revealed that *H. affinis* probably does **not** undertake extensive migrations by life history stages. That is, the larvae and juveniles appear in the same areas as the adults rather than moving from a "nursery" area. The greatest recorded movement of a tagged fish was 200 nautical miles and the fastest estimated speed was greater than 16 nautical miles per day (Oxenford *et al.* 1989). The longest time at liberty for a tagged flyingfish was 121 days with a mean time of 21 days. Twenty-two per cent of all tagged fish were recaptured in waters of countries other than those in which the fish were released. This indicates that flyingfish can move considerable distances and can be subject to capture in more than one fishery.

PREDATORS

As is well known, flyingfish escape predators by burst swimming that propels them into the air where they can glide with their enlarged pectoral and pelvic fins. Despite this elegant adaptation, flyingfish fall prey to many species. Flyingfish were consistently found in the stomachs of skipjack tuna and other large pelagics in the Pacific islands (South Pacific Commission, 1980-1985). Olson and Boggs (1986) estimate that flyingfish make up from 4 to 13 per cent of the diet of yellowfin tuna in the eastern Pacific. No information is available to suggest that the abundance of any flyingfish predators is limited by the availability of flyingfish.

FOOD AND FEEDING

The food of flyingfish consists mainly of large zooplankton and small fish. From analysis of stomach contents it has been found that feeding of *H. affinis* in the Caribbean takes place at night (Lewis *et al.*, 1962). Hall (1955) examined 425 stomachs of *H. affinis* and found 22.4 per cent of the stomachs contained copepods, 27.1 per cent contained other crustaceans, and 17.2 per cent of the stomachs contained small fish. The study by Lewis et al. (1962) found that fish occurred in 45.3 per cent of the stomachs examined, 32.2 per cent contained copepods, and 21.0 per cent contained other crustaceans. Gorelova (1980) found that the flyingfish he examined from the Pacific feed opportunistically. Between species of flyingfish, there was no evidence of specialized prey selectivity. He also concluded that larvae and juvenile flyingfish feed near the surface primarily during daylight hours at an average rate of 15-20 per cent of their body weight per day.

Flyingfish presumably eat the same food items as other pelagic predators, however, no information exists on how this potential competition may affect flyingfish survival.

GROWTH

Tropical flyingfish, like many pelagic fish species, grow rapidly. To date no growth studies are known to have been done on species supporting Pacific islands fisheries. Studies on growth of tropical flyingfish have been carried out in the Philippines (Dalzell *et al., unpubl. m.s.*), Indonesia (Watson, 1990), and in the Caribbean (Storey, 1983). Flyingfish in the tropics generally live to about 2 years of age and are mature after 10-14 months. The growth rate and maximum size varies by species with the oceanic species typically having a smaller maximum size. Many of the commercially important species (*e.g.* from the genera *Hirundichthys*, *Cypselurus*, and *Cheilopogon*) grow to about 20-25cm and attain weights of 300-450g.

SPAWNING

Flyingfish deposit their eggs on debris, algae, or other substrate. Oceanic species have fully pelagic free-floating eggs or deposit their eggs on the limited debris found in the open ocean. In Japan, studies of *Cypselurus opisthopus* indicate that this species of flyingfish spawns in association with sandy bottoms and is vulnerable to capture with bottom gillnets.

As an example of the range and period over which some species of flyingfish actively spawn, Breder and Rosen (1966) report that *Parexocoetus mento* spawn off Japan in the warm months from May to September. The same species collected off Fiji in October 1991 (where seasons are opposite to those in Japan) was found in spawning condition and had fully hydrated eggs in the ovaries. The Japanese studies cited by Breder and Rosen (1966) also state that most individuals of *P. mento* die after spawning.

In the Pacific, there are several anecdotal accounts of flyingfish spawning behaviour. In the Cook Islands, the people of Atiu celebrate the arrival of the flyingfish (Mokoroa, 1984). They observe three stages where capture is possible: when the fish jump and glide predictably in one direction toward the spawning grounds, when they lie still on the surface of the water to broadcast their eggs and milt, and finally when they begin sinking to greater depths. It is believed that a significant proportion of flyingfish die after spawning.

In Tokelau, similar behaviour thought to be associated with flyingfish spawning is known as *tuali*. On Huahine, French Polynesia, the flyingfish have been observed to spawn in the sand in shallow water. Johannes (1981) gives the following description of flyingfish spawning in Huahine, Society Islands:

> During certain months, the most important being August, September, and October, schools of flying fish come boiling through two reef passes near the town dock at sunset, pursued by predators. The fish swim into a few

inches of water close to shore, wriggle tail first into the sand and deposit their spawn much like California grunion. Spawning takes only a few seconds, after which the fish return to deeper water. No lunar periodicity was noted.

For many of these observations, it is impossible to determine which species is involved and how frequently these events occur. Some scientists have expressed skepticism about accounts of flyingfish spawning in sand because no other species in related families spawn in this manner. Furthermore, flyingfish easily lose their scales, hence they may not survive spawning that involves extensive contact with the substrate. Mature flyingfish in the tropics appear to spawn several times over the course of a year. In studies on the Caribbean species, *H. affinis*, four distinct egg sizes have been found in the ovaries with the largest being fully hydrated and ready to spawn (Storey 1983). This suggests that not all eggs are spawned at once and that the spawning season is protracted.

FECUNDITY

Small species of flyingfish (*Parexocoetus mento,* certain species of *Exocoetus* and *Prognichthys*) spawn between 400 to 1,100 eggs at a time (Kovalevskaya 1982). Larger forms have considerably greater fecundity, ranging between 16,000 and 24,000 eggs in certain species in the genera *Cheilopogon, Cypselurus, and Hirundichthys*. Flyingfish fecundity at a single spawning is not necessarily a measure of the total reproductive potential of that individual. The fact that many flyingfish species spawn several times per year suggests that total fecundity is a better measure of reproductive output. Studies of *H. affinis* egg size indicate that they may spawn at least four times per year (Storey 1983).

EARLY LIFE HISTORY

The eggs of flyingfish have several distinctive characteristics. Flyingfish eggs are negatively buoyant and typically have long sticky filaments that serve to attach the eggs to floating objects. Yellowish white gelatinous masses often observed on floating coconuts or other debris in the ocean are most likely flyingfish eggs. Species within the genus *Exocoetus* are unlike most flyingfish species in that their eggs are larger, do not have filaments, and are positively buoyant. Presumably this is an adaptation to their oceanic spawning nature.

Among species of flyingfish, mean egg size is inversely related to the number of eggs produced per unit of body weight. This implies that some flyingfish species have evolved to invest in larger but fewer eggs, while others have been successful with smaller but more numerous eggs. The survival of fish hatching from larger eggs would likely be higher than fish from small eggs under similar conditions.

Incubation of flyingfish eggs varies from about 4 days to 2 weeks with faster development occurring in warmer regions. The size at hatch ranges from 3.5 to 6 mm depending on the species (Collette *et al.*, 1984). Oxenford (1985) reports that *H. affinis* absorb their yolk sack within a day after hatching. By the time they are 7 to 10 days old the larvae are about 15 mm in length and are usually dark blue on the dorsal surface and silvery on the ventral surface. The morphology of different larval and juvenile stages changes in several species. Extended chin barbels are the most common characteristic of flyingfish larvae and vary considerably in shape and size among species. More primitive species of flyingfish, *e.g.* from the genus *Parexocoetus*, have an elongated lower jaw (Collette *et al.*, 1984).

MORTALITY

A knowledge of mortality is important to understand the potential productivity of the resource, particularly from a fisheries development perspective. Flyingfish appear to grow fast, be relatively short-lived, and spawn profusely. These features suggest a relatively high natural mortality rate. Inferences about Pacific islands species, however, can only be made from studies carried out on similar species elsewhere.

Based on tagging studies in the Caribbean, *H. affinis* appears to have a high natural mortality rate (Eastern Caribbean Flyingfish Project, 1989b). One explanation is that most *H. affinis* die after the spawning season. Alternatively, movement of *H. affinis* to areas where no fisheries occur may explain the pattern of disappearance. In the Philippines, Dalzell *et al.* (*unpubl. m.s.*) estimated natural mortality for *Cheilopogon nigricans*, and *Ch. opisthopus* to be in the range of 70 to 81 per cent per annum but did not discuss the possibility of extensive spawning-related mortalities. If flyingfish do have high natural mortality rates, the stocks may be relatively resilient to fishing pressure. The effect of spawning-related mortality requires further investigation, however.

RECRUITMENT

No information exists on flyingfish recruitment in the Pacific islands, much less the factors that may be controlling the recruitment levels. In the Caribbean, Mahon (1987) examined a suite of biological and environmental factors that may affect flyingfish recruitment. He concluded that environmental conditions influence recruitment more than the observed adult population size. This suggests that current abundance levels are likely to be relatively independent of past catches of previous generations of flyingfish. Abundance levels are therefore likely to be variable, depending on past and present oceanographic conditions as well as other factors such as predation.

IMPLICATIONS FOR DEVELOPMENT AND MANAGEMENT

In summary, several biological characteristics of flyingfish appear to be favourable from a fisheries development perspective: they appear to be short lived, fast growing, highly fecund animals with a wide ranging distribution. This would indicate that overfishing, at least to the moderate catch levels observed in locally developed fisheries, is unlikely. Studies in the Caribbean show the potential for interaction between fisheries in different islands based on the dispersion of tagged fish. This situation may develop in the Pacific but the distances among countries and the number of species involved are much greater. Hence, the likelihood of significant interactions between flyingfish fisheries in different Pacific islands countries is probably low.

III. FISHERIES FOR FLYINGFISH

PACIFIC ISLANDS FLYINGFISH FISHING

Traditional methods: Several techniques have been used in the Pacific islands to catch flyingfish. Documented traditional flyingfish catching methods are given in Table III. As with many aspects of Pacific traditional fisheries, much information on fishing methods has never been adequately recorded.

The dipnet/torch technique is the most widespread, occurring from Palau to French Polynesia. In areas where flyingfish fishing has developed beyond the subsistence level, such as in Tahiti and Rarotonga, a modification of the dipnet/torch technique is used. A good description of the traditional method in Vaitupu Atoll, Tuvalu, is given by Kennedy (1930):

> The canoes draw up in line (*tamanga*) facing north so as to sweep a front parallel with the reef on the lee side of the island. The scene is one of indescribable splendor, the village fires in the distance making dots of light in the palm jungle. When all are ready the line commences to move forward at a steady rate of about two knots. In the bow of each canoe stands the bow-paddler with his dipnet held horizontally across his front so that the bag is to starboard. That member of the crew immediately behind the netter in the bow stands and holds aloft the blazing torch. It is his duty to keep the torch well-trimmed and burning brightly. The other members of the crew ply their paddles and keep a sharp lookout for flyingfish lying or swimming near the surface in the vicinity of the canoe. These appear light grey in colour in the glare of the torches, and are easily seen at distances up to about forty feet. When the fish are running well the uproar is deafening. To the neophyte all seems chaos, but there is a definite thread of order and arrangement. Each canoe keeps

> its place in line. Usually the netter scoops up one fish at a time and flings it into a basket. In the thick of a school a netter may capture as many as three fish, one after another, before emptying his net. When the fish is lying dazed on the surface of the water, the mouth of the net is brought down flat on the water with a resounding slap, and in such a manner that the periphery of the bag surrounds the fish which, startled into flight leaps up into the sack of the bag. Immediately after the slap, the mouth of the bag is twisted quickly and lifted clear of the water with the fish inside. This is the quickest method of taking fish from the water, but can be used only with fish which are right on the surface. When the fish is swimming, the mouth of the bag is thrust under water a few inches in front of it, in such a manner that it will, unless it changes course, swim straight into the opening.

Dipnet fishing at night is still done using torches in some areas. On Temana Atoll, Kiribati, kerosene lamps have been forbidden because the people there perceived that flyingfish stocks would be overfished.

Modern methods: Powell (1989a, 1989b) describes the gradual evolution of the traditional dipnet/torch method into the technique used in Rarotonga today. Important aspects of this development include the introduction of kerosene lanterns in the late 1940s to replace palm frond torches, the use of skiffs powered by outboard motors to replace paddled canoes, and the use of halogen lamps to replace kerosene lanterns.

Dipnet/torch fishing has evolved to the greatest extent in French Polynesia. The typical boat (called *poti marara* which literally means flyingfish boat) used in that fishery is between 5 and 6 metres in length and uses a 60 horsepower outboard engine. In 1987 there were an estimated 272 of these flyingfish boats in French Polynesia (Service de la Mer, 1989).

In both French Polynesia and the Cook Islands, small generators are used to power the fishing lights. A high-powered light is affixed to a helmet worn by the fishermen. This allows the fishermen to direct the light while still having use of both hands to manoeuvre the boat and manipulate the dipnet. The boats in these areas are specially designed so that the fisherman can stand in the bow section of the boat to facilitate scooping. Steering is accomplished by the use of an aviation-type "joystick" which may have an integrated throttle. The shape of the hulls is such that they turn easily yet have enough V shape to be comfortable in moderate seas. An important characteristic of these boats is that they can easily be used for other types of fishing. In French Polynesia, only about 40 per cent of the fish landed from flyingfish boats are flyingfish. Recently, in response to a request from the Cook Islands Government, the FAO/UNDP Regional Fishery Support Programme (RFSP) contracted a naval architect to produce an alternative flyingfish fishing craft which would require a smaller outboard engine than the 40 to 60 hp versions that are presently being used.

Most accounts of night fishing for flyingfish indicate that conditions for catching are better during hours of maximum darkness. That is, the fisherman's light is most effective at spotting and immobilizing fish if the moon is below the horizon and there is no twilight. Calm conditions are often better because it is easier to spot fish; if there is wind, it is usually best to fish downwind or in the lee of an island. Scooping requires practice to become proficient and is done while the fish is in the water, usually not when fish takes flight. The fisherman must place the net so that the flyingfish swims into it and he must be quick so that the fish does not change direction and avoid the net. When fish are not very concentrated, fish that are missed can often be pursued until caught. Points of reef or land are generally better than bays. Shallow open ocean seamounts are also good, weather and distance permitting. Water clarity seems to affect catch rates either because there may be fewer flyingfish in murky water, or they may be more difficult to see.

Results from fishing introduction trials: In the recent past there have been several attempts to introduce modern flyingfish fishing methods in the region. Trials of night fishing for flyingfish using a kerosene lantern in American Samoa by masterfishermen from the South Pacific Commission yielded catch rates of 14.9 fish (3.63 kg) per hour over 3 nights (8 hrs total) of fishing (A. Moana *unpubl. m.s.*). In Niue, an SPC masterfisherman averaged 45.3 fish per hour over 16 trips during 1988 and 1989. In Yap, C. Friberg (Yap Fishing Authority) reported an average of 23 flyingfish per hour were caught based on 20 trips which took place during August and September. This project was aided by an experienced Cook Island fisherman whose conclusion was that catch rates in Yap were similar to those in the Cook Islands during the peak season. There is one report of catching 15 to 20 fish per hour using a kerosene lantern and household battery-powered torches in Solomon Islands (D. Ham, *pers. comm.*). In Vava'u, catch rates from 19 trips between January 1987 to November 1989 averaged 18.4 fish per hour using electric lights at night (P. Mead *unpubl. m.s.*). In Fiji, Walton (1991) reports that initial trials held outside of Suva Harbour entrance during August 1991, yielded roughly 10 fish per hour. An experienced SPC masterfisherman from the Cook Islands assigned to that project asserted that catch rates would probably be higher during the warmer months (October to March). Despite promising indications from the above tests, none of these fishing trials have resulted in the establishment of viable fisheries.

DESCRIPTIONS OF FISHING METHODS FROM OTHER REGIONS

Fishing practices from other areas of the world can provide some perspective on alternative Pacific islands flyingfish fishing methods.

Table III. Traditional Pacific Islands methods for catching flyingfish.

Location	Method	Source
Southern Cook Islands	Scooping fish at night using dipnet and torches	Ministry of Marine Resources, 1989
	Scooping fish at night using dipnet and torches, hooking using floating lines with baited hooks. Catching fish by hand during occurence of inshore spawning aggregations.	Powell, 1989 Mokoroa, 1984; Powell, 1989
Northern Cook Islands	Scooping fish at night using dipnet and torches.	Andrews, 1987; Beaglehole & Beaglehole, 1938
Federated States of Micronesia	Scooping fish at night using dipnet and torches.	Buck, 1950
Tuvalu	Scooping of fish during day, scooping of fish at night using dipnet and torches, herding fish into apex of V-shaped net.	Kennedy, 1930
	Scooping fish at night using dipnet and torches, trolling using small hooks baited with coconut.	Zann, 1980
Tokelau	Scooping fish at night using dipnet and torches.	MacGregor, 1937
Kiribati	Night fishing with torches and scoop nets when the moon is full, night fishing with torches and scoop nets when there is no moon, fishing with torches and scoop nets at sunset, fishing with hooks and floats, trolling.	Turbott, 1950 Lawrence, 1983
	Trolling using lure made of coconut mid-rib.	Kennedy, 1930
Palau	Scooping fish at night using dipnet and torch.	Black, 1968; Johannes, 1981
Marshall Islands	Scooping fish at night using dipnet and torch/lamps.	Knight, n.d.
French Polynesia	Scooping fish at night using dipnet and head-mounted lamps. Catching fish by hand during occurence of inshore spawning aggregations.	Bagnis *et al.*, 1973 Johannes, 1981
Solomon Islands	Fishing with carved floats, coconut mid-rib hooks, and thin lines.	Wata, 1985
Mariana Islands	Catching fish using small hooks, thin lines, and calabash floats.	Driver, 1989

In the eastern Caribbean, flyingfish fishing is highly seasonal and targets on the spawning behaviour of the principal species, *H. affinis*. Fishermen drift alongside rafts of palm leaf or other vegetation which, together with a chum basket containing chopped fish and fish oil held over the side, attract schools of flyingfish. The flyingfish are then caught during the daytime with hand-held dipnets or gillnets.

In the Indian Ocean, fishermen also take advantage of flyingfish spawning aggregations. Some fishing is done with gillnets in conjunction with floating vegetation, which presumably provide an attractive spawning habitat as a lure. The general applicability of flyingfish fishing using gillnets is currently being extensively tested in the Bay of Bengal (Pajot 1991).

In the Philippines, Martin (1938) described four methods of fishing for flyingfish found there: using traps, large and small gillnets and purse seine. Dalzell *et al.* (1990) describe the current use of gillnets and drive-in nets used in the Philippines.

In Indonesia, fishermen collect the eggs of flyingfish off special bamboo rafts; the eggs are dried and exported to Japan. A variation of these rafts also trap the flyingfish which are sold on the local market (Basuki 1989).

CATCH STATISTICS

Pacific islands landings: Statistics on subsistence and artisanal fisheries are often difficult to obtain and those which are available are sometimes unreliable. This is especially true when dealing with flyingfish in the Pacific islands. Data on catches of these fish are apparently only available for French Polynesia, the Cook Islands, and Kiribati.

Service de la Mer (1989) indicates that 46 *poti marara* fishing from the small ports of Paea, Puunauia, and Arue, on the Island of Tahiti, caught a total of 213 t of flyingfish in 1988. It is estimated that there are a total of 272 *poti marara* in French Polynesia. It would seem reasonable to assume that the catches of those based furthest from the commercial centres would be smaller than those of the boats from the three sampled ports because of the smaller markets in more rural areas. Catches from the subsistence sector must also be considered. A rough estimate of the total landings of flying fish from the 130 islands in French Polynesia might therefore be about 800 to 1,000 $t.yr^{-1}$.

In 1979 the Agriculture Unit of the Cook Islands government estimated that 46.1 t of flyingfish were landed in five islands in the southern Cook Islands. The Ministry of Marine Resources (1989) indicated that subsistence and inter-island trade of these fish average about 3 to 5 $t.yr^{-1}$ on Palmerston Atoll. Data supplied to FAO (FAO 1989) show that in the years 1984 to 1987 the Cook Islands annual catch was between 40 and 44 tonnes. Considering the more detailed data above and the active subsistence fishery for flyingfish in the northern Cook Islands, the FAO figure appears low. About 60 $t.yr^{-1}$ is perhaps a more realistic estimate.

Mees (1984) gives data from which estimates of flyingfish catches on 6 atolls in the Gilbert Group of Kiribati can be made. These estimates range from 16 to 51 t per atoll per year (average 26 $t.yr^{-1}$). Extrapolating this to the 17 atolls of the Gilbert Group gives a crude estimate of 453 $t.yr^{-1}$. Data supplied to FAO (FAO, 1989) however, show that, in the years from 1984 to 1987, estimates of flyingfish catches ranged from 161 to 2,455 t.

Anecdotal information from Tokelau, Tuvalu, the Marshall Islands, the Federated States of Micronesia, Niue, and Palau indicate that active subsistence fisheries for flyingfish exist in those locations. Although Melanesian catches are likely to be small, at particular islands in Vanuatu, Solomon Islands, and Papua New Guinea where there is a strong fishing heritage (*e.g.* Futuna, Belona, Manus), flyingfish are taken. Apparently, few, if any, flyingfish are caught in Fiji at present. Considering the above, a crude estimate of the total annual landings of flyingfish in the Pacific islands is about 2,000 t.

Catches from other regions: To give some perspective of flyingfish development potential, it is useful to consider catches obtained from tropical flyingfish fisheries in other parts of the world. In the Indian Ocean, recorded catches have ranged from 504 t in 1986 to over 1,600 t by 1989 (FAO, 1991). Currently the fishery is expanding through the use of gillnets on larger vessels. In the eastern Caribbean, catches have steadily increased since the beginning of the fishery in the late 1940s to present annual catches between 2,000 and 5,000 t. In the Philippines, flyingfish catches have consistently been about 17,000 t per annum. Indonesia reported annual catches of over 11,000 t from 1987-1989 (FAO 1991). Using the rough estimate presented in the previous section, less than 6 per cent of the world landings of flyingfish are caught in the Pacific islands region.

POST-HARVEST ASPECTS

Currently there are three known commercial markets for flyingfish products. First in importance is the use of flyingfish for direct human consumption. Flyingfish are also sold for bait, primarily for sport fishing. A market also exists for flyingfish roe.

Regarding consumption, flyingfish is a nutritious food. It is high in protein and, according to FAO (1990), has fewer calories and fat per gram than many other fishes. Ciguatera poisoning has not been associated with the consumption of flyingfish. Because flyingfish feed primarily on plankton and small fish, they are relatively low in the food chain and thus less likely to concentrate biotoxins in their flesh.

Flyingfish are currently processed as fresh, fresh frozen, salted/dried, and smoked. Depending on the length of time required to deliver the flyingfish to the market, they may be iced while at sea. In the Caribbean, a special "butterfly fillet" is made whereby all bones are removed and a single one-piece fillet remains. FAO (1990) produced a manual illustrating this filleting method, as well as several aspects of handling and preserving flyingfish. Frozen flyingfish are commonly filleted first and fast frozen in vacuum packs for maximum quality. Preservation of flyingfish is particularly important in fisheries which are highly seasonal.

Flyingfish represent a significant source of revenue in many areas. In the Cook Islands, the 1990 price for a string of seven flyingfish sold for US$2.80 (approximately US$2.50 per kg). In the eastern Caribbean, the annual landed value of flyingfish in recent years has been about US$5.5 million (Mahon 1989).

In a study of processing flyingfish, Herborg (1971) found that it was possible to preserve flyingfish by marinating them for three months at room temperature. The final product, presented in "pickled" form, has a shelf-life of several months under refrigeration. Fish jerky made from tuna has recently been successfully produced in the Tokelau Islands and requires minimal technology[1]. This type of processing may be appropriate for flyingfish as well. Such value-added products increase locally earned revenue.

Flyingfish are considered one of the best bait species for deepwater pelagic sport fishing. Some claim that flyingfish can be up to ten times more effective than artificial lures (*e.g.* P. Mead, 1991). They keep well when frozen and can even be re-frozen successfully without becoming too soft to be useful. Mead describes one technique for rigging and fishing with flyingfish as trolling bait (*ibid.*). Preston *et al.* (1987) present another method.

There are fisheries for flyingfish eggs, especially in Indonesia. Fishermen there use unique bamboo rafts that attract flyingfish during periods when they are known to be actively spawning. The flyingfish deposit their eggs on the rafts; the fishermen collect, dry, and eventually ship the eggs to Japan. Redmayne (1989) reported that in the United States during 1988 whole flyingfish sold for US$2.24/kg while the processed roe sold under its Japanese name, *tobiko,* brought an average price of US$25.20/kg. He describes in detail the qualities of flyingfish roe as a food item:

> *Tobiko*...is a flaming fluorescent orange. The color is artificial, looks artificial, and is intended to add fun to other food. Not only does *tobiko* supply a psychedelic touch to sushi, but it adds hundreds of small mouth explosions as the berries burst on your palate...color and pop are essential to the product...*Tobiko* without the pop is like champagne without the fizz.

IV. DISCUSSION

INDICATIONS OF FISHERY POTENTIAL

There are several indications that the Pacific islands flyingfish resources have potential for further development.

On a biological basis, commercially important flyingfish species found in the tropics appear to be short-lived, fast growing, highly fecund animals with a wide-ranging distribution. This suggests that their populations should be fairly resilient to fishing pressure.

Development potential is also suggested by the fact that areas where no flyingfish fisheries exist have similar climates and geography to areas with developed fisheries.

For example, French Polynesia has a substantial flyingfish fishery while in Fiji, at the same latitude, virtually no flyingfish fishing occurs. There is no indication that the productivity of the waters surrounding Tahiti is greater than those surrounding Fiji.

Comparisons of Pacific islands flyingfish fisheries with fisheries outside the region also reflect the potential of the resource. An estimated 6 per cent of the world landings of flyingfish comes from the Pacific islands region, yet geographically, the Pacific islands region is substantially larger than the other primary "regions" where flyingfish are caught (Indonesia, the Philippines, the Indian Ocean, and the eastern Caribbean).

The magnitude of pelagic fish habitat can also be shown by comparing catches of skipjack and yellowfin tuna, two species that are common where flyingfish are found. Catches of these tuna species from Pacific islands waters represent about 46 per cent of the world landings[2] while flyingfish landings are almost an order of magnitude smaller. This represents some evidence, albeit circumstantial, that the capacity to harvest flyingfish on a sustainable basis in the Pacific islands may be large enough to withstand increased fishing effort and development.

There is no published evidence that flyingfish stocks in the Caribbean have been overfished, even though the fishery has produced steady catches since the late 1940s. Dalzell *et al.* (*unpubl. m.s.*) estimated the flyingfish exploitation rates for the principal species in the Philippines to be over 50 per cent per annum, suggesting that the stocks are very heavily exploited. Despite this, catches have remained stable at over 17,000 t since 1987. Some researchers caution however, that flyingfish populations may behave similarly to clupeoids such as the Californian sardine or the Peruvian anchovy and may collapse when a threshold level of exploitation is exceeded.

SUGGESTED FUTURE WORK

Taxonomy: In order to address fundamental questions on population dynamics and biology of flyingfish, a reliable method of identifying the species is required. A taxonomic revision of the family followed by the publication of a catalogue of flyingfish species is needed.

Tagging: The tagging of flyingfish could help resolve certain constraints to development. For example on Temana Atoll, Kiribati, where gear restrictions have been established due to perceived local over-exploitation, a tagging study similar to that carried out in the Caribbean may resolve the need for local regulation by revealing the range of the target species.

In areas where the fishery is developed, such as the Cook Islands and Tahiti, tagging studies would also be useful to estimate the overall productivity of the resource. This information would be useful in determining the need for management with a view to maximizing long term catches.

Investigations on markets for flyingfish: In areas where local consumers are unfamiliar with flyingfish, a programme may be needed to introduce the product. This might consist of supplying the market with flyingfish for trial sales and, if needed, providing cooked samples for potential consumers to sample.

Areas in which flyingfish are abundant but where the market is limited would benefit from investigation of alternative products. The processing of flyingfish for long-term storage through appropiate technology such as pickling or drying may increase the marketability of flyingfish and add value. These methods would be particularly applicable in outer island areas without freezers.

Flyingfish have proved to be a superior bait for trolling but their utility as longline bait has yet to be tested. Quantitative trials of flyingfish as tuna longline bait are needed to gauge its effectiveness. Presently, the standard imported saury tuna longline bait sells for about US$2.70/kg and its availability has been a major constraint to small-scale longline fishing in the Pacific islands.

Demonstrations of development potential: In areas where flyingfish are not caught, the abundance and seasonality of the flyingfish resource need to be assessed. Following this, demonstrations of the fishery potential to local fishermen are needed. This could consist of making fishermen aware of the relatively low capital expense required to start fishing for flyingfish and the possible advantage of this fishery as a supplement to other fishing activities. The actual fishing methods also need to be demonstrated. This could be carried out through a masterfisherman extension programme. Alternatively, a video of fishing methods could be produced.

Investigations into alternative fishing methods: There are several successful flyingfish fishing methods from other areas that may be worth trying in the Pacific islands region. The practice of "chumming" flyingfish schools during their spawning season, as is done in the eastern Caribbean, may warrant investigation. This method would require less fuel than the current commercial fishing method and may be possible to carry out in conjunction with other fisheries such as tuna handlining.

In the Indian Ocean and Indonesia, the flyingfish fisheries also take advantage of flyingfish spawning aggregations. Adapting fishing methods which target spawning aggregations of flyingfish in the Pacific islands region thus appears to be an area of research that may be fruitful. It should be noted, however, that successful fishing methods for a particular species in one area may not necessarily work in another area, even for the same species. In many instances fish behaviour is specific to certain areas and environmental conditions.

With regards to fishing for flyingfish using lights at night, some innovation on different lighting systems may be useful.

V. CONCLUSIONS

There appears to be potential for the development of flyingfish fisheries in the Pacific islands. This contention is based on what is known of the biology of the fish, locations in the Pacific islands where considerable development has occurred, and comparison with other regions of the world. Development of a flyingfish fishery for small-scale fishermen seems possible because of the relatively low technology required and, in many cases, the proximity and apparent abundance of the resource. Development is presently constrained by the difficulty in properly identifying flyingfish species, the limitations of existing markets, and the lack of awareness of the flyingfish resource and fishing techniques.

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NOTES

1. SPC (1991) Report on SPC coastal fisheries programme activities in 1990/1991. Working Paper 5, 23rd Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea, 20 pages.
2. Based on FAO (1991) world landings and estimates reported in the Regional Tuna Bulletin, First Quarter, 1990. South Pacific Commission.

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