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THE EEL RESOURCES OF FIJI

John P. Beumer
Fisheries Management Branch

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PREFACE

Following a request from the Government of Fiji for expert advice on the biology of eels and their economic use, the Queensland Department of Primary Industries provided the services of Dr. John Beumer, Fisheries Biologist, Fisheries Management Branch, Queensland Department of Primary Industries who initiated a short-term study to provide advice on the commercial potential of the eel resources of Fiji. Before joining the Queensland Department of Primary Industries, Dr. Beumer was involved for eight years with research and management of the commercial eel fishery in the State of Victoria, Australia.

The Government of Fiji has recorded its appreciation for the co-operation and assistance of the Queensland State Government which made Dr Beumer's services available for the term of the study. Funding for the study came from the Small Grants Scheme of the Australian Federal Government. A fyke net and a glass-eel net were provided under the Japanese Aid Programme to Fiji.

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INTRODUCTION

The Government of Fiji, through its Fisheries Division, Ministry for Primary Industries, has received a number of requests from overseas countries, particularly those in South-east Asia for export of eels of the genus Anguilla (Family Anguillidae) The majority of these requests has been for glass-eels (juvenile unpigmented eels of 40 to 60 mm in total length) which form the basis of culture stock for intensive farming of eels. Countries, such as Japan, are unable to provide adequate supplies of glass-eels from native stocks and are prepared to pay high prices for suitable imported stocks.

Considerable interest has been expressed also within Fiji in the potential of its eel resources. At present, these resources form the basis of a small subsistence fishery with the catch consumed by local peoples. Successful smoking of eels has also been undertaken on a limited basis. Passive methods of capture include plaited traps (Hornell, 1939) and hollow bamboo poles while active methods include spearing or knifing by hand and fishing with hand-lines. Chicken gut is considered as the most successful bait.

Within the islands of Fiji, freshwater eels (Anguilla) are commonly known by the Fijian name of 'duna' Although four species of Anguilla have been reported from the islands of Fiji (Ege, 1939) only two of these species, Anguilla obscura Gunther, 1871 and Anguilla australis Richardson, 1841 have any real potential for export either as culture stock for south-east Asia or as adult specimens for processing and shipment to Europe. Both species are short-finned eels and have uniform body coloration, features shared with the two major commercial species of eel in the world, the European eel, Anguilla anguilla (Linneaus, 1758) and the Japanese eel, Anguilla japonic a Temminck and Schlegel, 1846. The other two species recorded from Fiji are Anguilla marmorata Quoy and Gaimard 1824 and Anguilla megastoma Kaup, 1856. Both species are long-finned and have a mottled or blotched body coloration. The economic potential of these eels is limited and lies in the export of live specimens, greater than 1.5 kg, to South-east Asian markets.

The study reported here was undertaken during the period 9 to 30 November 1984 to provide biological and technical advice on a number of aspects of commercial eel fishing, particularly in relation to the economic potential of eel resources of Fiji.

The specific terms of reference for the study were as follows:

(a) identify the main eel species present and their distributions in the freshwaters of Fiji and advise on their market acceptability;

(b) draw up a programme for estimating the abundance of adults and elvers in selected streams and for identifying optimal capture methods;

(c) devise appropriate development strategies for a Fijian eel fishery, in conjunction with Fisheries Division staff, should its potential be established.

It should be noted that while commercial eel fisheries based on Anguilla spp. exist in the temperate region (Australia and New Zealand) of the south-west Pacific, the only current (small) commercial eel fishery in the tropical region is based on Mitiaro Islands, Cook Group, where catches of A. obscura are taken from a large inland lake.

LIFE CYCLE OF AHGPILLIDS

Although the specific details of the life cycle for all species of Anguilla have not been fully documented, the sequence of development is essentially the same with a complex life cycle punctuated by a number of clearly defined stages.

All Anguilla species are catadromous with adults spawning at sea. Fertilised eggs develop into elongate leaf-shaped larvae known as leptocephali which are planktonic. The leptocephali are transparent and passive, being carried from the spawning grounds by ocean currents. On reaching the relatively shallower depths (for example continental shelf) of waters surrounding major land-masses and islands, the leptocephali metamorphose through a reduction in both body depth and length to the familiar eel-shape.

Now termed as glass-eels with no body pigment and the internal organs (vertebrae, heart, stomach, etc.) clearly visible, these young eels invade estuaries and brackish lower reaches of rivers and creeks. The invasion into estuaries may extend over a number of months. However, in studies of glass-eel invasions in temperate regions of the south-west Pacific, definitive peaks occur during winter to spring for two species, A. australis and A. dieffenbachii and during autumn for A. reinhardtii. This comparatively passive invasion is largely dependent on tidal movements and includes a period of physiological transition from the marine to the freshwater environment. On completion of the body pigmentation, the eels are termed brown elvers and active migration upstream into swamps, lakes and head -waters occurs.

Brown elver migrations are relatively easy to observe at natural or artificial barriers on rivers and creeks. This juvenile stage develops into the sexually immature stage termed yellow or brown feeding eels. Such eels may inhabit a particular area of river, lake or swamp for a considerable period, for example 10 years, while continuing to feed, grow and form gonads to develop into sexually mature silver eels. These eels are readily recognisable by their grey to black dorsal body and white to silver ventral body colouration. An increase in eye-size, blackening and lengthening of the pectoral fins and a more pronounced lateral line are other notable features. Body condition is also highest at this time with peak levels of fat and oil. The fat content of silver eels may be more than 50% greater than that of the yellow feeding eels.

A downstream migration to the spawning grounds follows. It is assumed adults die after spawning. The precise locality (localities) of the spawning grounds has (have) not been determined for species of Anguilla occurring in the South-west Pacific. Only 16 specimens of leptocephali have been collected in this region of the Pacific Ocean (Jespersen, 1942; Castle, 1963), the majority coming from an area to the north-west and west of the Fiji Islands. On the extremely limited distributional data available, there may be several spawning grounds but additional and extensive sampling is required before the spawning grounds may be defined.

SPECIES IDENTIFICATION

As indicated earlier, four species of Anguilla have been reported from the Fijian islands (see Ege (1939), Fowler (1959), Castle (1963), Tesch (1977) and Ryan (1980) Rapid specific identification of the anguillids has always been difficult, largely due to the lack of many external diagnostic features. A key for separating the species occurring in and around the Fijian islands is provided (Appendix i Figs. 6 and 7)

The major features presently utilised for separation of species are:

(i) body colouration;

(ii) position of the origin of the dorsal fin relative to the anus;

(iii) distribution of teeth in the upper jaw;

(iv) counts of prehaemal, caudal and total vertebrae;

(v) proportions derived from various body and head measurements.

For market purposes, features (i) and (ii) are normally and readily used for separating adult anguillids as the application of the remaining features require some form of physical control over individual specimens. While this control may be applied indirectly through refrigeration of specimens (for example placement of the catch in a cold-room for several hours) or directly with an appropriate fish anaesthetic, such handling procedures may result in a loss of market quality of the catch and unacceptable mortalities, leading to a reduced economic return.

For juvenile eels, either glass -eels or elvers, the above identification techniques are impractical, especially in terms of time and handling mortality. Separation of species may not be possible till body pigmentation is completed and a size suitable for grading, e.g. 10 centimetres or larger, is attained. However, there is a lower market demand for larger-sized juveniles than for glass-eels, resulting in reduced financial returns.

As many other species of eels (for example muraenids, congrids) have unplgmented glass-eel stages that inhabit estuarine waters, a catch of glass-eels from such waters may be contaminated' by those of the non-target species, that is non-anguillids. Separation may be possible through placing the entire catch in freshwater where, assuming a low tolerance for this environment by essentially marine species, the non-target species should have high to very high mortalities. Removal of remaining live anguillid glass-eels may then be achieved by sieving of the entire catch.

The extent of body and bead pigmentation (Appendix II, Fig. 8) on leptocephali and glass-eels has been classified into a number of stages (Gilson, 1908; Strubberg, 1913) from Stage I (fully grown leptocephalus, no pigment, marine) to Stage VA (metamorphosis complete, glass-eel with caudal pigment only, invading estuaries) to Stage VIB (head and body almost fully pigmented with pigment rows becoming indistinct, essentially freshwater).

SPECIES DISTRIBUTION

The revision of the genus Anguilla Shaw by Ege (1939) concluded that six (6) species of this genus were present in the South-west Pacific Region. Four of these are long-finned species, A. megastoma, A. marmorata. A. reinhardtii and A. dieffenbachi while the remaining two are short-finned species, A. obscura and A. australis.

Of the four species recorded from Fiji (Table 1) only one long-finned species, A. marmorata, and one short-finned species, A. obscura, are well-represented in collections. The second long-finned species, A. megastoma, is poorly represented in collections while the inclusion of Fiji as part of the distribution of the second short-finned species, A. australis. is based entirely on the published record of a single specimen (Ege, 1939)- Ege (1939) questioned the validity of an 'isolated' specimen and recognised the need for additional material before confirmation of A. australis occurring in Fiji may be made.

Apart from the research of Ege (1939) and Jespersen (1942), only Fowler (1959) provides some additional locality records for Fiji. Relatively recent publications on the distribution of the Anguilla in the South-west Pacific Region (Castle, 1963; Tesch, 1977) and in Fiji (Ryan, 1980) do not give additional locality records. Castle (1963) tentatively assigns a 24.6 mm long leptocephalus larva from east (14°37'S, 170°03'E) of Vanuatu to A. australis. However, the small size of this larva indicates that an extended larval drift is still to be undertaken. This drift would take such larvae well south of Fiji.

Table 1. Distribution records of *Anguilla* spp. from Fiji.

Species	Locality	Reference
A. megastoma	Viti Levu	Ege (1939)
	Kanathea (=Kanacea)	Fowler (1959)
A. marmorata	Suva, Fiji	Ege (1939)
	Ovalau	Ege (1939)
	Narokorokoyawa	Ege (1939)
	Kandavu (=Kadavu)	Fowler (1959)
	Nairai	Fowler (1959)
	Rewa River, Viti Levu	Jellyman (pers. comm., 1980)
A. obscura	Suva, Fiji	Ege (1939)
	Kanathea (=Kanacea)	Ege (1939)
	Off Vitu Levu (18°21'S,178°21'E)	Jespersen (1942)
	Rewa River, Viti Levu	Todd (pers. comm., 1979)
A. australis	Viti Levu	Ege (1939)
Anguilla sp.	Nadi River, Viti Levu	Anon. (1983)

* leptocephalus larva

SURVEY LOCALITIES AMD SAMPLING GEAR

Following discussions with staff of the Fisheries Division, Fiji the estuarine and lower reaches of the Rewa River delta (Fig. 1) were selected as sampling sites for both adult and juvenile eel specimens. The Rewa River is the largest of the river systems within Fiji and relatively well placed, being proximal to the capital of Suva with its available logistic support, export point and daily market. In addition a section of the upper tidal reach of the Navua River was also sampled for adult eels on one occasion in conjunction with the ika droka (jungle perch) tagging programme. Initially trial settings with each different type of net were undertaken on 14 November during daylight hours to familiarise staff with gear and setting procedures and to acquaint the author with the local intertidal habitat and extent of tidal range.

Sampling for adult eel specimens was undertaken with fyke nets. The nets were set independent of tidal cycle or lunar periodicity. Only the net set in Wainikai Creek was baited. Ika droka were used.

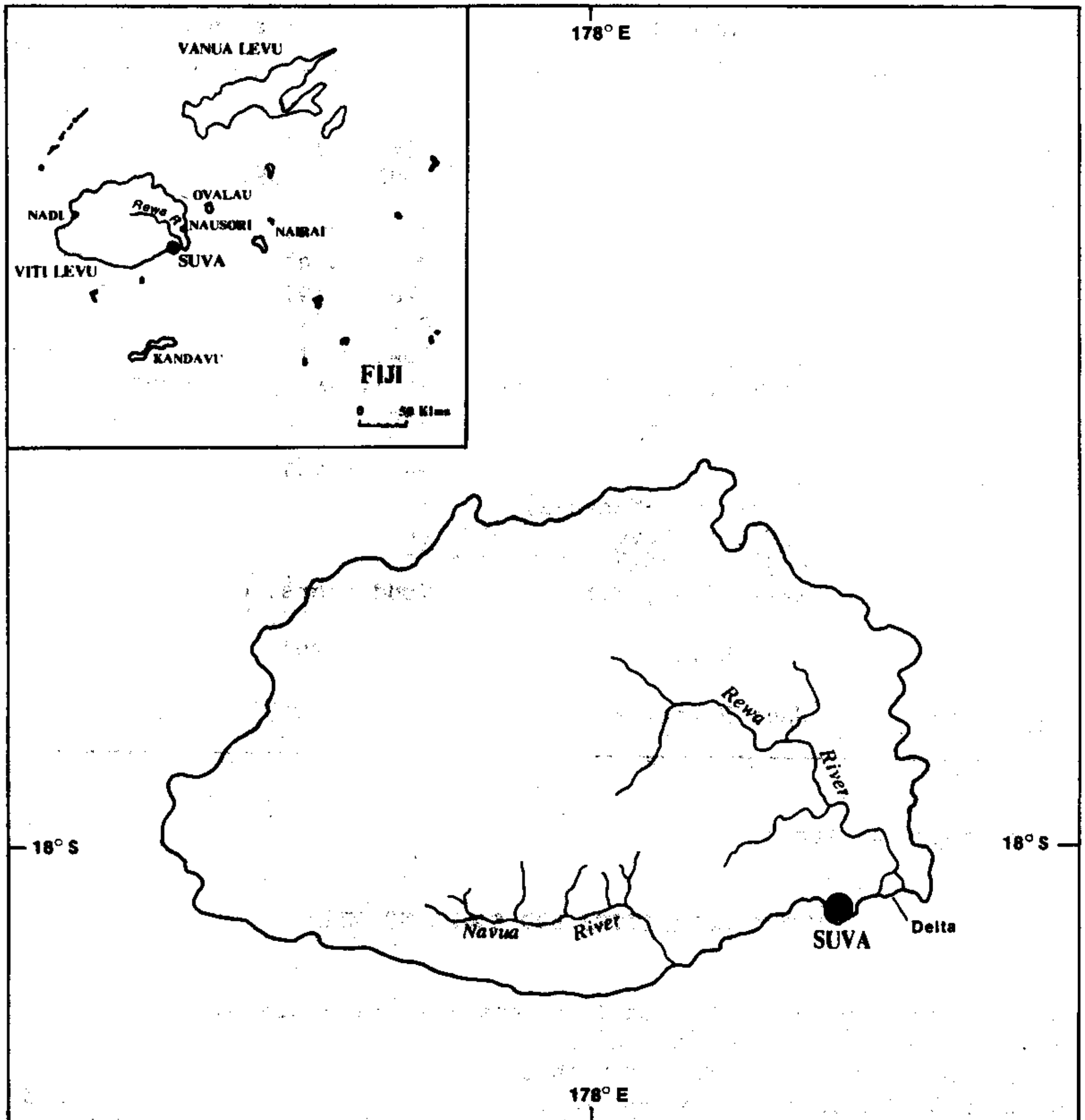

Fig. 1 Viti Levu showing Rewa River delta.

Two different types of nets were used. A small multi-hooped net with semi-circular entrance hoop (Fig. 2a), commonly employed by commercial eel fishermen in Victoria and Tasmania, was set in shallow water areas. Eels move through a series of funnels to the bag-end. This net has two outer wings and a single median wing. The versatility of this net lies in the options available for use of the wings, e.g. all three simultaneously, independently or in a number of combinations.

The second type of fyke net, a larger double-hooped net with a single funnel, from Japan, with two outer wings, was set in deeper, stronger flow situations (Fig. 2b). Both nets have the advantage that, once set, the bag-end may be checked without removing the entire net from the water. This allows clearing and cleaning of nets to be done relatively quickly and simply and little fishing time is lost. Each of the fyke nets had a skirt between the lead-lines of the outer wing and the bottom of the first hoop to prevent eels escaping under the hoop.

The glass-eel net, a large Japanese model, had two outer wings (Fig. 3) and a single funnel extending to a fine-mesh bag-end. This net was set only in the estuarine regions of the Rewa delta in the late afternoon (1600 hours onwards) on days when the second high tide occurred between 1800 and 0200 hours around the last quarter and new moon phases. The bag-end of this net is positioned upstream. The full effectiveness of the net is attained on an incoming tide when tidal flow opens both wings and the funnel to passively carry glass-eels, other fishes and debris through to the bag-end. Again the catch may be collected from the bag-end without removal of the rest of the net from the water.

In addition to the samples taken by the author, a number of specimens of eels, taken by hand-line, were purchased from local villagers. A long-line of 10 hooks was also set on one occasion in the Rewa delta. Spot-sampling with derris dust (rotenone) was also undertaken in several headwater locations of the Rewa catchment to determine possible upstream limits of distribution.

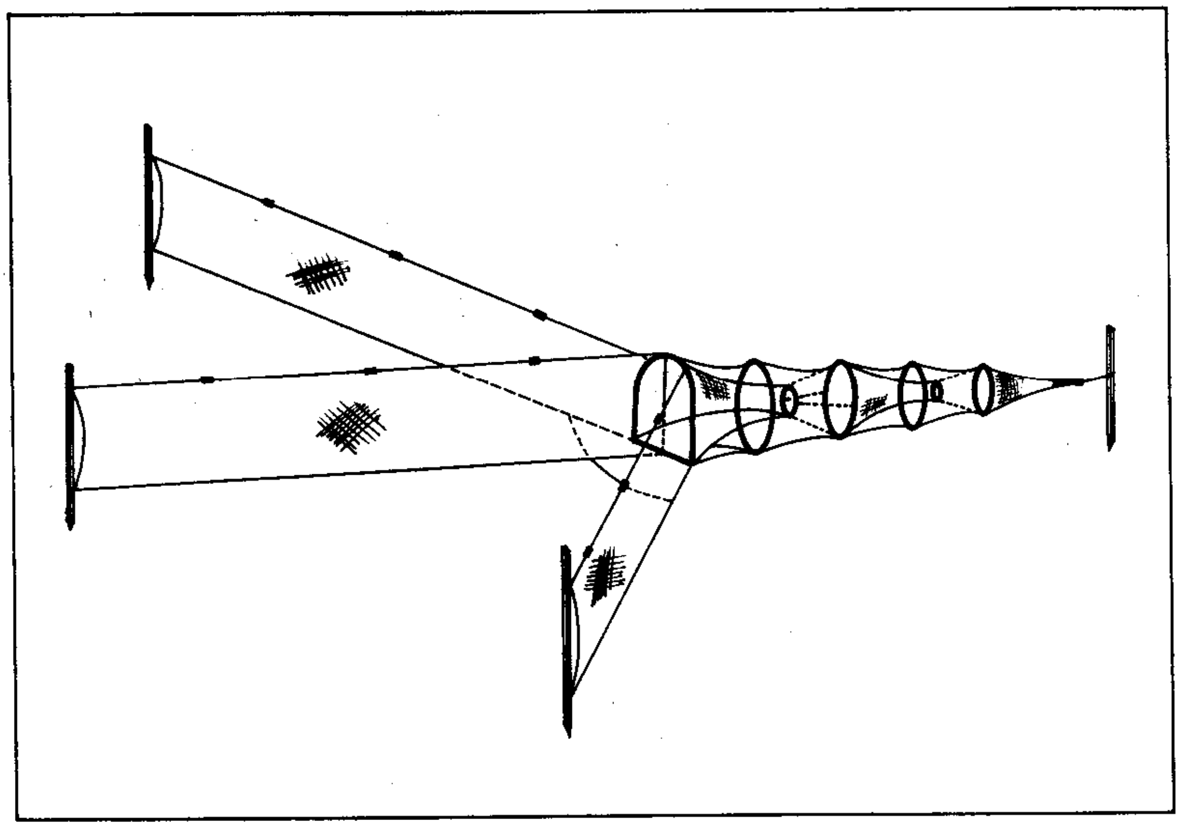

Fig. 2a   Diagram of three-wing fyke net.

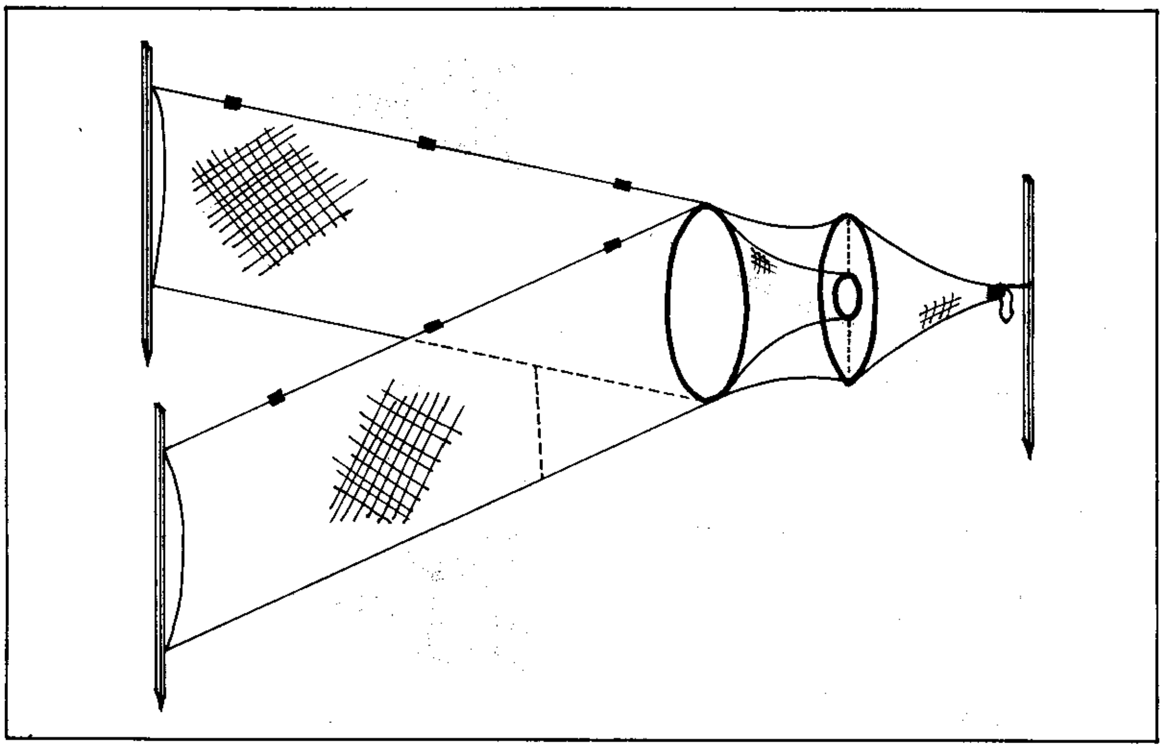

Fig. 2b Diagram of two-wing fyke net.

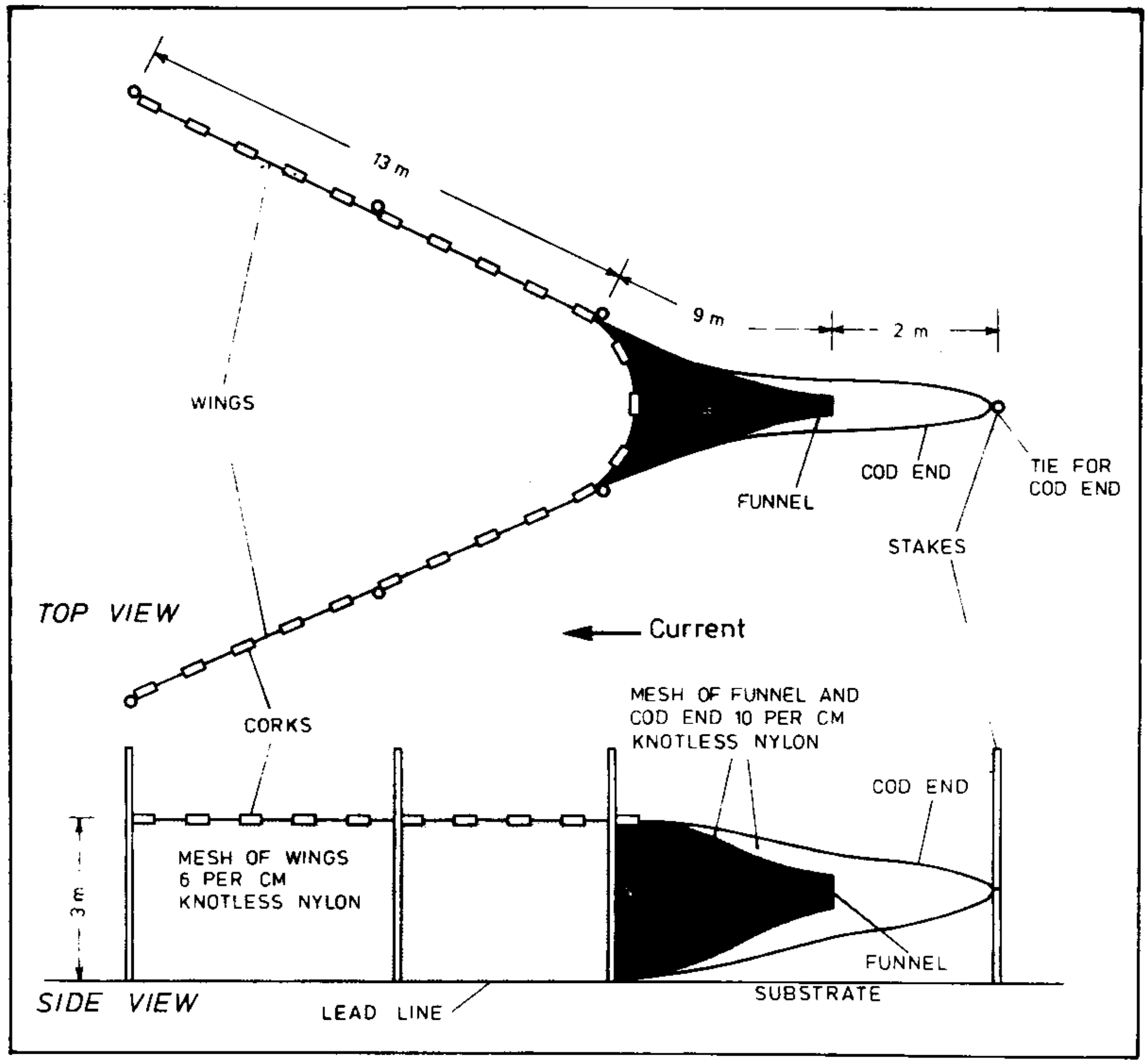

Fig. 3 Glass-eel net (Japanese), after Beumer & Harrington (1980).

SURVEY RESULTS

Fyke nets

These nets were set for a total of 316 hours, each net being set for half this time (Table 2). No eels were taken in the Navua River sampling although eels are known to be abundant in that river, particularly in small drains and marshes.

Catches of adult and larger juveniles in the Rewa delta were either small (maximum of four eels per net) or nil. In total, seven eels were taken in the three-wing multi-hooped fyke net and one eel in the two-wing double-hooped type. Only two species were collected with five specimens (total weight = 2100 g) of A. obscura and three specimens (1120 g) of A. marmorata.

Other methods for obtaining adults and larger juveniles

Twelve eels were purchased from villagers who had collected these eels with hand-line. Two of these specimens (one A. obscura (160) and one A. marmorata (35 g)) were taken from a small drain running into the Rewa River immediately downstream of the Nausori road-bridge. The remaining ten eels (all A. obscura, total weight = 2150 g) were caught in the lower Rewa delta at Noco.

Two further eels were collected during ditch maintenance work at the Fisheries Station Lami. Both were A. obscura (total weight = 50 g approximately).

No anguillid eels were taken with the long-line on 15 November in the Rewa delta or by rotenone used in three localities in the head-waters of the Rewa catchment on 28 November.

Size composition and maturity

The A. marmorata specimens varied in size (Fig. 4) from 277 to 620 mm (length) and 35 to 600 g (weight). Of the four specimens taken, there were two immature adults (277 and 306 mm long), one mature female (620 mm) and one mature male (610 mm). This species attains a weight of at least 5kg in Fiji (Lewis, pers.comm.).

The male A. marmorata specimen, from Nukunikula Creek, had a number of features characteristic of migratory or silver eels:-

(a) enlarged eyes with an average area of 81.4 mm^2 (horizontal x vertical diameter of eye, after Boetius & Boetius, 1967) and with a coppery sheen. (It should be noted that the average eye area of the female A. marmorata specimen, although slightly longer in total length (620 mm), was only 51.4 mm^2).

(b) numerous fat bodies throughout the alimentary mesentery, and

(c) prominent testes with the lobules clearly visible to the naked eye (Stage 3 of 7 Stages, after Boetius & Boetius, 1967).

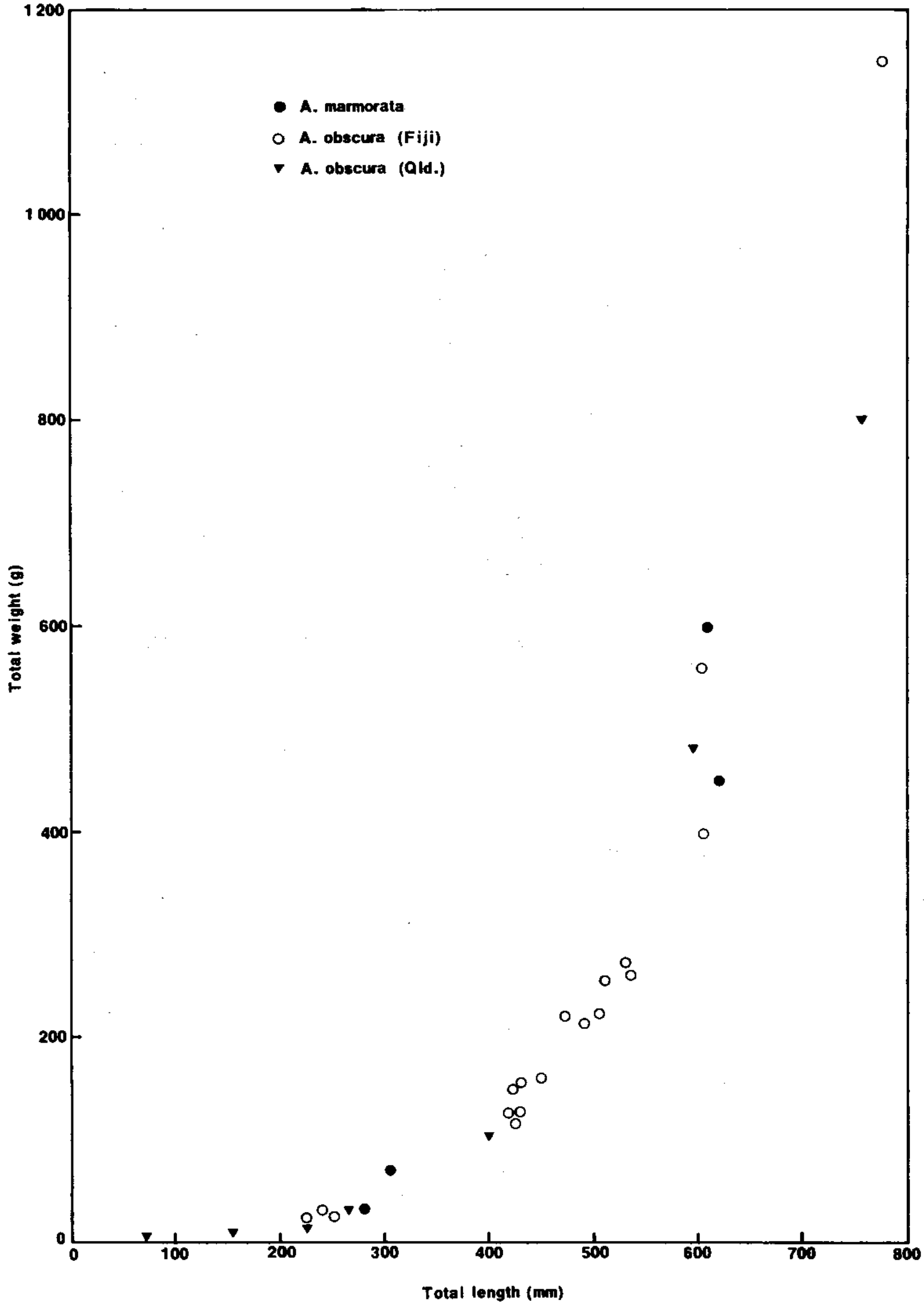

Fig. 4 Length - weight graph of A. obscura specimens from North Queensland and Fiji and of A. marmorata specimens.

Specimens of A. obscura varied in size (Fig. 4) from 225 to 775 mm (length) and 20 to 1150 g (weight) and were either immature adults or mature females with 14 (78%) of the specimens measuring 400 to 700 mm (the preferred length range for export) and eight (44%) weighing between 200 and 800 g (the preferred weight for export).

The length-weight distribution of the A. obscura specimens from the Rewa River delta, Fiji followed a similar pattern to that of A. obscura specimens (Fig. 4) recorded from various drainages in North Queensland, Australia (Beumer et al, 1981) which lie at about the same latitude as Fiji.

Other Aspects

All 18 specimens of A. obscura examined had distinctive yellow nostrils. This feature has not been previously described for any of the Anguilla species. However, recent examination of preserved anguillid specimens from Papua New Guinea also revealed pale nostrils (possibly yellow in live material) for specimens assigned to A. bicolor McClelland, 1844). Further examination of live material may indicate whether this feature occurs in both species or whether these species should be considered as a single taxonomic entity. A. bicolor has not been recorded from east or south of Papua New Guinea.

Of the 22 anguillid specimens examined, three had copepod parasites located on the mid-region of the tongue. These specimens were a single A. obscura (447 mm) and an A. marmorata (277 mm), both from the Rewa River (Nausori road-bridge) on 15 November, and one A. marmorata (610 mm) taken in Nukunikula Creek on 23 November.

Glass-eel net

This net was set for a period of 25 hours over six nights (Table 2) in the Vunindawa River around the last quarter (15 and 16 November) and the new moon (22 to 24 and 26 November) phases of the lunar cycle. Salinities were relatively brackish (surface 7.8 ppt, bottom 15.8 ppt) with temperatures high (27.5°C and 27.8°C respectively) on 15 November. Catches of leptocephali and/or glass-eels were taken on four nights only with anguillid glass-eels being collected on two nights (24 and 26 November).

The glass-eel sample of 24 November yielded a single muraenid (17%) and five long-finned specimens (83%) tentatively assigned to A. marmorata. These ranged in total length from 49.2 to 51.1 mm (mean = 49.9 + 0.73). All were at Stage VA (Appendix II) with caudal pigment only.

Seven anguillid glass-eels were taken on 26 November with three short-finned specimens tentatively assigned to A. obscura (range 46.0 to 46.9 mm, mean = 46.3 + 0.52) and four long-finned specimens assigned to A. marmorata (range 45.0 to 50.8 mm, mean = 47.2 + 2.71). Again all seven were at Stage VA with caudal pigment only.

Of the sample (26 November) when anguillids (two species) and non-anguillids (=? muraenids) were collected, the anguillid component

(7 specimens) accounted for only 14% of the total glass-eel catch (n = 50).

The leptocephali (single specimens taken on 22 and 26 November) and the remaining (non-anguillid) glass-eels (16 and 26 November) were identified as belonging to the muraenid group of eels. These leptocephali and glass-eels were forwarded to Dr Peter Castle, Victoria University of Wellington, New Zealand for further identification. A summary of Dr Castle's finding forms Appendix III.

Table 2. Relative catches of fyke nets and glass-eel net at various localities, Viti Levu, Fiji. Lokia Creek, Vunindawa River, Nukunikula Creek and Wainikai Creek lie within Rewa Delta.

			Catch		
Date	Locality	Hours fished	3w Fyke	2w Fyke	Glass-eel
15.11.84	Lokia Ck	6	nil	nil	-
	Vunindawa R	6	-	-	nil
16.11.84[a]	Lokia Ck	10	1/-	nil	-
	Vunindawa R	10	-	-	*
19.11.84	Navua R	9	nil	nil	-
21.11.84	Nukunikula Ck	13	-	nil	-
	Wainikai Ck	13	nil	-	-
22.11.84	Nukunikula Ck	24	-	nil	-
	Wainikai Ck	24	3/1	-	-
	Vunindawa R	2	-	-	*
23.11.84[b]	Nukunikula Ck	24	-	-/1	-
	Wainikai Ck	24	nil	-	-
	Vunindawa R[c]	1	-	-	nil
24.11.84	Nukunikula Ck	24	-	nil	-
	Wainikai Ck	24	nil	-	-
	Vunindawa R	3	-	-	*
25.11.84	Nukunikula Ck	24	nil	-	-
	Wainikai Ck	24	nil	-	-
26.11.84	Nukunikula Ck	24	-	nil	-
	Wainikai Ck	24	1/1	-	-
	Vunindawa R	3	-	-	*

a = last quarter
b = new moon
c = sampling aborted because of flood
* = leptocephalus and/or glass-eels taken
n/n = number of <u>A. obscura</u>/number of <u>A. marmorata</u>

SUMMARY

Catches of adult and larger juvenile eels were relatively low. with more eels being taken in the three-wing fyke net than in the two-wing net.

A. marmorata accounted for 18 $ (4) of all eels examined with A. obscura forming the remainder (82%) (18).

Of all adult and larger juvenile specimens examined. 73% (16) by length and 45% (10) by weight were of a marketable size.

The single male A. marmorata specimen with migratory features taken in November suggests a seaward migration of silver eels in summer.

Catches of anguillid glass-eels were also relatively low but encouraging.

All anguillid glass-eels were of Stage VA suggesting a recent invasion (September to October) from the sea into the Vunindawa estuary.

Anguillid glass-eels accounted for 21$ (12) of all glass-eel specimens (56) taken.

Three (25%) of the anguillid glass-eels were A. obscura, the remainder (9) were A. marmorata.

RECOMMENDATIONS

The recommendations are considered in terms of gear, sampling programme and fishery development (Fig. 5). It is emphasised that these recommendations are based on the findings of the two and a half week study undertaken during November. Additional surveys at other times may have lead to further recommendations or amendments to those made below.

1. Gear

The suitability of each particular item of equipment should be considered in terms of its use for either research work) (e.g. distribution patterns; quick surveys) or commercial purposes (e.g. most effective method for catching large numbers of marketable eels, i.e. a high catch per unit effort).

(i) Adults

Fishing effort for adult eels should be concentrated in shallower, marshy lowland areas. These areas tend to support larger populations of eels. However other types of habitat should not be discounted as particular species may have distinct preferences for alternate habitat.

(a) Fyke nets

These nets are considered to be the most efficient when large numbers of eels are present. Experience during this study and from previous use of fyke nets suggests that multi-hooped nets with a series of funnels are more efficient than bi-hooped single-funnel nets. Eels are extremely successful at escaping from nets, particularly from single-funnel nets. In addition, a semi-circular first hoop is preferred for fyke nets as this primary hoop sits more firmly onto or into a substrate on its flat surface than a round hoop which may cause the net to roll during tidal flows or periods of strong current flow in freshwaters.

The use of baits was not investigated to any extent during this study. Use of traditional hand-line baits, such as chicken gut, may increase net catches markedly. Eels also tend to congregate near outfalls of abattoirs and the like. Bait such as offal from these facilities may also prove suitable. However, eels taken from such outfalls may not be suitable for local or export markets.

The costs of fyke nets (approximately $A100 per net) may prevent large scale use of such nets. Use of the existing fyke nets as templates for local net-makers may overcome this cost factor.

(b) Traps

The use of locally made wooden-slat traps may be a cheaper way of collecting eels. The effectiveness of these traps as opposed

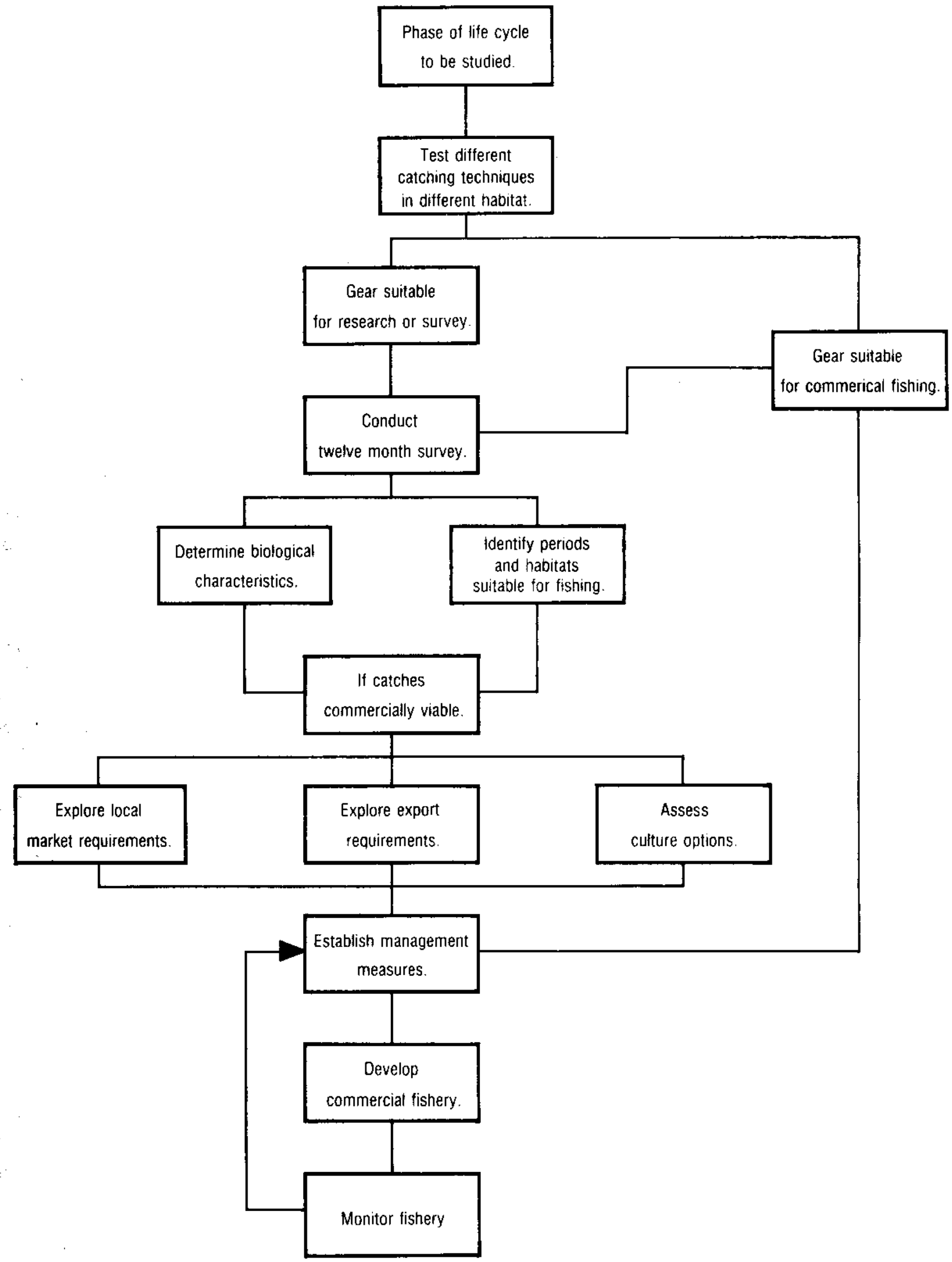

Fig. 5 Fishery development process for *Anguilla* species.

to fyke nets should be considered and, where possible, tested. The escape of eels from traps should also be considered.

(c) Rotenone

This method can be extremely effective under suitable conditions. However, loss of non-target species of fish as well as aquatic invertebrates may preclude the use of rotenone in some areas. The relatively high tolerance of eels to rotenone necessitates the use of higher concentrations of this chemical, the side-effects of which may be unwarranted.

(d) Electrofishing

This form of sampling equipment is ideal for all types of sampling, commercial or research (Beumer et al, 1984). The range of electrofishing equipment available at present allows for back-pack, bank-mounted or boat-mounted models which provide a rapid assessment of the distribution and abundance of eels (and other fish species) in any one area. Given that the entire catch, eels and non-target species of fish, is taken live, samples may be sorted in a manner which allows return of non-target species and unmarketable eels.

However, because this method operates essentially on a flow of electricity (from a power-source such as batteries or small generator) from one electrode through water to another electrode, the equipment should only be used by trained personnel. It is recommended that a biologist with experience in electrofishing should conduct a short-term training and familiarisation course with electrofishing equipment for Fisheries staff. Dr Peter Jackson, Arthur Rylah Institute for Environmental Research, P.O. Box 137, Heidelberg, Victoria, 3084, Australia, is qualified and may be willing to undertake to conduct such a course in Fiji.

Glass-eels/Brown elvers

The large Japanese glass-eel net employed during this study proved effective. However, there are a number of factors which suggest alternative methods may be more suitable:

(a) Setting of such nets requires at least two persons when conditions are good to average. Under difficult conditions, for example, during or immediately after flooding, a third person may also be required to assist in setting, cleaning or removing the net.

(b) Due to the large catching area of these nets and the small mesh-size (10 meshes to the centimetre) used, there is a tremendous amount of water pressure on the net, particularly on an incoming tide or during floods.

    In addition to the pressure problem, the small mesh-size traps a variety of debris, particularly colloidal clays which reduce the effective mesh-size and cause an increase in the overall pressure on the net. Daily cleaning of the net by shaking and washing and by stiff brushes is recommended when nets are to be used longer than 6 hours in any one location. Regular cleaning also ensures that dead fishes are removed from the net. Failure to do so often leads to numerous holes from crabs which have broken through the mesh to feed on the dead fish.

(c) Stakes or poles for such glass-eel/brown elver nets need to be relatively long, e.g. 4 to 5 metres, to allow for tidal amplitude, but at the same time also need to be manageable and strong. The use of established sampling sites with permanent stakes or poles may overcome these difficulties.

(d) The number of floats on the head-rope of the net used in this study proved ineffective. Additional floats were added but supplementary floats will still be required to ensure that the upper portion of the water column is sampled.

(e) A smaller version of the glass-eel net, the Elton net, as described by Beumer & Harrington (1930), may prove more suitable. This net is particularly effective in relatively shallow waters. As this net may be set by a single operator, man-power requirements are reduced. The detachable bag-end of the Elton net doubles as a holding bag and its rapid replacement ensures that little fishing time is lost. Such nets cost $A250 to $A300 each.

(f) The use of miners lights, mounted on helmets and powered by portable rechargeable batteries, make setting and cleaning of the net and sorting of the catch during the night a relatively simple operation. To some degree, the use of such lights reduces the manpower requirements as none of the existing field staff are required to operate hand-held torches. Miner's lights operate a dual-bulb system for close-up work such as on-board sorting of the catch or for long-distance lighting. These lights are particularly useful when operating at night in areas with which the field staff are not familiar or during periods of inclement weather.

2. Sampling programme

This programme should be considered in two separate sections; essential sampling and developmental sampling.

(i) Adults

The major essential aspect to be determined is a better understanding of the specific distribution and abundance of the anguillids within Fiji. This will require additional surveys, with appropriate gear, of fresh and estuarine waters on Viti Levu, Vanua Levu and some of the other larger islands. Such sampling will allow better definition of existing species, their distribution and abundance. Attention should be paid to the maturity stages of all eels to determine the occurrence, if any, of silver, migratory eels.

A twelve month sampling programme to determine seasonal changes, if any, of body condition should also be undertaken. This programme would include estuarine and freshwater sites and should provide data on migration eriodicities of silver eels. These periodicities occur in temperate South-west Pacific in summer to autumn but in the tropics such a set period may not occur. Migration studies are best undertaken in small manageable rivers where the mouth may be blocked by a series of fyke nets to catch silver eels moving dowstream. The rivers between Sigatoka and Korolevu appear ideal for migration studies. Samples from the above two studies should provide the basis of some fisheries developmental work as detailed below.

(ii) Glass-eels/Brown Elvers

A twelve month survey of estuarine (tidal) areas should be undertaken to determine the occurrence and abundance of anguillid glass-eels. This survey should provide data on seasonality of upstream migrations, the relative pigmentation stages of anguillid glass-eels, the catch composition of estuarine non-target eels compared to anguillids and any distribution (occurrence, abundance) patterns that specific anguillids may have.

Sampling at a single site would provide base-line data for a particular estuary. These data may then be used to predict migrations in other estuaries where trials could test the accuracy of the predictions.

Sampling for brown elvers is not considered to be an essential or primary activity. This would occur in freshwaters. Such sampling is dependent largely on the demand for this stage within Fiji rather than overseas as export of brown elvers is not economically viable.

3. Fisheries Development

Commercial fisheries are playing a key role in the economy of Fiji (Kwong, 1984) and proper development of an eel fishery may strengthen the basis of this primary industry.

(1) Export

If sufficient stocks of anguillids, particularly of A. obscura. are identified, an inland eel fishery should be established subject to acceptance at village level of the nature of the fishery and specific requirements. Initially the fishery should have a limited number of fishermen who would operate under specific conditions. These conditions could include areas open to fishing, restrictions on numbers of nets and mesh-size, a legal minimum size, and a requirement to furnish some form of catch or production return. Monitoring of market sales may also provide data for fishery assessment. Zonation with the fishery may also be appropriate in the light of existing land-ownership patterns. A particular zone would have a specific number of eel fishermen who would act as on-site "managers" of the eel stocks.

Concurrent with the sampling programme described above in 2(i), trials should be undertaken on the specific processing requirements necessary before eels may be exported. Such trials will involve an assessment of handling techniques, purging of eels, separation of species, desliming and packaging methods. Health and other import requirements from countries where the eels are to be sent are also to be assessed. The establishment of one or more processing facilities may be dependent on approval of standards by importing countries.

Export of glass-eels should only occur if there are no local (culture) requirements for these. Again an assessment of handling procedures, particularly packaging and transport methods, and the requirements of importing countries should be determined.

At a later stage, intensive culture of glass-eels within Fiji may be warranted. Such an operation should aim to provide eels for export markets and supplement eels taken from the "wild" eel fishery.

The ultimate success of intensive eel-farming will depend on the regular (annual) availability of glass-eels. Where possible only local stocks of glass-eels should be used. However, importation of culture stock may be an economic and biological alternative if introduction of exotic diseases/parasites can be prevented, e.g. by prophylactic treatments of imported stock. The labour-intensive nature of this operation ensures employment but such benefits will not be maintained in the long-term if adequate culture stock is not available. Training of local staff and the establishment of a local fish-meal plant to supply specific feed for eel culture are two factors which would stabilise the infra-structure of an eel culture fishery.

Stocking of reservoirs, e.g. Vaturu on the Nadi River or Monasavu on the Rewa River, and farm-dams with glass-eels and/or brown elvers warrants consideration as a form of extensive culture. Stocking of reservoirs should occur only if existing fisheries (e.g. sports fisheries) are not effected.

(ii) Within Fiji

The development of an eel fishery within Fiji may be considered in terms of local (indigenous) requirements and those of tourists.

Locally, there appears to be no preference for the use and consumption of eels over other fishes, marine or freshwater, on a regular basis. Catches of eels from fyke nets or traps should be available in a live and good condition for low cost sales at local markets.

The potential of eels as a delicacy product for visiting tourists also warrants assessment. This assessment would include preparation and processing of eels in a variety of ways, e.g. pate, smoked eel. Tourist resorts should be approached to conduct trials with various eel products to determine whether particular groups of tourists have specific requirements.

There should thus be a programme to implement the recommendations outlined above as soon as resources and funding permit. Such a programme would extend over 12 months, where possible; to be followed by a review leading to a final assessment of the potential of the eel fishery.

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APPENDIX 1

Key to the species of Anguilla from Fiji

A number of body, head and dentition measurements (Figs. 6 and 7) may be made to facilitate use of the this key. The definitions of these measurements are given below.

1.a. Skin uniform in colouration; dorsal fin originating only slightly in front, in line with, or slightly behind vertical through the anus 2

b. Skin mottled or blotched; dorsal fin originating well in advance of vertical through the anus 3

2.a. Intermaxillary-vomerine band (v) of teeth on upper jaw narrows markedly at middle of band or slightly before it; total vertebrae 102-108 of which 40-43 prehaemal; distance from perpendicular through eye-centre on margin of upper jaw to angle of gape (e/gx100) more than 22% length of gape . . . A. obscura

b. Intermaxillary-vomerine band of teeth on upper jaw narrows markedly between middle and end of band; total vertebrae 109-116 of which 45-48 prehaemal; distance from perpendicular through eye-centre on margin of uppper jaw to angle of gape less than *22%* length of gape . . . . A. australis

3.a. Maxillary bands (mx) of teeth in both upper and lower jaws broad and continuous; total vertebrae 108-116 of which 40-44 prehaemal; distance from perpendicular through eye-centre on margin of upper jaw to angle of gape more than *25%* length of gape . . . . A. megastoma

b. Maxillary bands (mx) of teeth in both upper and lower jaws relatively narrow with a longitudinal groove free of teeth extending to posterior of bands; total vertebrae 100-110 of which 39-43 prehaemal; distance from perpendicular through eye-centre on margin of upper jaw to angle of gape less than *25%* length of gape . . . . A. marmorata

Measurements:

(i) total length (t) - distance from the tip of the lower jaw, mouth closed, to the end of the caudal fin.

(ii) predorsal length (d) - distance from the tip of the lower jaw to the vertical through the origin of the dorsal fin.

(iii) pre-anal length (a) - distance from the tip of the lower jaw to the vertical through the anus.

(iv) head length (h) - distance from the tip of the lower jaw to lowest point of the gill-slit.

(v) gape length (g) - distance from the tip of the lower jaw to the corner of the mouth itself.

(vi) eye-jaw perpendicular length (e) - distance from the perpendicular through the eye-centre on the margin of the upper jaw to the angle (or corner) of the gape.

(vii) intermaxillary-vomerine band length (v) - distance from the anterior point to the posterior tip of this band of teeth in the upper jaw.

(viii) maxillary band length (mx) - distance from the anterior point of the intermaxillary-vomerine band to the posterior tip of the right maxillary band.

Proportions:

The following proportions (x100) may be determined from the measurements taken:

a/t, a-h/t, a-d/t, h/t, g/h, e/g, and v/mx

A summary of the average (1) and range (2) of values for (Ege, 1939) for these proportions is given below for each species:

Proportion		*A. obscura*	*A. australis*	*A. megastoma*	*A. marmorata*
a/t	(1)	41.9	42.7	38.5	41.5
	(2)	(38-47)	(37-47)	(34-42)	(38-47)
a-h/t	(1)	28.3	30.3	25.9	28.2
	(2)	(24-31)	(25-33)	(23-28)	(24-30)
a-d/t	(1)	3.6	1.9	11.1	16.3
	(2)	(-2-7)	(-2-6)	(7-14)	(12-19)
d-h/t	(1)	24.6	28.4	14.8	11.9
	(2)	(20-30)	(22-34)	(12-19)	(8-15)
h/t	(1)	15.0	13.0	13.5	15.5
	(2)	(12-18)	(10-16)	(10-16)	(12-18)
g/h	(1)	31.5	26.0	40.5	32.5
	(2)	(21-38)	(20-31)	(26-45)	(25-38)
e/g	(1)	30.5	19.0	40.0	26.0
	(2)	(0-40)	(2-28)	(8-48)	(0-34)
v/mx	(1)	71.0	70.0	80.5	70.0
	(2)	(55-90)	(60-100)	(65-95)	(55-90)

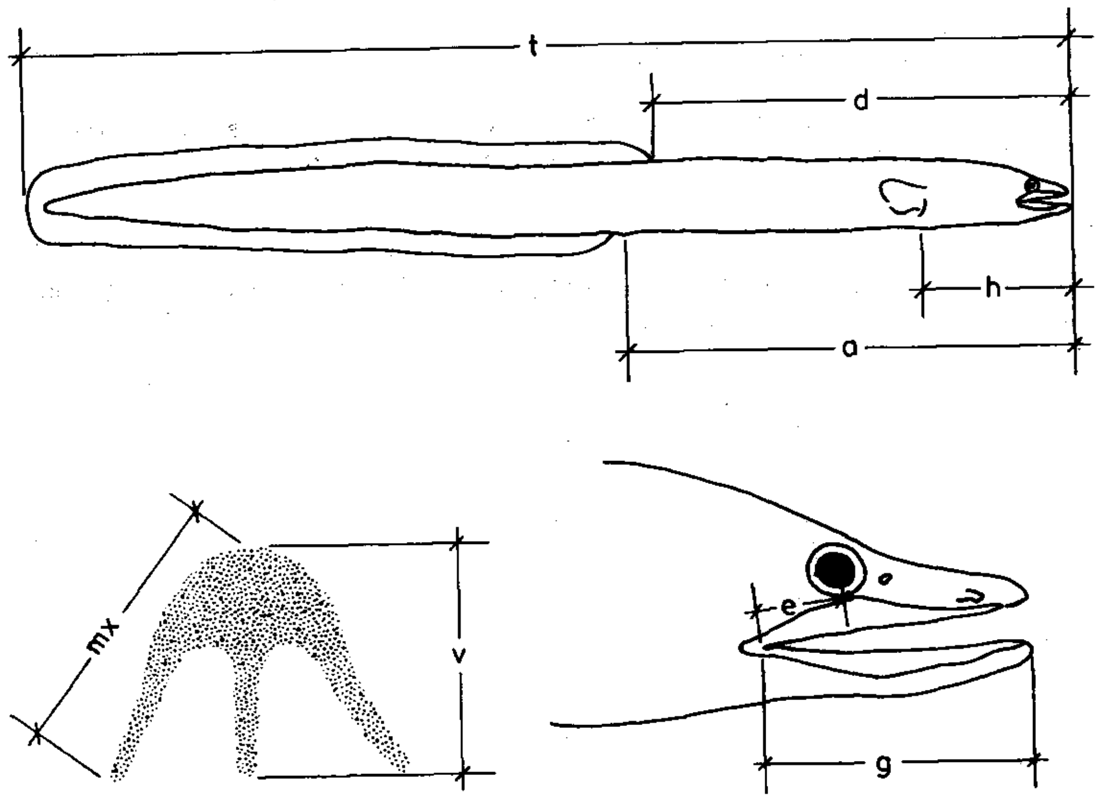

Fig. 6 Representation of head, body and dentition measurements.

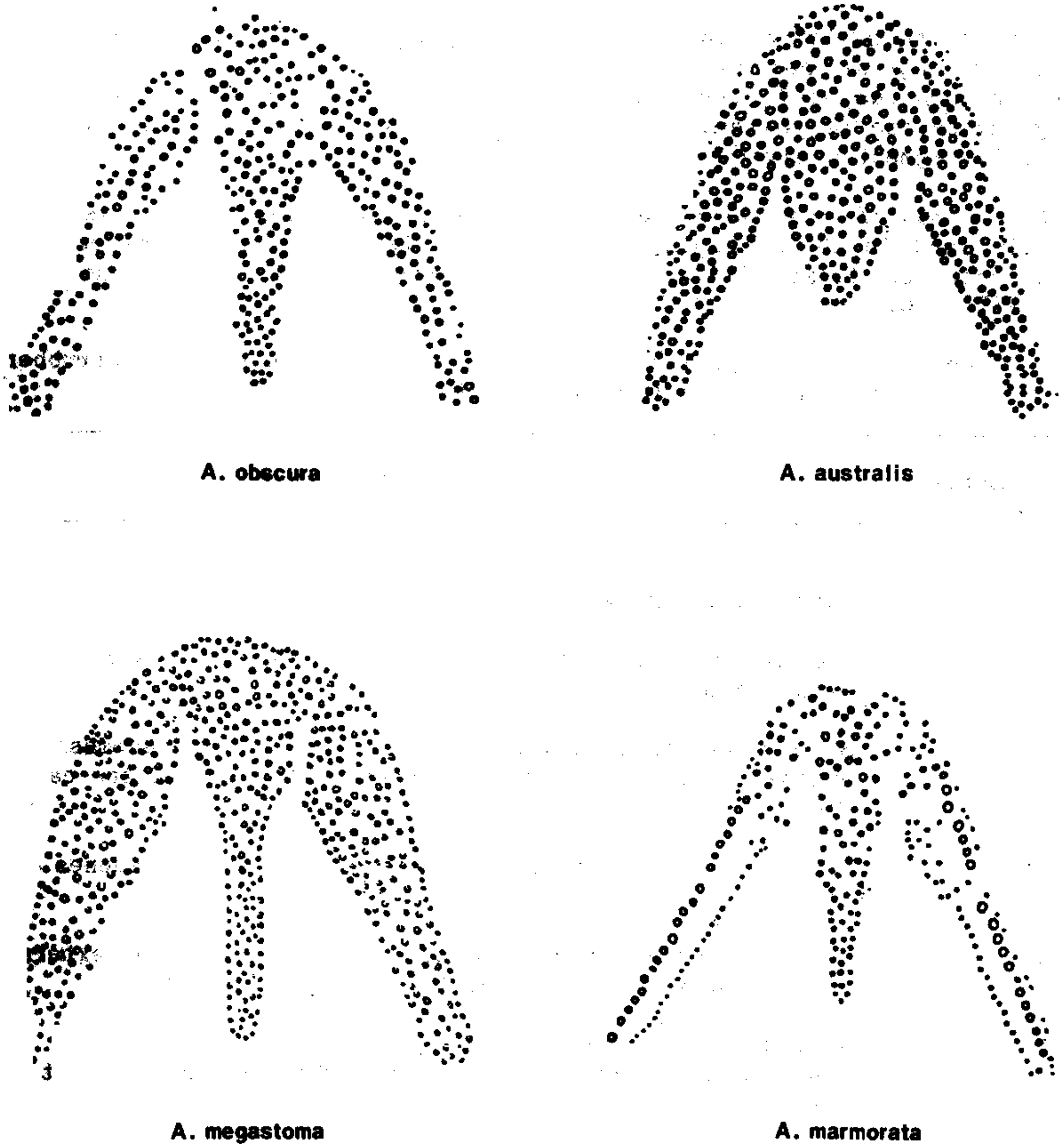

Fig. 7 Dentition patterns of 4 Anguilla species reported from Fiji.

APPENDIX II

Body and head pigmentation classification of glass-eels

Within the early development of eels (Anguilla spp.) there are six (6) which may be recognised. The first four (I-IV) relate to the leptocephalus while the remaining two (V and VI) refer to the gradual pigmentation of the newly-metamorphosed glass-eel to that of the brown fully-pigmented elver.

A listing of the stages with descriptions of pigmentation is given below and in the accompanying diagrams (Fig. 8). For a more complete description Gilson (1908), Strubberg (1913), Bertin (1956) and Tesch (1977) should be consulted.

Development of pigmentation in Anguilla (abridged from Strubberg 1913, and adapted from Berlin, 1956).

Stage	Characteristics
I	Larva, fully grown leptocephalus
II	Semilarva, pigmentation on the posterior end of the spinal chord
III	Semilarva,pigmentation on the nerve chord becomes more extensive, skin pigment also seen on the tip of the caudal fin
IV	Semilarva, pigmentation on the nerve chord reaches the head
V A	Metamorphosis complete, eel-like in form, no external pigment (glass eel) except the caudal spot
V B	No pigment on the back, body or tail region, except for the skull, caudal spots and some rostral pigment (2 phases)
VI A_I	Development of pigmentation along the whole dorsum, postanal dorsolateral pigment develops, no clear mediolateral pigment
VI A_{II}	No preanal ventrolateral pigment. Postanal development of mediolateral pigment (4 phases)
VI A_{III}	No preanal ventrolateral pigment. Clear preanal development of mediolateral pigment, postanally over almost entire dorsum, pigment rows along the myosepta and, in places, doubling of the mediolateral melanophores (3 phases)

Clear development of preanal ventrolateral pigmentation. initially, in places, a doubling of the mediolateral meiaaophopes in the preanal region, postanal pigment between the myosepta in the ventral region, and finally, similar changes in the preanal region (4 phases).

Pigment rows along the myosepta becoming indistinct. Lateral line still recognisable, as are the individual melanophores on the head, behind and below the eyes, and on the lower jaw.

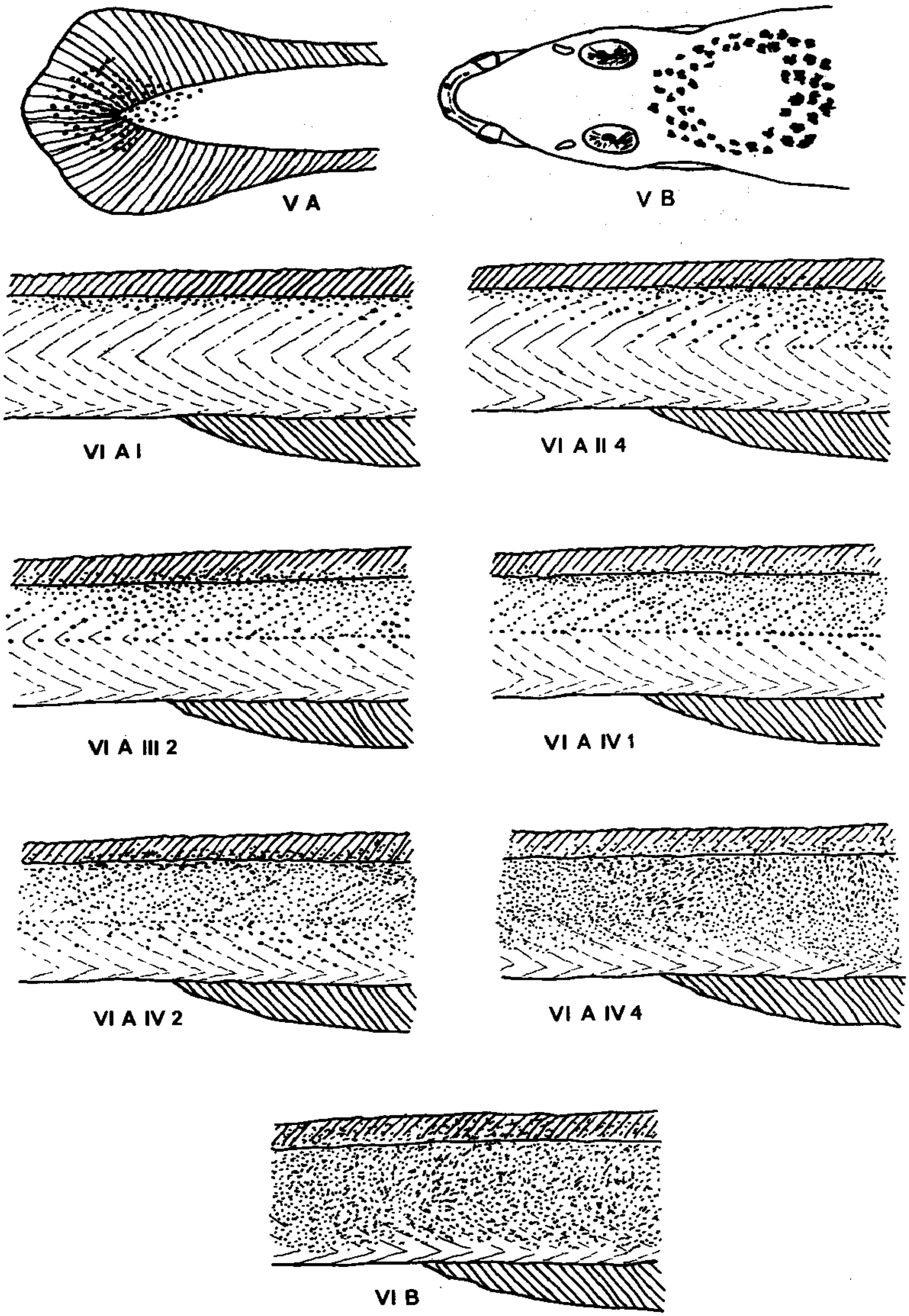

Fig. 8 Development sequence of head and body pigmentation of anguillid glass-eels.

APPENDIX III

Summary of identifications made by Dr Peter Castle of non-anguillid eels taken during survey.

Date		Species	Capture Method
(a) Vunindawa River			
16 November	(i)	Moringua sp. (Fam. Moringuidae) - as glass-eels	Glass-eel net
22 November	(i)	Moringua sp. - as metamorphosing larvae	Glass-eel net
	(ii)	Gymnothorax sp. - as glass-eel	
24 November	(i)	Moringua sp. - as metamorphosing glass-eel	Glass-eel net
	(ii)	Bascanichthys cf. B. filaria (Fam. Ophichthidae) - as juveniles	Scooped at night
	(iii)	Moraenichthys cf. M. gymnoptenus (Fam. Ophichthidae) - as juvenile	Scooped at night
26 November	(i)	Moringua sp. - as glass-eels	Glass-eel net
	(ii)	Muraenid glass-eel	
	(iii)	Heterocongrid leptocephalus	
(b) Lokia River			
16 November	(i)	? Archirophichthys sp. (Fam. Ophichthidae)	Fyke net