THE DISTRIBUTION AND PRODUCTION OF ANCHOVIES IN PAPUA NEW GUINEA WATERS

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ABSTRACT

There are 20 members of the family Engraulidae in Papua New Guinea waters. The distribution of these species is determined by environmental aspects of the various coastal habitats, with the greatest number of species found in the Gulf of Papua. The annual catch of anchovies in the Gulf of Papua is estimated to be between 60–1300 tonnes. A predictive model for catches of S. heterolobus *and* S. devisi *in the inshore coralline waters was constructed where:* $C/f.km^2 = 0.394 - 0.64 \times 10^{-4}.f$. *The maximum annual sustainable yield of* S. heterolobus *and* S. devisi *is 0.61 t/km²*. *Expansion of anchovy fishing is unlikely in the Gulf of Papua but there may be potential for sun dried stolephorid anchovies from the inshore coralline areas as an export product.*

INTRODUCTION

Papua New Guinea (PNG) has, in common with its neighbours in the Indo-Pacific region, a diverse anchovy fauna. In Malaysia, Indonesia and the Philippines the abundance of some anchovy species is such that they support substantial industrial and artisanal fisheries (Tiews *et al.* 1970; Tham 1972). In PNG there has been relatively little exploitation of this resource until recently. Large catches of anchovies in Papua New Guinea are not used for food but constitute part of the discarded by-catch of the Gulf of Papua prawn fishery (Kailola and Wilson 1978) and are used as live bait in the domestic pole-and-line skipjack tuna fishery (Dalzell 1980).

As with many of PNG's marine fish stocks there is potential for expansion of the anchovy fisheries by artisanal fishermen (Anon 1979a). The catching and processing of anchovies requires low levels of technical expertise which are readily applicable to an artisanal fishery.

The objectives of this paper are to summarise the data on the distribution, abundance and yields of PNG's anchovies. If there is interest in expanding this fishery in the future then this paper may provide a basis for development and management strategies.

ANCHOVY FAUNA

The family Engraulidae is represented in PNG waters by 20 species (*Table 1*), 16 of which are contained within two genera, *Stolephorus* and *Thryssa* (Munro 1967; Kailola and Wilson 1978; Wongratana 1983). The stolephorid anchovies are the smallest of the Engraulidae found in PNG waters and the largest species in this genus is *Stolephorus indicus* (van Hasselt) which reaches a maximum size of 14 cm. The genus *Stolephorus* is characterised by highly deciduous scales and translucent bodies with gold and silver lateral bands. (Munro 1967). The other anchovy genera are larger in both length and body depth and have non-deciduous scales; they have a dark

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dorsal surface and have a silver ventral surface.

DISTRIBUTION

Anchovies are found around the entire coast-line of PNG but the environmental features of the coast determine the distribution of individual species. The PNG coastline can be divided into three broad geographic types.

TYPE 1: 'Oceanic'. Open ocean water with isolated coral reefs, coral atolls and islands of which the Hermit, Ninigo and Nukumanu islands are typical. Salinity varies over a narrow range of 34.5 to 36.5 ppt. (parts per thousand) (Donguy and Henin 1978). The low influx of nutrients of terrestrial origin means that the water remains generally clear.

TYPE 2: 'Inshore coralline'. The coralline coastal waters of the mainland and larger islands such as New Ireland and New Britain. Salinity in these areas is linked with gross environmental changes. Mean rainfall and salinity data collected at Kavieng between 1981–1983 indicate that high rainfall in these areas depresses salinity (*Figure 1*). Water clarity is generally high although it is reduced during periods of strong winds and heavy rainfall. Coral reefs consisting of either barrier, fringing or patch formations are numerous, except in immediate proximity to river mouths.

TYPE 3: 'Estuarine'. Areas of particularly heavy freshwater discharge, especially the Gulf of Papua and the estuaries of the Sepik and Markham rivers. Salinities in the Gulf of Papua are depressed for a considerable distance from the shore (Rapson 1955; Scully-Power 1973). Salinity of inshore waters in the Purari may range from 5–27 ppt. The heavy freshwater inflow results in very high turbidities (Liem and Haines 1977). These conditions account for the poor development of coral reefs in these areas (Whitehouse 1973).

Anchovies are present in all three of these habitats. In addition, one species of anchovy, *Thryssa scrathchleyi* (Ramsey and Ogilby), is found in the Strickland River which is entirely fresh water. The distribution of PNG's anchovy fauna is indicated in *Table 1.* Only one species, *Stolephorus punctifer* (Fowler), lives in oceanic water. Adults have been recorded up to 1120 km from the nearest land (Hida 1973), and the eggs and larvae have been taken in plankton tows 800 km offshore (Gorbunova 1971).

Stolephorus punctifer occasionally moves into coastal waters inhabited by *Stolephorus heterolobus* (Ruppel) and *Stolephorus devisi* (Whitley) (Wilson 1977; Lewis 1977; Kearney *et al.* 1979; Dalzell and Wankowski 1980). Dalzell (1984a) showed that the abundance of *S. punctifer* in coastal waters is strongly influenced by rainfall and hence presumably salinity. Spawning of *S. punctifer* appears to take place in the open ocean (Gorbunova 1971). Other factors such as food availability may be responsible for the movement of *S. punctifer* inshore.

The anchovy fauna of the inshore coralline waters is dominated by species of the genus *Stolephorus*. The two species *S. heterolobus* and *S. devisi*, are abundant along the South Papuan coast from Port Moresby eastwards, on the north coast of the mainland and around the larger island groups (Anon 1969; Lewis 1977; Cooper and Wankowski 1980; Dalzell and Wankowski 1980; Dalzell 1984b).

The larger members of the genus, *S. indicus*, *Stolephorus bataviensis* Hardenberg and *Stolephorus commersoni* (Lacépède), though less abundant, are relatively widely distributed and are occasionally caught in bait catches of

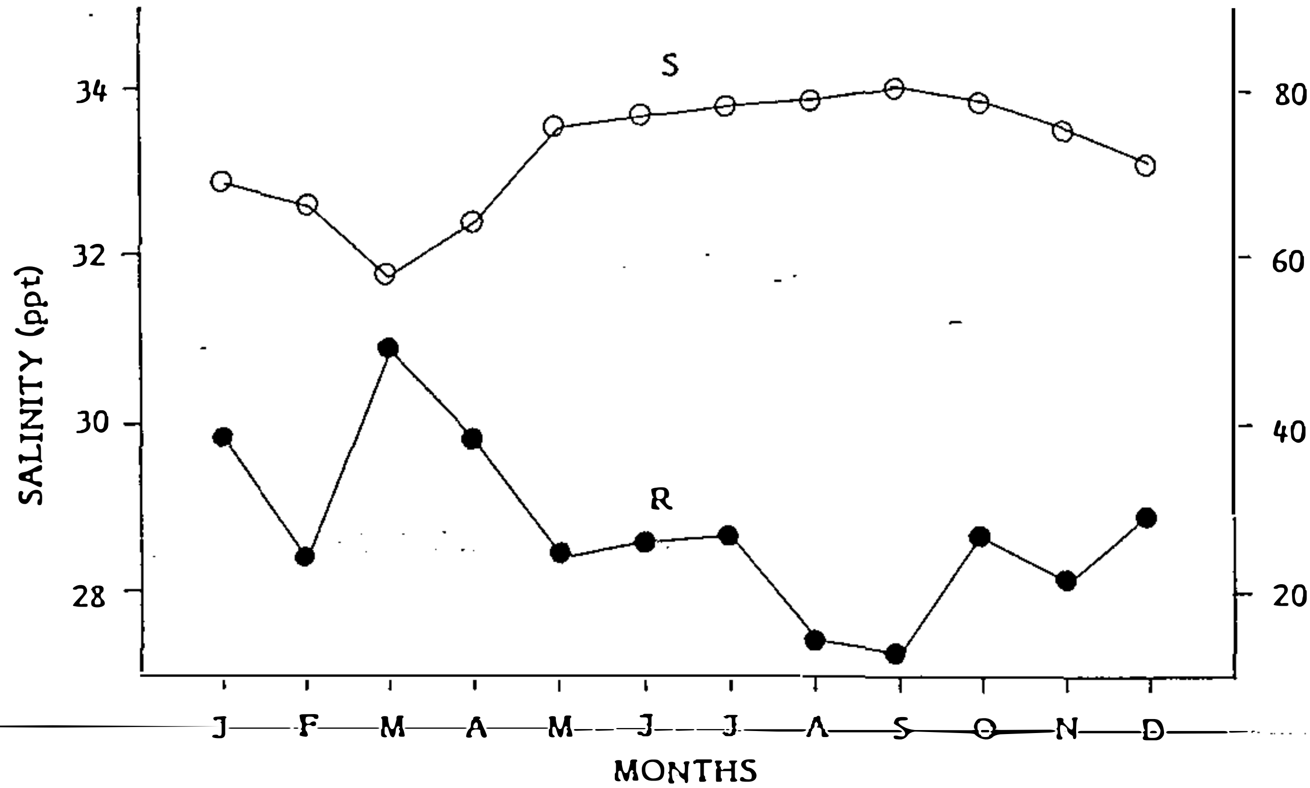

Figure 1.–**Mean monthly rainfall (R) and salinity (S) data for Kavieng Harbour from 1981–1983 (Dalzell, unpub. data)**

the domestic pole-and-line fleet (Lewis *et al.* 1974; Dalzell and Wankowski 1980). Elsewhere in the South East Asian region the dominance of *S. heterolobus* and *S. devisi* conforms with observations in PNG waters (Tiews *et al.* 1970; Tham 1972; Burhanuddin *et al.* 1975). In many of the island groups throughout Polynesia, Melanesia and Micronesia these two species also dominate the anchovy fauna of the inshore coralline waters (Kearney and Lewis 1978; Kearney and Hallier 1978abc; Kearney *et al.* 1978).

One other species, *Thryssa balaema* (Forsskäl), is also found within the inshore coralline environment and is associated with the mangrove areas bordering reef and lagoon systems. Places where *T. balaema* appears in any large quantities, such as in commercial bait catches, are usually marginal habitats for *S. heterolobus* and *S. devisi* (Lewis 1977).

The remaining species are confined to areas where the freshwater influx is substantial, particularly the Gulf of Papua. Here the large *Stolephorus* anchovies are also present but the smaller species *S. heterolobus, S. devisi* and *S. punctifer* are absent (Kailola and Wilson 1978). The two newly described stolephorid anchovies, *Stolephorus carpenteriae* (Munro) and *Stolephorus brachycephalus* (Wongratana) have only been found in the Gulf of Papua in PNG waters (Wongratana, 1983).

The presence of *T. scratchleyi* has probably developed through some past migration inland by an estuarine species. This species may be analogous to some of the African clupeids such as *Stolothrissa tanganicae* Stiendachner and *Limnothrissa miodon* Boulenger on Lake Tanganyika (Coulter 1974).

Many factors are responsible for the distribution of the majority of anchovy species in PNG waters. The oceanic

Table 1.-The Papua New Guinea anchovy fauna. Distribution by environment is shown on the right of the table

Species	Environment			
	Oceanic	Inshore Coralline	Estuarine	Fresh-water
Stolephorus punctifer (Fowler)	0	0		
S. heterolobus (Ruppel)		0		
S. devisi (Whitley)		0		
S. indicus (van Hasselt)		0	0	
S. bataviensis (Hardenberg)		0	0	
S. commersoni (Lacépède)		0	0	
S. tri (Bleeker)		0	0	
S. carpenteriae (Munro)			0	
S. brachycephalus (Wongratana)			0	
Thryssa balaema (Forsskäl)		0	0	
T. hamiltoni (Gray)			0	
T. kamalensis (Bleeker)			0	
T. mystax (Schneider)			0	
T. purava (Hamilton-Buchanon)			0	
T. setirostris (Broussonet)			0	
T. scratchleyi (Ramsey and Ogilby)				0
Setipinna taty (Valenciennes)			0	
S. godavari (Babu Rao)			0	
S. papuaensis (Munro)			0	
Papuaengraulis micropinna (Munro)			0	

and freshwater anchovies, *S. punctifer* and *T. scratchleyi* inhabit opposite ends of the salinity range in which anchovies are known to occur. Most anchovies have a wide tolerance of salinities (Longhurst 1970) although it is likely that both *S. heterolobus* and *S. devisi* are less tolerant than other species in the same genus (Tham 1972; Lewis 1977). An inverse relationship between increased stream discharge and abundance of *Stolephorus purpureus* Flower was observed by Weatherall (1977). This species has similar habitat preferences to *S. devisi* and *S. heterolobus*.

In the coastal waters of PNG the distribution of anchovies may be determined by the degree of food selection, rather than salinity. The smaller stolephorid anchovies are almost exclusively pelagic planktivores (Tham 1950; Hida 1973; Burhannudin *et al.* 1975; Muller 1976; Chapau 1983a). High primary productivity levels in surface and near surface waters have been shown to be necessary for the occurrence of *S. heterolobus* (Muller 1976) and a positive correlation between the abundance of both zooplankton and *S. heterolobus* in the Singapore Straits was demonstrated by Tham (1953). These species may be thus excluded from the turbid waters of extensive estuarine areas by virtue of their specialised feeding habits.

The anchovies found in the Gulf of Papua are less selective feeders than the small planktivorous stolephorids. The food of *Thryssa mystax* (Schneider) in Indian waters was found to be pelagic crustaceans, benthic polychaetes and shrimps (Venkatamaran 1956). Similar observations have been reported for *Thryssa hamiltoni* (Gray), *Thryssa purava* (Hamilton-Buchanon) and *Setipinna phasa* Hamilton-Buchanan (Mookerjee and Mookerjee 1950; Bal and Bapat 1950; Jones and Menon 1951). The larger *Stolephorus* anchovies, *S. indicus* and *S. bataviensis*, were shown to feed both in the pelagic and benthic zones of the Singapore straits (Tham 1950).

YIELDS

Most of the anchovy species present in PNG waters are found in the Gulf of Papua. Catch and effort data for the by-catch of the prawn fishery are limited and preliminary yield estimates of the potential anchovy catch of this region must be subjective until better data are obtained. The data from experimental trawl fishing between 1960 and 1968 in the Gulf of Papua were summarised by Kailola and Wilson (1978). The mean percentage composition by weight of clupeoids in the catch was 13%. The ratio of anchovies to other clupeoids (calculated from Kailola and Wilson's data) was 2.5:1 and this gave an index of anchovy abundance in the by-catch of 9% by weight. The ratio of by-catch weight-to-prawn weight in the Gulf of Papua has been reported to be within the range from 6:1 to 8.8:1 (Anon 1979b; Watson 1984). Taking the mean this gives an average by-catch ratio of 7.4:1 and from this the by-catch between the years 1977 to 1982 was calculated and is presented in *Table 2*. More data are required for precise estimates of the anchovy harvest from this fishery. The figures given here, however, serve to illustrate the order of magnitude of possible anchovy yields from this area.

For the bait-fish catches of the domestic pole-and-line fleet accurate catch (C) and effort (f) data are available for a number of years (Dalzell and Wankowski 1980; Dalzell 1984b) and an estimation of potential yield of *S. heterolobus* and *S. devisi* from the inshore coralline waters can be made. The method of fishing has been described in detail by Dalzell (1980). Baitfish are aggregated around an underwater light for several hours after dark and captured in a lift net. Catch (tonnes) and effort (boat-nights) data for *S. heterolobus* and *S. devisi* from the Ysabel Passage (New Ireland Province) and Cape Lambert (East New Britain Province) are given in *Tables 3* and *4*. The areas of the bait grounds were 336 km^2 for the Ysabel Passage and 407 km^2 for Cape Lambert. The catch/effort/km^2 for both species of anchovy combined are presented in *Table 5*.

Schaeffer (1954) developed a simple logistic model for yellowfin tuna catches in the eastern tropical Pacific which uses only catch and effort data to obtain estimates of maximum sustainable yield (MSY) and optimal fishing effort (f.opt). Since the initial application of this model by Schaeffer (1954), this model has been applied with success to a wide range of temperate and tropical fish stocks (Gulland 1983). In its simplest version the model takes the form:

$$C/f = a - bf \qquad (1)$$

which is a linear relationship and can be solved by plotting C/f on f. The model can be transformed into a parabola by multiplying through by f such that:

Table 2.–Estimated anchovy catch in the Gulf of Papua trawl fishery. Prawn catch data from Kolkolo (1983)

Year	Prawn catch* (tonnes)	By catch (tonnes)	Estimated anchovy catch (tonnes)
1977	882	6,527	587
1978	1,661	12,291	1,106
1979	1,962	14,519	1,307
1980	1,962	14,519	1,307
1981	1,710	12,654	1,139
1982	1,465	10,841	976

Notes: * Original figures multiplied by 1.7 to give whole prawn weight (Anon 1979b)

$$C = af - bf^2 \quad (2)$$

When the slope of the parabola is zero, at the apex, then this is the point of maximum sustainable yield (MSY) and optimum fishing effort (f. opt.) Alternatively these can be calculated from:

$$MSY = a^2/4b \quad (3)$$

$$f.opt = a/2b \quad (4)$$

From this model it was possible to determine the maximum sustainable yield of the combined stocks of *S. heterolobus* and *S. devisi* by the use of the

Table 3.–Catch and effort data for the anchovy catches from the Ysabel Passage bait-fishery

Year	Effort	Catch in tonnes		Total
	(Boat-nights)	*S. heterolobus*	*S. devisi*	
1972	1819	145.8	90.1	235.9
1973	1792	131.7	46.4	178.1
1976	3052	190.8	108.4	299.2
1977	3717	138.3	102.5	240.8
1978	4463	404.0	126.0	530.0
1979	3038	191.8	146.8	338.6
1980	3709	72.1	12.7	84.8
1981	2170	65.8	24.5	90.3

Table 4.–Catch and effort data for the anchovy catches from the Cape Lambert bait-fishery

Year	Effort	Catch in tonnes		Total
	(Boat-nights)	*S. heterolobus*	*S. devisi*	
1972	1780	115.8	66.8	182.6
1973	3360	210.2	115.4	325.6
1977	3288	39.4	132.3	171.7
1980	1377	106.7	39.5	146.2
1981	1223	132.3	49.7	182.0

Table 5.–Combined catch, effort and area data in $kg/boat\text{-}night/km^2$ for the Ysabel Passage and Cape Lambert bait-grounds

Effort (boat-nights)	$kg/f/km^2$
1819	0.386
1792	0.296
3052	0.106
3717	0.193
4463	0.353
3088	0.326
3709	0.068
2170	0.124
1780	0.251
3360	0.238
3280	0.397
1377	0.258
1223	0.348

catch and effort data in *Table 5*. In this instance C/f/km² was plotted on f and a theoretical yield curve determined from:

$$C/km^2 = af - bf^2 \quad (5)$$

The relationship between catch per unit area and effort was:

$$C/f/km^2 = 0.394 - 0.64 \times 10^{-4}f. \quad (6)$$

Two points, one from the Ysabel Passage and one from the Cape Lambert data sets were excluded from the regression to obtain a better fit of the line (see *Figure 2*).

Table 6 gives the areas for several locations around PNG's coralline coast that have recognised anchovy resources. The predicted sustainable

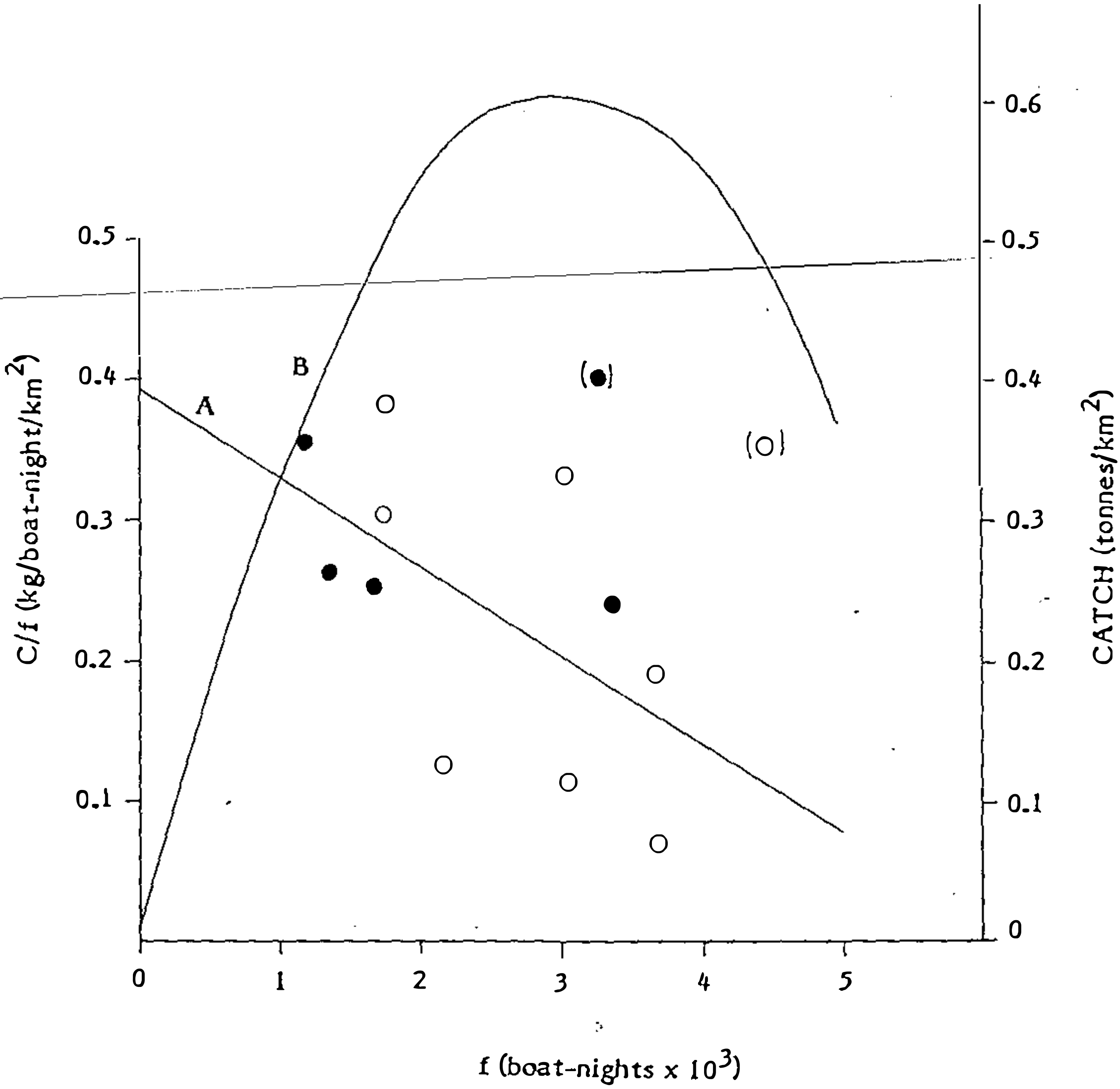

Figure 2.–The relationship between catch, effort and area for combined catches of *S. heterolobus* and *S. devisi* at the Ysabel Passage (o) and Cape Lambert (•). Points in parentheses have been excluded from the regression. Line A: $C/f/km^2 = 0.394 - 0.64 \times 10f$, $r = -0.62$, $p<0.05$. Line B: theoretical yield curve

yields from these areas were calculated from the model and are also presented. The total annual catch of *S. heterolobus* and *S. devisi* from these areas alone is 1,025 t. The locations listed in *Table 6* refer to bait grounds, where large (> 20 m in length) boats can enter and fish nets of 20 m^2 can be hung safely without snagging on the bottom.

The conditions determining the kind of boats that can enter an area restrict the number of places *Stolephorus* anchovies can be caught in PNG waters. In areas inaccessible to such vessels the potential exists for the development of artisanal gear such as small lift nets, beach seines and fish traps, which would lead to an increase in total production. Given the extensive inshore coralline coastline of PNG it is reasonable to suggest that sustained annual catches of between 5,000–10,000 t could be achieved by increased exploitation of this resource.

DISCUSSION

From the data presented here it is clear that PNG has a substantial anchovy resource. Apart from catches in two specialised industrial fisheries the resource is under-exploited. The predictive estimates of anchovy catch in the Gulf of Papua whilst being empirical, indicate a substantial anchovy catch in this region. However, the primary target of the trawl fishery is prawns and the by-catch is discarded for economic reasons.

The anchovy yields that are predicted for the inshore coralline waters are based on *S. heterolobus* and *S. devisi* which are by far the most dominant species in this region. In estimating the yields for other locations it is assumed that conditions are similar to those at Ysabel Passage and Cape Lambert. Muller (1977) estimated the MSY of *S. heterolobus* in the Palau bait-fishery to be 0.48 t/km^2. The physical characteristics of the Palau bait-ground resemble those of the Ysabel Passage and Cape Lambert. All three locations are partially enclosed sheltered waters bordered by high islands and coral reefs. Rainfall averages between 200–400 mm/month (Muller 1976; Dalzell 1984a) and the temperature and salinity of the sea water in all three bait

Table 6.–Area and potential annual yield of *S. heterolobus* and *S. devisi* at several locations in Papua New Guinea waters

Location	Position	Area (km^2)	Potential yield (tonnes)
Sek Harbour	(145° 49′E, 5°06′S)	36.0	22.0
Seaddler Harbour	(147° 23′E, 2°00′S)	30.6	18.7
Stettin Bay	(150° 25′E, 5°15′S)	149.0	90.9
Open Bay	(151° 35′E, 4°55′S)	85.5	52.2
Riebeck Bay	(149° 55′E, 5°25′S)	175.5	107.1
Eleonora Bay	(149° 45′E, 5°30′S)	69.3	42.3
Emeline Bay	(149° 39′E, 5°30′S)	12.6	7.7
Rein Bay	(149° 15′E, 5°27′S)	12.6	7.7
Cheshunt Bay	(148° 28′E, 10°10′S)	58.5	35.7
Fairfax Harbour	(147° 05′E, 9°59′S)	2.7	1.6
Arawe Harbour	(149° 00′E, 6°05′S)	134.0	81.7
Ysabel Passage	(150° 30′E, 2°30′S)	336.0	204.9
Cape Lambert	(151° 40′E, 4°10′S)	407.0	248.3
Richthofen Bay	(149° 55′E, 6°20′S)	30.0	18.3
Gasmata Bay	(150° 18′E, 6°18′S)	40.0	24.4
Garua Harbour	(150° 03′E, 5°19′S)	40.0	24.4
Silver Sound	(150° 45′E, 2°40′S)	39.9	24.3
Three Island Harbour	(150° 10′E, 2°23′S)	21.0	12.8
Total		1,680.2	1,025.0

grounds are similar (Muller 1976; Chapau 1983b; Dalzell 1984b). An analysis of only the catch data pertaining to *S. heterolobus* (*Figure 3*) gave an annual sustainable yield of this species of 0.44 t/km². The predictive model used in this paper therefore appears to be reasonable.

The expansion of the anchovy fisheries in PNG waters would depend on suitable markets for such a product. The demand for anchovies at present within PNG is such that it would be uneconomic to separate them from the by-catch of the Gulf of Papua prawn trawlers. Further, the amount of fresh clupeoid or herring like fish such as anchovies in the diet of PNG nationals appears to be limited, based upon observations of coastal reef and estuarine fisheries (Opnai 1984; Wright and Richards 1985; Lock 1986).

There may, however, be an export potential of sun-dried stolephorid anchovies, caught in PNG's inshore coralline waters, to south East Asia, where high population densities put an ever increasing strain on the fisheries of the region. This increase in demand is reflected in the stolephorid anchovy catches which have increased from 149,000 t to 223,000 t between 1977 and

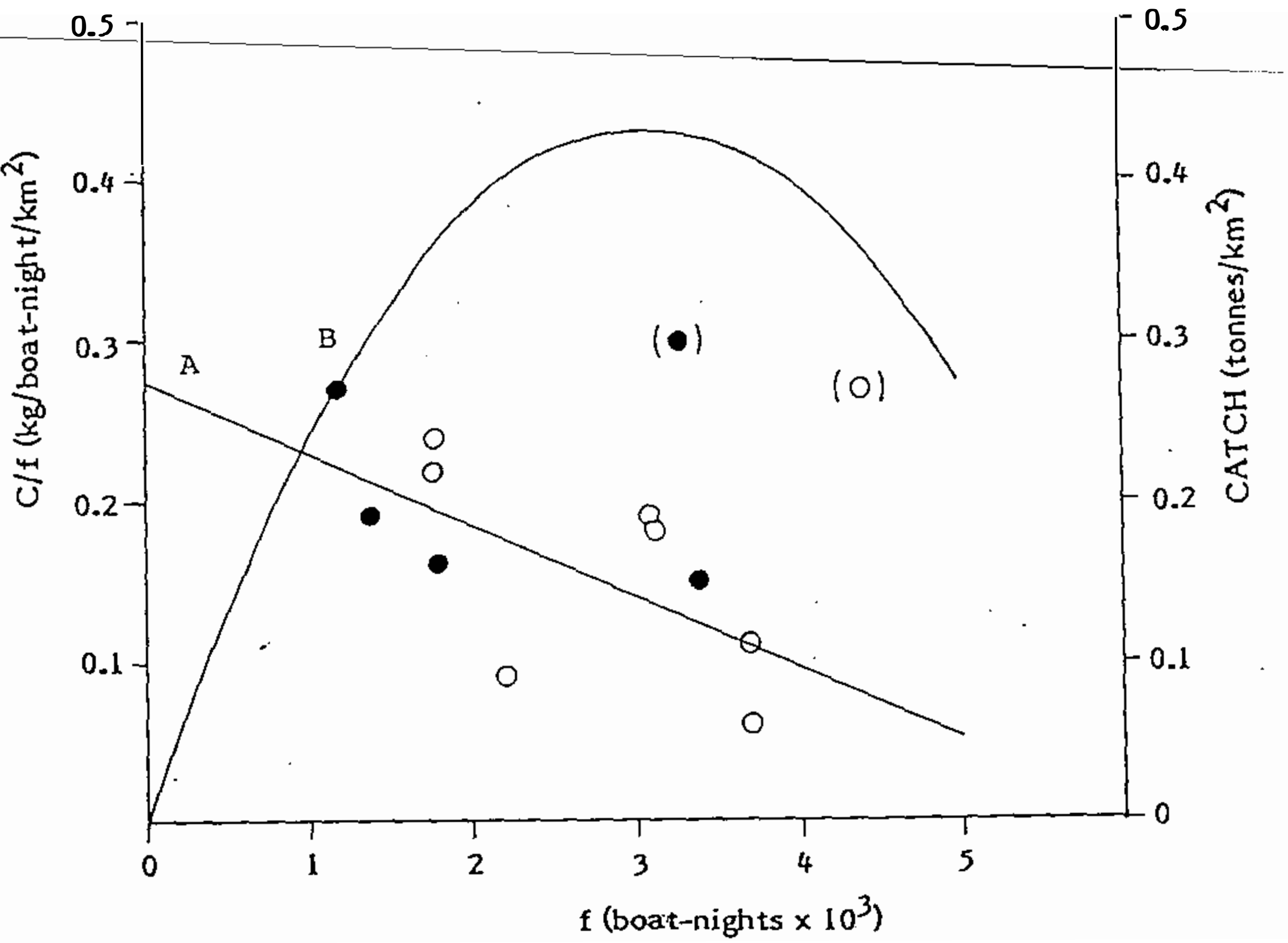

Figure 3.–The relationship between catch, effort and area for catches of *S. heterolobus* at the Ysabel Passage (o) and Cape Lambert (•). Points in parentheses have been excluded from the regression. Line A: $C/f/km^2 = 0.280 - 0.48 \times 10^{-4}f$, $r = -0.66$, $p<0.05$. Line B: theoretical yield curve.

1983 in this area (FAO 1984). This represents a net increase of 33% in the landings of these fish. The catching and processing of stolephorid anchovies requires only basic methods and sun-drying lends itself to the development of the resource without investment in costly freezers or transportation systems (I.A. Ronquillo unpub. manuscript).

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