The Influence of Rainfall on Catches of Stolephorid anchovies in Papua New Guinea Waters.

by

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Report No.84-04

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Introduction

The Papua New Guinea (P.N.G.) domestic pole-and-line skipjack tuna fishery commenced in 1970 and maintained operations more or less continually until 1981. This fishery was closed at the end of 1981 due to economic factors that have been well documented (Doulman & Wright 1982, and Doulman 1983).

The pole-and-line fishery was wholly dependant on large amounts of locally caught live bait. Whilst up to 300 species contributed to the bait catch, it was the stolephorid anchovies, Stolephorus heterolobus, S. devisi and to a lesser extent S. buccaneeri that were recognised as the main target species (Smith 1977, Dalzell & Wankowski 1980, Dalzell in prep). Populations of these anchovies were observed to undergo marked annual fluctuations in abundance and yield. Dalzell (1983, in prep.) related some of the variability in yield of stolephorid anchovies to changes in fishing pressure. It was clear, however, that fishing pressure alone was incapable of explaining the high degree of variability between years in the yields of these species.

Several authors have demonstrated that there is a relationship between rainfall or the resultant freshwater influx, and yield in several tropical coastal marine fisheries (Tham 1953, Ben-Tuvia 1960, Antony-Raja 1964, Weatherall 1977, Pauly 1977, Binet 1982). Bait-fish, including the stolephorid anchovies, are caught in sheltered coastal waters that are protected by barrier reefs or outlying islands. Such waters are not associated with large influxes of fresh water, however, some stream discharge and terrestrial runoff is often a necessary criterion for a good bait site (Muller 1976, Lewis 1977). It is the intention of this report to present evidence that there is a relationship between rainfall and yield of stolephorid anchovies at two bait grounds in P.N.G. waters, Ysabel Passage and Cape Lambert. It is not known if the pole-and-line fishery will re-open in the future, however, should this occur then the results discussed here will be important for future management of these fisheries. In the past management has taken the form of an effort limiting strategy without regard for environmental effects (Anon 1982).

Material and Methods

Both the Ysabel Passage and Cape Lambert are situated in the northern P.N.G. islands region (Fig. 1) facing northwards. They are thus sheltered for most of the year from the prevailing S.E. Trade Winds. Rainfall is generally continous throughout the year but is heavier during the N.W. Monsoon which produces the greatest amount of rain, with March normally being the wettest month (Fig. 2).

Rainfall at the Ysabel Passage was recorded daily at two sites, Puas and Taskul, approximately 30km apart on the western shore of the bait-ground. Measurements were not recorded synchronously. The records from Taskul in the south extend from 1971 to 1977 and for Puas in the north from 1979 onwards. No records were kept for the years 1970, 1973, and 1978. For these years figures recorded at Kavieng, 28km to the east were used. The rainfall figures used in conjuction with the yield data for the Cape Lambert bait-fishery were collected at Rabaul, 40km to the east. It was assumed that there were little climatic differences between the two adjacent areas due to the similarities in topography and orientation. The annual rainfall figures for both the Ysabel Passage and Cape Lambert are given in Table 1.

Bait-fishing takes place at night and 1-1.5kw submersible lamps are used to aggregate the bait-fish prior to hauling the net. The lamps are suspended from floating platforms, usually small dories, or from the fishing vessel itself. The bait net or Bouke-ami is mounted on the deck of the tuna boat and consists of two bamboo outriggers and boom construction from which the net hangs when it is set. Detailed descriptions of the fishing method are given by Ben-Yami (1976) and Dalzell (1980).

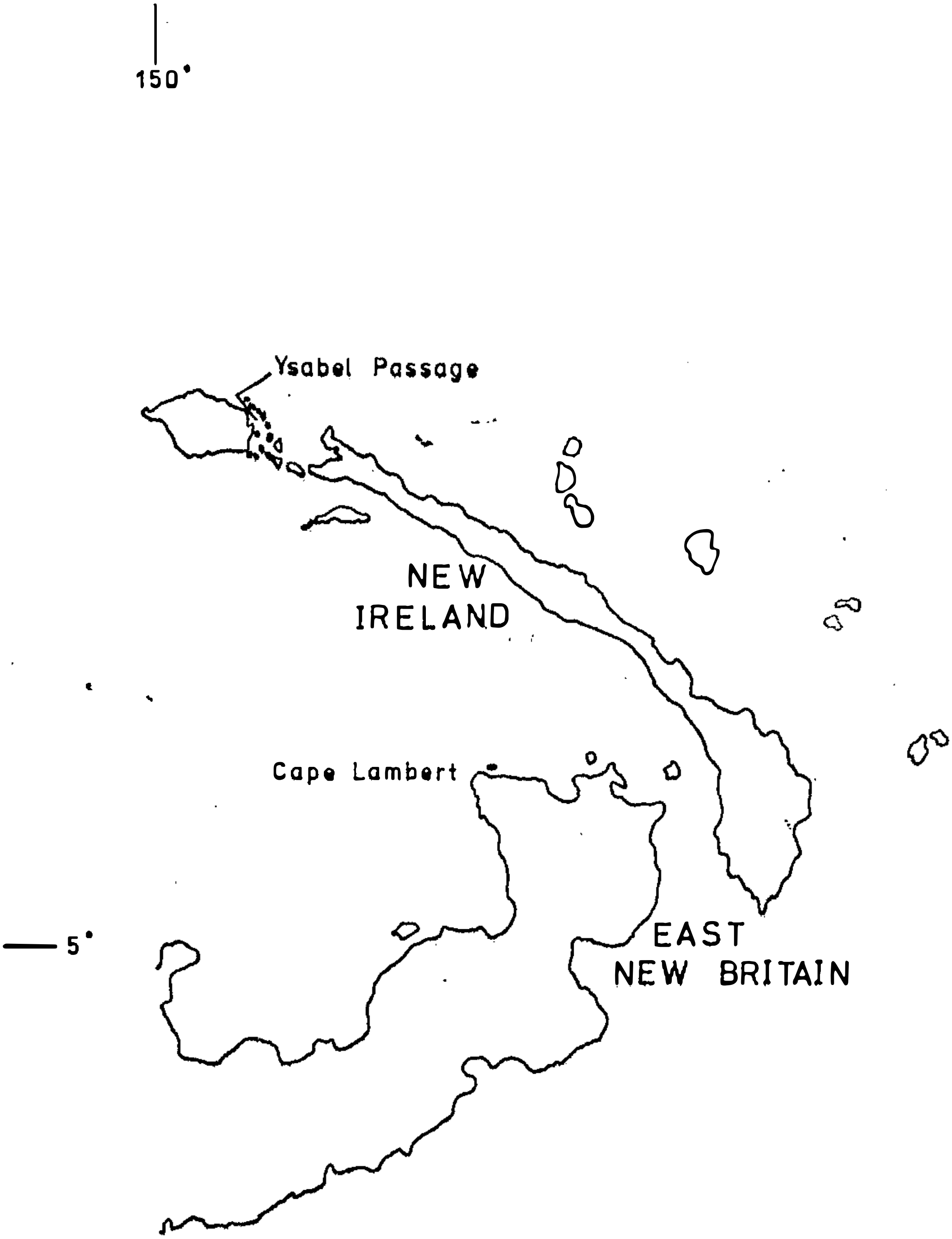

Fig. 1. Location of the Ysabel Passage and Cape Lambert.

Fig. 2. Mean monthly rainfall based on data from 1970-1981 for Ysabel Passage (YP) and Cape Lambert (CL).

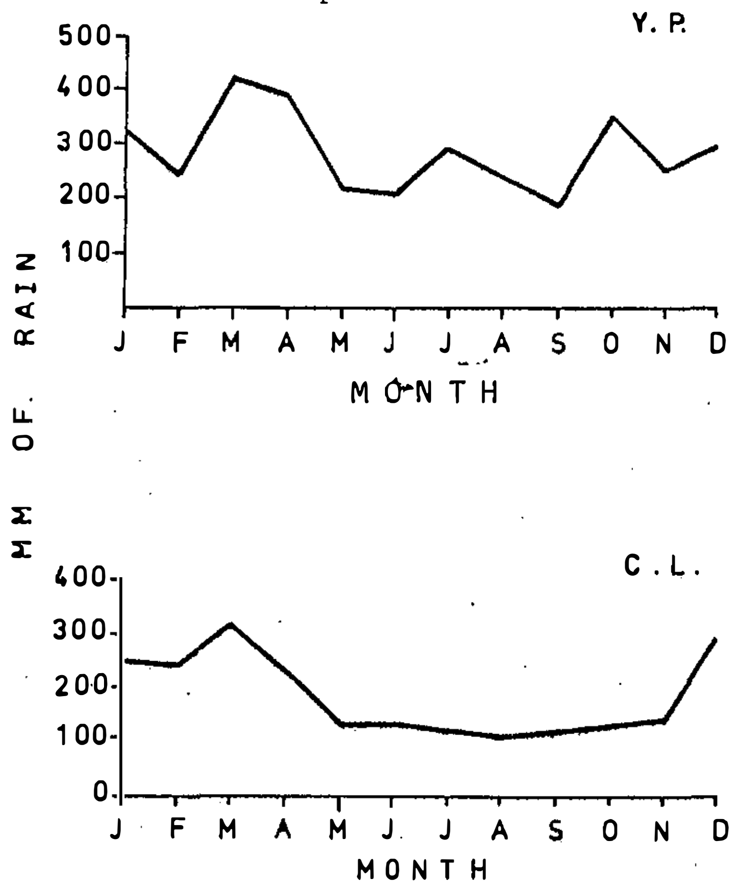

Table 1. Rainfall figures for the Ysabel Passage and Cape Lambert areas.

Year	Rainfall in mm: Ysabel Passage	Rainfall in mm: Cape Lambert
1970	3150	-
1971	3133	2406
1972	2511	1949
1973	3825	1822
1974	1883	1923
1975	2447	1453
1976	3671	2516
1977	3637	2479
1978	3315	2493
1979	3766	2240
1980	4153	2255
1981	4202	2251

Data from the Ysabel Passage (150°40'E, 2°30'S) and Cape Lambert (151°'E, 4°10'S) (Fig. 1) were selected for analysis as these two bait grounds were the most important in the country and have been fished from 1970 onwards during successive fishing seasons. The total catch and effort data for these two bait grounds are given in Tables 2 & 3. Bait catch was initially recorded in units of buckets by the fishermen then changed to weight (kg) by the conversion factor : 1 buckets = 2.5kg (Lewis 1977). The weights of stolephorid anchovies in the catch are given in Tables 4 & 5. These weights are not known for each year as catch sampling was not undertaken every year since 1970.

Catch per effort is normally used as an index of productivity and abundance (Ricker 1975, Rothschild 1977). To enable comparison between bait grounds, the catch of stolephorid anchovies was divided by the product of the effort and the area of the bait ground to give a yield per unit area (Coulter 1974, Dalzell 1983) and these are given in Table 6 & 7. The areas of each bait ground were determined from Australian Admirably sea charts with a polar plainmeter and were 336km^2 for the Ysabel Passage and 407km^2 for Cape Lambert. The units of effort used were boat-nights, which were recorded since the inception of the fishery. Between 1-3 hauls are made during each boat-night and catch per haul is a more applicable unit of effort. However, the number of hauls per boat-night were not recorded until 1976.

Table 2. Catch (C) and effort (f) data for the Ysabel Passage bait-ground.

Year	f Boat-nights	C tonnes
1970	510	75
1971	1253	235
1972	1819	348
1973	1792	318
1974	2674	498
1975	2247	455
1976	3052	360
1977	3717	732
1978	4463	984
1979	3038	517
1980	3709	707
1981	2170	319

Table 3. Catch (C) and effort (f) data for the Cape Lambert bait-ground N.A. = not available.

Year	f boat-nights	C tonnes
1970	N.A.	N.A.
1971	320	55
1972	1780	255
1973	3360	530
1974	2180	320
1975	1120	130
1976	1644	148
1977	3288	604
1978	2763	466
1979	1846	323
1980	1377	255
1981	1223	296

Table 4. Total annual catch of stolephorid anchovies from the Ysabel Passage bait-fishery.

	Catch in tonnes	
Year	S. heterolobus	S.devisi
1972	146	90
1973	132	46
1976	191	108
1977	138	102
1978	404	126
1979	192	146
1980	72	13
1981	66	25

Table 5. Total annual catch of Stolephorid anchovies from the Cape Lambert bait ground.

	Catch in tonnes		
Year	S. heterolobus	S. devisi	S. buccaneeri
1972	116	67	29
1973	196	112	47
1977	398	133	11
1980	107	39	15
1981	132	50	0.2

Table 6. Yield data ($kg/f.km^2$) by species for the Ysabel Passage bait-ground.

Year	S. heterolobus	S.devisi
1972	0.23	0.15
1973	0.22	0.08
1976	0.19	0.11
1977	0.11	0.08
1978	0.27	0.08
1979	0.19	0.14
1980	0.06	0.01
1981	0.09	0.03

Table 7. Yield data ($kg.f^{-1}.km^{-2}$) by species for the Cape Lambert bait-ground.

Year	S. heterolobus	S. devisi	S. buccaneeri
1972	0.16	0.09	0.04
1973	0.14	0.08	0.03
1977	0.30	0.10	0.01
1980	0.19	0.07	0.02
1981	0.27	0.10	0.01

Results

Three species of stolephorid anchovy are caught regularly at Cape Lambert, *Stolephorus heterolobus*, *S. devisi* and *S. buccaneeri* (Lewis 1977, Anon 1982). At the Ysabel Passage *S. buccaneeri* is rarely observed in bait catches, and *S. heterolobus* and *S. devisi* are the only stolephorid anchovies taken with any regularity at this bait ground (Dalzell & Wankowski 1980).

The relationships between the yields and rainfall of *S. heterolobus*, *S. devisi* and *S. buccaneeri*, and rainfall are shown in Figs. 3-5. A positive correlation was obtained between the yield of *S. heterolobus* and increasing rainfall. The inference from this is that an increase in the annual rainfall promotes a greater yield of *S. heterolobus*. No relationship could be reliably established between the yield of *S. devisi* and rainfall at Cape Lambert. Although the slope of the regression line was positive the correlation was extremely poor. For *S. buccaneeri* the relationship between yield and rainfall was distinctly negative indicating that increased rainfall leads to a decline in the abundance and yield of this species at Cape Lambert.

The relationships between yield and rainfall for *S. heterolobus* and *S. devisi* at the Ysabel Passage are shown in Figs. 6 & 7. For both species the response to increased rainfall was a decline in productivity and yield.

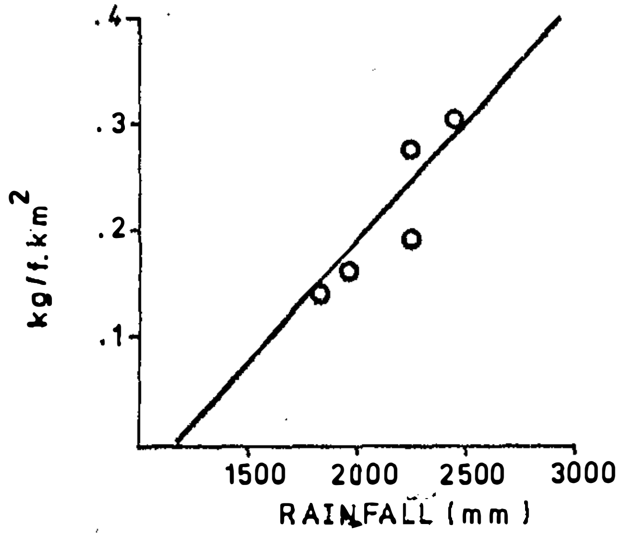

Fig. 3. Relationship between rainfall and yield for *S. heterolobus* at Cape Lambert.
$y = -0.2766 + 2.2880.10^{-4}x$
$r^2 = 0.80$.

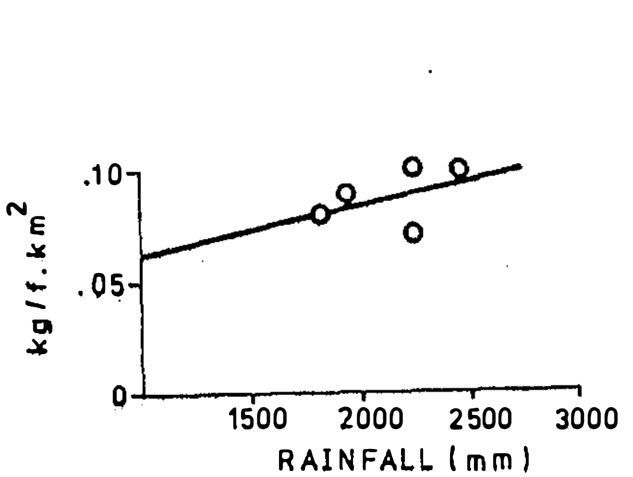

Fig. 4. Relationship between rainfall and yield of *S. devisi* at Cape Lambert.
$y = 0.0454 + 1.980.10^{-5}x$
$r^2 = 0.16$

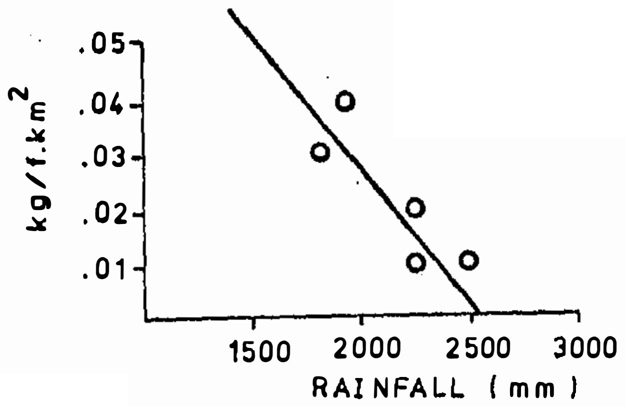

Fig. 5. Relationship between rainfall and yield of *S. buccaneeri* at Cape Lambert.
$y = 0.1358 - 5.4.10^{-5} x$
$r^2 = 0.71$.

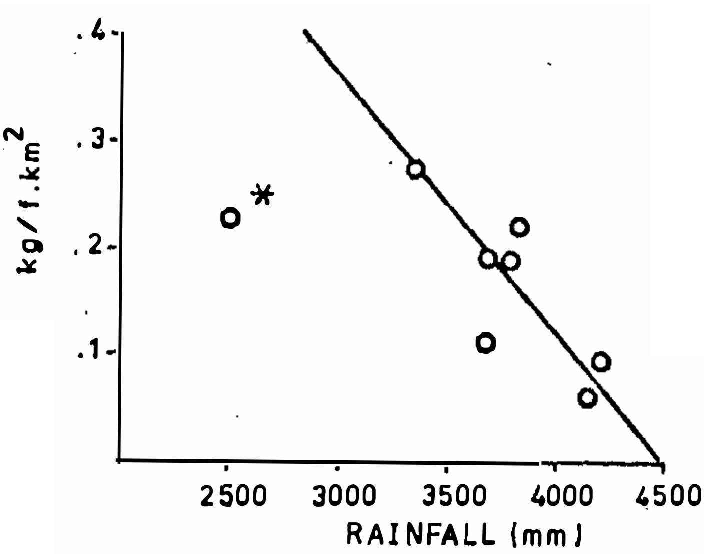

Fig. 6. Relationship between rainfall and yield of *S. heterolobus* at the Ysabel Passage.
$y = 0.803 - 2.23.10^{-4} x$
$r^2 = 0.80$
* excluded from regression.

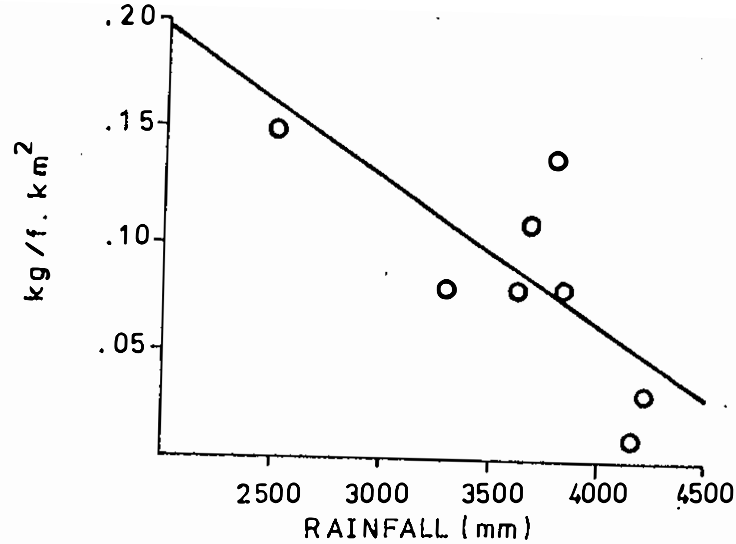

Fig. 7. Relationship between rainfall and yield of *S. devisi* at the Ysabel Passage.
$y = 0.327 - 6.601.10^{-5} x$
$r^2 = 0.54$

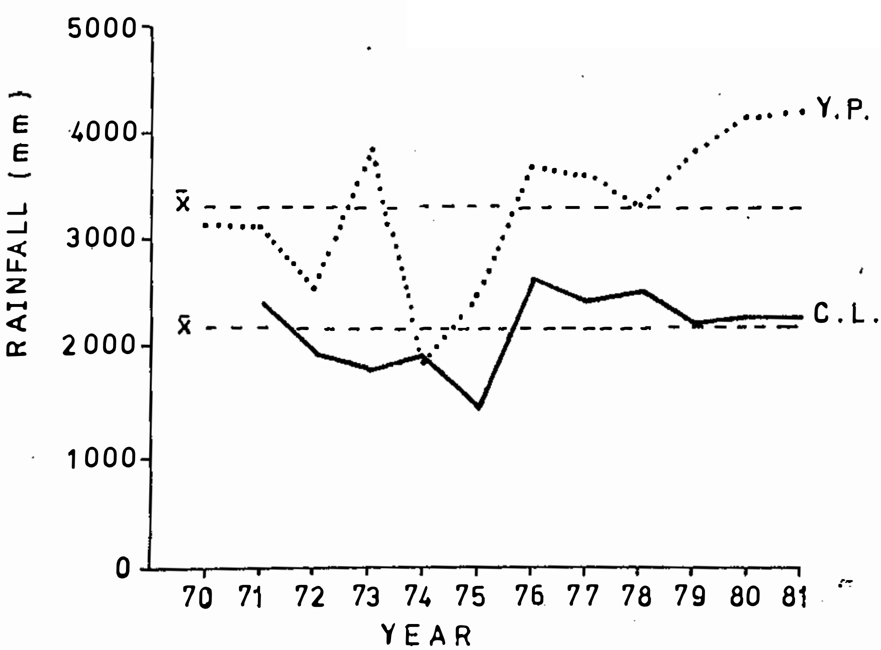

Fig. 8. Comparison of rainfall at Ysabel Passage and Cape Lambert.

Discussion

Despite the small size of the data sets available for analysis, especially for Cape Lambert, the results indicated that different trends were apparent with respect to rainfall and yield at the Ysabel Passage and Cape Lambert bait-fisheries. The effect of rainfall in coastal ecosystems in the present study was to increase stream discharge and terrestrial runoff. Both mechanisms act as transport for allochthanous nutrient material of terrestrial origin. Muller (1976) pointed out the importance of this nutrient input for the presence or absence of S. heterolobus in the tropical Indo-Pacific region and suggested that a threshold primary productivity level of 2mg $C.m^{-3}.h^{-1}$, as measured by C^{14} uptake was necessary for the presence of this species. Further Muller (1976) emphasised the importance of rainfall for the successful recruitment of S. heterolobus in Palau waters and constructed a stock recruitment model which incorporated a rainfall term. A reduced rainfall regime during late 1969 and early 1970 in Palau led to a decline in recruitment with a concomitant severe reduction in yield of S. heterolobus.

The lack of any distinct relationship between yield of S. devisi and rainfall at Cape Lambert may indicate that other factors operate to prevent the population of this species benefiting from an increased food supply. At both Cape Lambert and the Ysabel Passage, S. devisi is sub-dominant to S. heterolobus (Dalzell & Wankowski 1980, Anon 1982, Dalzell in prep.). The ratio of abundance of S. heterolobus to S. devisi is on average about 2.5:1 at each bait-ground (Dalzell in prep.). In years where S. heterolobus has shown dramatic increases in productivity, such as 1976 at Cape Lambert and 1978 at the Ysabel Passage (Tables 4-7), this has not been paralleled by a similar increase in the productivity of S. devisi. Little is known of the interspecific relationships between the two species, specifically the degree of competition for the same food resource. Krebs (1972) summarised the apparent paradoxes of competitive interactions; he found that it is often difficult to prove in the natural state that there are degrees of competitive displacement between similar species in the same environment. Chapau (1983) has, however, indicated that both S. heterolobus and S. devisi have similar food preferences and feed predominantly on copeponds. Assuming that in pelagic species space is not a limiting factor as in reef fish (Sale 1982), then it is reasonable to suggest that as the productivity of S. heterolobus increases it may compete with S. devisi limiting its productivity.

The negative correlation between the yield of S. buccaneeri and increased rainfall is to be expected as this species is stenohaline and is the only member of the genus Stolephorus that prefers an oceanic habitat. The occasional appearance of this species at the Cape Lambert bait-fishery suggests that this area of water is more influenced by the bathing of the coastal region with oceanic water than the Ysabel Passage. A similar occurrence has been observed for Sardinella aurita, another stenohaline species off the West African coast (Binet 1982). The success of this fishery is dependant on the upwelling of ocean currents in the coastal region and excessive freshwater influx causes a decrease in productivity and yield.

The Ysabel Passage and Cape Lambert differ geographically. The Cape Lambert bait ground is a body of water between the coast and a series of barrier reefs offshore. The Ysabel Passage is an enclosed strait of water, open only at one end to oceanic influence. The Cape Lambert area is thus likely to be influenced to a greater degree by oceanic conditions, particularly during the N.W. monsoon when the prevailing winds blow directly onto this coast. Since S. buccaneeri prefers waters of high salinity, dilution of the coastal water by freshwater influx will present an unfavourable habitat for this species, a factor not apparently offset by any increase in plankton productivity.

In contrast to the results for yields of S. heterolobus and S. devisi at the Cape Lambert bait-ground, both these species exhibited a decrease in yield when rainfall increased at the Ysabel Passage. Tham (1953) demonstrated that whilst rainfall was related to plankton abundance and hence yields of stolephorid anchovies in the Singapore Straits, excessive rainfall produced a decrease in the catch rates of these species. Tham ascribed this decline in productivity to high turbidity which made the capture of prey such as copepods and zooplankton in general more difficult. Tham also postulated that a heavy particulate suspension may also interfere with the efficiency of the fishes' respiration.

The rainfall regime at the Ysabel Passage is markedly higher than at Cape Lambert, with mean values for annual rainfall between 1970 to 1981 of 3,307mm and 2,162mm respectively (Fig.8). On average the rainfall at the Ysabel Passage is greater by a factor of 1.5. One possible explanation that would encompass both the results for S. heterolobus and S. devisi from both bait-grounds is that there is an optimum annual rainfall regime. This was tested by combining the results from both locations and fitting a simple parabolic curve to the data of the form $y = a + bx - cx^2$ (Figs. 9 & 10).

The reasonably good fits that result are encouraging but it should be stressed that this simplistic analysis assumes a high degree of ecological similarity between the areas, when, as discussed previously, due to geographic and climatic differences, this may not be the case. The effects of rainfall may work through other environmental factor(s) that differ between the two areas to produce contrary effects. However, it is important to note in this context that the presences of S. buccaneeri at Cape Lambert and the virtual absence of this species from the Ysabel Passage is consistant with the differences between the rainfall regimes at the two locations.

The important conclusions of this analysis are that in two locations in P.N.G. rainfall has a demonstrable effect on the production and yield of stolephorid anchovies, particularly that of S. heterolobus. Management based on effort restrictions alone will not therefore achieve effective stability of stolephorid anchovy production. Whilst a degree of the variability in catch rates of these species can be ascribed to changes in effort (Muller 1976, Dalzell 1983, Dalzell in prep.) marked fluctuations in yield will occur when the annual rainfall alters appreciably.

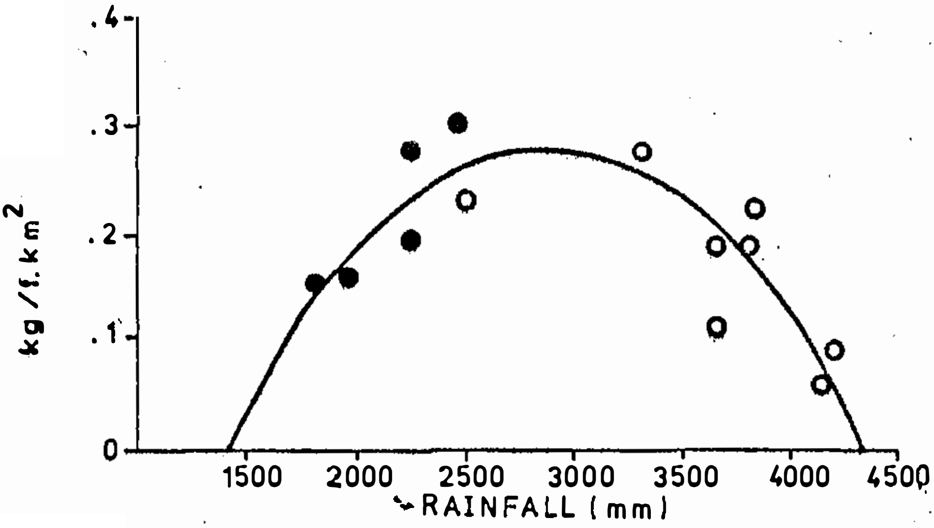

Fig. 9. Possible relationship between rainfall and yield of *S. heterolobus* from combined catch data from the Ysabel Passage (O) and Cape Lambert (●).
$y = -0.752 + 0.7.10^{-3}x - 1.24.10^{-7}x^2$
$r^2 = 0.79$.

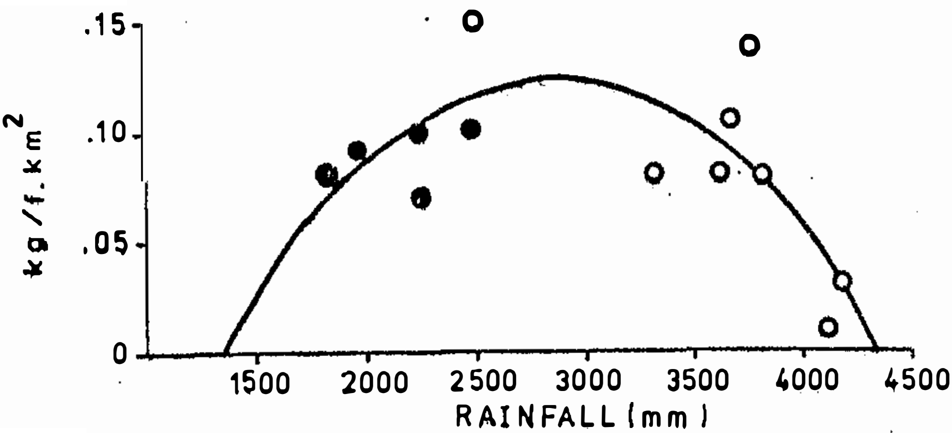

Fig. 10. Possible relationship between rainfall and yield of *S. devisi* from combined catch data from the Ysabel Passage (O) and Cape Lambert (●).
$y = -0.311 + 3.03x - 5.2.10^{-8}x^2$
$r^2 = 0.513$.

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