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FURTHER OBSERVATIONS ON FISHING PERFORMANCE OF BAITFISH SPECIES IN THE SOUTH PACIFIC COMMISSION AREA

(Paper Prepared by the Skipjack Programme)

1.0 INTRODUCTION

Baitfish species from the families Engraulidae (anchovies), Clupeidae (sardines and herrings), Dussumieriidae (sprats) and Atherinidae (hardyheads) are the most commonly used live bait by tuna pole-and-line vessels in the South Pacific Commission area. Their abundance and availability varies greatly amongst countries of this area; this, in part, determines the potential for development and expansion of local pole-and-line fisheries (Working Paper 12). Also of considerable importance is the fishing performance of these baitfish, that is, how well do they survive while confined in bait tanks and how well do they stimulate tunas to bite.

This working paper contrasts performance of the above natural baitfish families, and two cultured baitfish, mollies (*Poecilia mexicana*) and milkfish (*Chanos chanos*), both of which are considered to have some potential as baitfish for pole-and-line fisheries (Gopalakrishnan, 1976 and Bryan, 1980). Measures of tuna catch per unit of bait (the tuna/bait ratio), chumming success, tuna catch per "positive" school, tuna catch per fishing day and daily mortality while held in bait tanks are used as indicators of baitfish performance. Last year we presented a similar comparison between cultured baitfish and an aggregate of natural bait species, using a subset of Skipjack Survey and Assessment Programme data (Skipjack Programme, 1980). Results in this paper are from 488 fishing days in the waters of 21 South Pacific Commission countries.

2.0 DATA USED FOR BAITFISH COMPARISONS

Tropical anchovies, sardines, sprats and hardyheads accounted for 80 per cent of the bait used by the Programme in the SPC area (Table 1); mollies and milkfish represented six per cent. The remaining 14 per cent consisted of various tropical baitfish families (Apogonidae, Caesiodidae, etc.), temperate sardines captured in New Zealand, and temperate anchovies and sardines purchased in Japan.

TABLE 1. KILOGRAMS OF BAIT LOADED ON THE RESEARCH VESSELS FOR FISHING IN SOUTH PACIFIC COMMISSION WATERS*

The most common species that were loaded are listed in order of their abundance by weight within each group.

	Tropical Anchovies	Tropical Sprats	Tropical Sardines	Tropical Hardyheads	Other Tropical Species	Mollies	Milkfish	Temperate Species	Total
Kilograms	27,322	8,771	18,019	2,720	7,134	1,745	2,213	3,128	71,052
Percentage	38.5%	12.3%	25.4%	3.8%	10.0%	2.5%	3.1%	4.4%	

COMMON SPECIES

	Tropical Anchovies	Tropical Sprats	Tropical Sardines	Tropical Hardyheads	Other Tropical Species	Mollies	Milkfish	Temperate Species
1.	Stolephorus devisi	Spratelloides delicatulus	Sardinella marquesensis	Hypoatherina ovalaua	Apogonidae	Poecilia mexicana	Chanos chanos	Sardinops neopilchardus
2.	S. heterolobus	S. gracilis	S. sirm	Pranesus pinguis	Caesiodidae			Engraulis japonicus
3.	S. buccaneeri		Herklotsichthys punctatus		Carangidae			Sardinops melanosticta
4.	Thrissina baelama				Mullidae			
5.	S. indicus							

* These data are from Tables 1 and 2, Working Paper 12

Comparisons presented below are limited to the tropical and cultured baitfish groups which were used while the research vessels were in SPC waters. In these comparisons, anchovies were predominantly from the genus Stolephorus, and sprats were exclusively from the genus Spratelloides. The basic sampling unit was a day of fishing when at least one school was chummed; 406 of 488 fishing days satisfied this criterion. Further filtering of the data set was necessary to isolate the days on which each baitfish group dominated in the bait used as chum. Seventy per cent was used as the cut-off level in allocating a particular fishing day to a baitfish group, that is 70 per cent of bait on board at the commencement of fishing belonged to one group. Due to limited data the hardyhead cut-off level was set at 50 per cent. On average for these groupings, over 80 per cent of the bait used each day was from a single group (hardyheads 69 per cent). Sample sizes for each baitfish group were : anchovies, 90 days; sardines, 37 days; hardyheads, 15 days; mollies, 17 days; milkfish, 20 days; and sprats, 45 days.

Four indices, calculated for each fishing day, formed the basis for fishing effectiveness comparisons. The tuna/bait ratio (the ratio of total tuna catch in kilograms to kilograms of bait used as chum) is commonly used for baitfish comparisons (Baldwin, 1980; Bryan, 1980; Kearney and Rivkin, 1981). The second index, chumming success, is defined as the percentage of schools chummed which responded positively, that is at least one fish was landed by pole-and-line gear. It is one measure of the "attractiveness" of bait to the predator species. A more appropriate index of "attractiveness", at least from a fisherman's point of view, is catch in kilograms per positive school. One could view this index as the ability of a bait species to stimulate intense tuna feeding and to hold tuna within fishing range of the vessel. The fourth index, catch in kilograms per fishing day, is in effect an index which integrates over the previous three indices.

Mortality comparisons utilized the above data sets, but only for those days on which some bait survived until the end of the day, since mortality was estimated at the end of each day on the percentage of bait which survived to the end of the day. Sample sizes for mortality comparisons were : anchovies, 44 days; sardines, 11 days; hardyheads, 12 days; mollies, 16 days; milkfish, 18 days; and sprats, 19 days. The instantaneous rate of mortality, calculated for each fishing day, was the basis for comparison between baitfish groups.

The following information was recorded on each fishing day: hours spent fishing, number of schools sighted while fishing, number of schools chummed, number of "positive" schools, tuna catch per day, percentage species composition of the bait carried at commencement of fishing, kilograms of bait carried at commencement of fishing, kilograms of bait used as chum, kilograms of dead bait, sea condition while fishing (Beaufort scale), and moon age (days after new moon). Tuna catch includes skipjack and other species (yellowfin, mackerel tuna, etc.). However, species other than skipjack accounted for less than 10 per cent of our total catch.

3.0 FACTORS AFFECTING FISHING EFFECTIVENESS AND BAITFISH MORTALITY

Ideally baitfish species should be compared under identical fishing and environmental conditions. This is seldom possible, especially for a broad resource assessment survey such as the Skipjack Programme. However, regional comparisons of baitfish do provide useful information, particularly if some correction can be made for variable fishing and environmental conditions.

3.1 Independent Variables

Hours spent fishing, sea conditions, amount of bait carried and availability of tuna, affect indices of baitfish performance in various ways. Some might question inclusion of moon age and distance from land among such independent variables, yet there are examples (moon age, Kearney, 1977) of relationships between these variables and fishing indices. The Programme obtained measures for all these factors, for each fishing day. Unfortunately, the estimate of tuna availability (number of tuna schools sighted per hour spent fishing) was inversely correlated with hours spent fishing (fishing hours included both time spent searching for tuna, with bait on board, and time spent fishing). Since there was no independent estimate of tuna availability, we simply accepted this added variability and assumed that it was evenly distributed over the days when different bait species were used. Distance from land posed a few problems as well. Because of the mobility of the fishing vessel, it was not possible to estimate either the portion of daily fishing time, or the portion of bait used, for various distances from land. However, distance from land was recorded for each school that we observed. From these aggregate data, presented in Table 2 for seven intervals of distance from land, we conclude that fishing effectiveness probably does not vary systematically with distance from land. Indices of fishing effectiveness were not adjusted for distance from land.

In the analyses presented below we adjusted fishing effectiveness indices (the dependent variables) for four independent variables: hours spent fishing, bait carried at commencement of fishing, sea condition while fishing, and moon age. For mortality comparisons we added a fifth variable, the fraction of bait used for chumming (bait used/bait carried), as this seemed a reasonable proxy for the amount of handling that bait was subjected to during fishing.

Figures 1 and 3 (upper) present, for each baitfish group, average values for the independent variables and 95 per cent confidence limits on these averages. These data illustrate some of the underlying bias and variability which may distort comparisons between baitfish groups. It is not unexpected that simple averages of the dependent variables for each baitfish group have, in many cases, very wide and overlapping confidence intervals (Figures 2 and 3 (lower)).

3.2 A Multivariate Analysis of Baitfish Performance

Multivariate statistics provide a means to isolate the effects of independent variables, and to adjust values of the dependent variables for these effects. After a series of multivariate regression analyses for each baitfish group we concluded that, in general, catch per day was most influenced by the amount of bait carried at the commencement of fishing (positive relationship), followed in importance by sea condition during fishing (negative relationship), and by hours fished (positive relationship). The tuna/bait ratio was negatively related to both sea condition and hours fished. Chumming success was also negatively related to these independent variables. Catch per positive school was generally not strongly correlated with any of the independent variables. Daily baitfish mortality was negatively correlated with the amount carried, that is, the mortality rate generally became less at higher bait densities; and the mortality rate tended to increase with increased bait handling.

TABLE 2. CHUMMING SUCCESS, CATCH PER POSITIVE SCHOOL AND PERCENTAGE OF TOTAL CATCH FOR SEVEN INTERVALS OF DISTANCE FROM LAND

	Nautical Miles from Land						
	0-1	1.1-2.5	2.6-5	5.1-10	10.1-20	20.1-50	>50
Chumming success(%)	53	38	53	52	61	55	42
Catch per positive school(kg)	548	556	296	487	558	487	698
Percentage of total catch	13	12	15	24	17	13	6

TABLE 3. FISHING EFFECTIVENESS INDICES AND DAILY PERCENTAGE MORTALITY ESTIMATES FOR EACH BAITFISH CATEGORY

Indices with asterisks are the uncorrected mean values. The remainder were estimated from the appropriate regression equations for each baitfish category, using average daily values for the independent variables, i.e. 8 hours fished per day, 267 kg of bait carried per day, daily sea condition of 2.8 and moon age of 14 days.

	Catch per fishing day (kg)	Catch per positive school (kg)	Tuna/bait ratio (kg/kg)	Chumming success	Daily percentage bait mortality
Anchovies	1,610	980	9.3	54%	26%
Sardines	1,230	530	7.9	60%	42%*
Hardyheads	245*	265*	3.4*	33%	27%*
Mollies	405	230*	13.2	53%*	8%
Milkfish	1,275*	470*	14.0*	54%	5%
Sprats	1,145	560*	10.0	56%	9%

Most relationships were, of course, not altogether surprising, although they did not dramatically reduce residual variation in the dependent variables (average R^2 of .276). What was of some interest were the relationships for individual baitfish groups. Figures 4 to 8 present bi-variate plots for some of the baitfish groups and some of the variables. For example, note in Figure 4 that chumming success for sardines tended to increase under adverse sea conditions, and that the tuna/bait ratio for mollies (and chumming success, not shown), tended to decrease with worsening seas. Thus, it is not unexpected to see in Figure 5 that these two groups have opposite relationships between catch per day and sea conditions (mollies-negative and sardines-positive). These relationships suggest differences in behaviour between the species. For example, sardines may school more effectively near the vessel when seas are rough, whereas mollies, being small and weak swimmers, may be carried further from the vessel (or blown away in the wind) under similar rough conditions.

Another interesting correlation was between baitfish mortality and the amount of baitfish carried. Sprats (Figure 8 upper) and anchovies often had low mortality at high baitfish density. Perhaps this also reflects behavioural differences attributable to schooling. When larger amounts of bait were held in the bait wells, both groups were observed to form tight schools, and to settle down quickly after having been disturbed. The positive relationship between the bait handling index (percentage of bait used) and bait mortality for milkfish (Figure 8 lower) is, of course, not unexpected.

One could continue with bi-variate comparisons such as the above. They are interesting, but they do not allow one to decide how the baitfish groups rank with respect to overall performance. Statistical analyses are continuing. However, at this time we are confident that what we present below reflects a reasonable ranking of the different baitfish groups.

4.0 SPECIES COMPARISONS AND CONCLUDING REMARKS

Table 3 presents averages of fishing effectiveness indices and daily percentage mortality for each baitfish group. These values have been adjusted for bias due to the independent variables whenever there were statistically significant relationships between dependent and independent variables. To calculate corrected values we assumed average fishing and environmental conditions (see caption Table 3), and calculated these from a random sample of the complete data set (148 days chosen from a total of 406 days). Because some of the averages in Table 3 have been extrapolated beyond the range for certain independent variables, we caution against making detailed quantitative comparisons.

From the above data some generalizations can be made. Hardyheads were clearly the least effective bait, and mollies were not much better. Sprats, sardines, and milkfish performed equally, and all three produced higher catches than mollies and hardyheads. Stolephorid anchovies produced the highest tuna catches, and performed reasonably well for the remaining fishing effectiveness indices. This ranking of baitfish groups did not change substantially when fishing and environmental conditions were varied.

These would not have been our conclusions if we had simply compared tuna/bait ratios. Tuna/bait ratios are heavily dependent on fishing strategy, which changes with the amount of bait carried, sea conditions, and so on. When fishermen are conserving bait, which was often our strategy with mollies and milkfish, chummers will throw only the minimum bait necessary to attract and keep tuna within range of the polers. Chummers often "waste" bait when a surplus of bait is on board. Clearly these strategies will distort baitfish comparisons based solely on the tuna/bait ratio.

Mollies, milkfish, and sprats all had relatively low rates of mortality in the bait wells (less than 10%). In contrast, sardines, anchovies, and hardyheads experienced high daily mortalities in the range of 25 to 45 per cent.

What can be said in summary? Hardyheads worst? Anchovies best? Unfortunately, the analysis of baitfish performance is not so simple. There are obviously situations where each of the baitfish groups can be used effectively. These situations will depend on fishing strategies, fishing costs, baitfish availability, baitfish costs, as well as indices of baitfish performance as noted above. Even the least effective bait species can and has produced reasonable catches, though whether economical catches can be maintained over lengthy periods using the poorer species is doubtful.

5.0 REFERENCES

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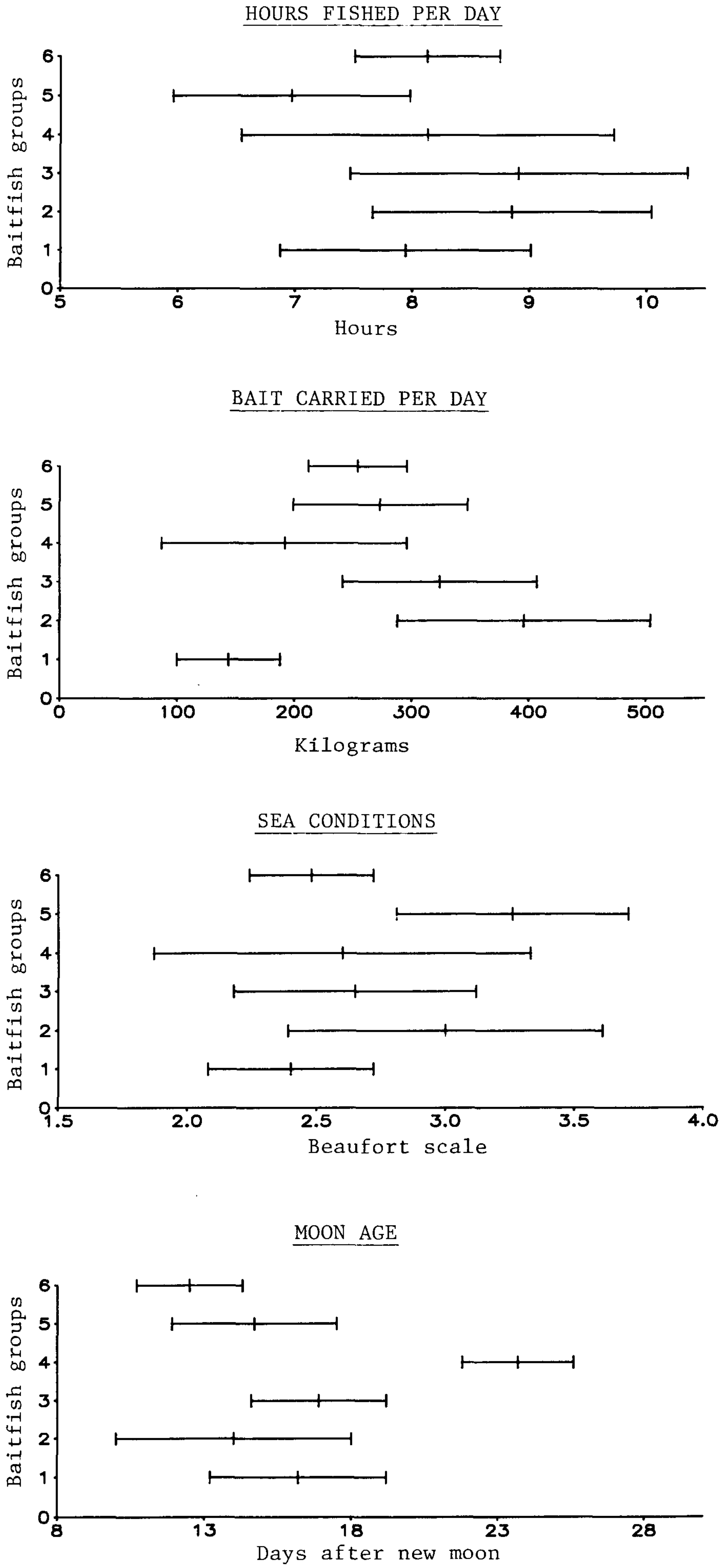


Figure 1. Means (middle bar) and 95 per cent confidence limits on the means for independent variables for each baitfish group. Baitfish groups are: sprats, 1; milkfish, 2; mollies, 3; hardyheads, 4; sardines, 5; anchovies, 6.

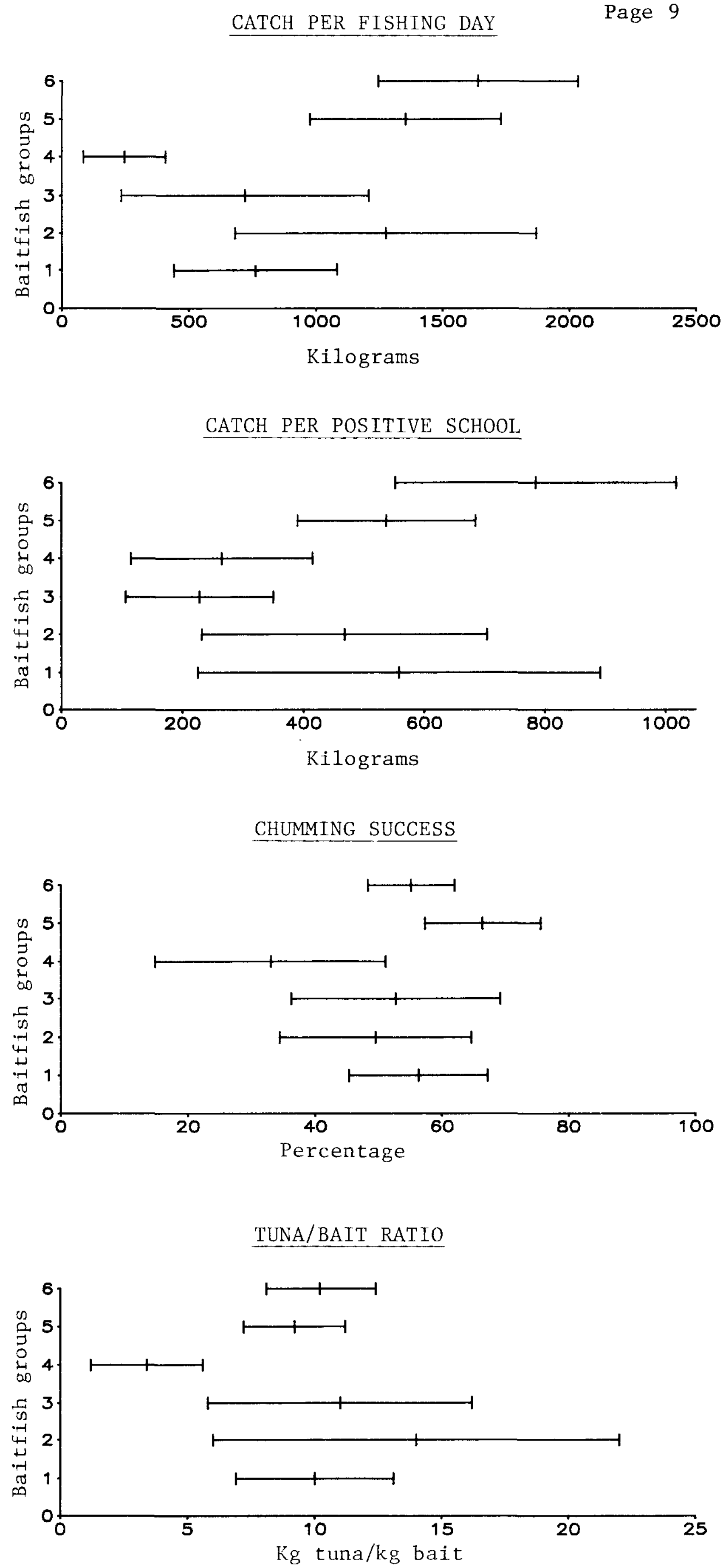
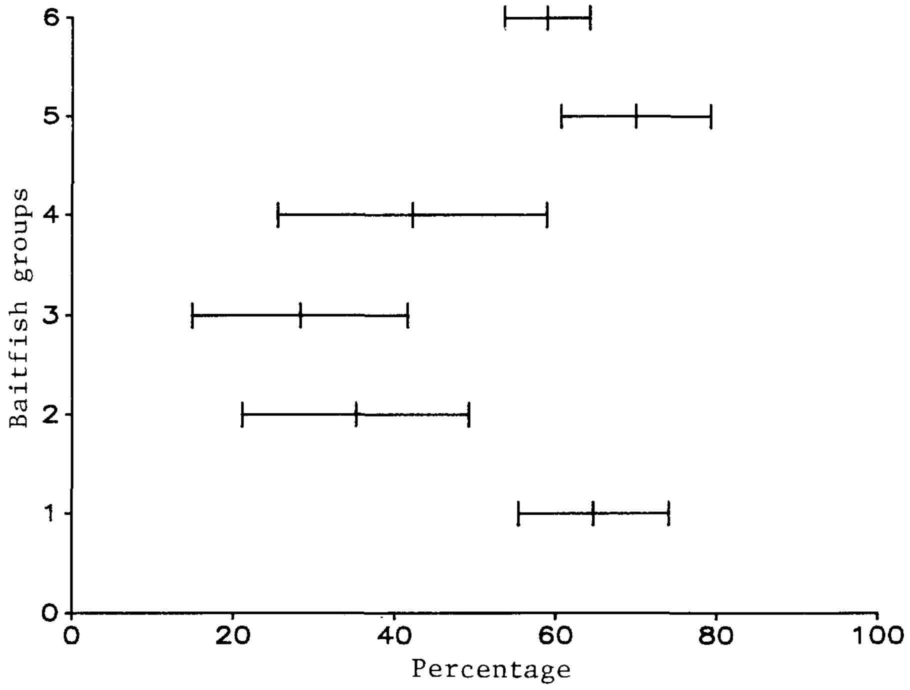


Figure 2. Means (middle bar) and 95 per cent confidence limits on the means for fishing effectiveness variables for each baitfish group. Baitfish groups are: sprats, 1; milkfish, 2; mollies, 3; hardyheads, 4; sardines, 5; anchovies, 6.

BAIT USED/BAIT CARRIED



DAILY MORTALITY

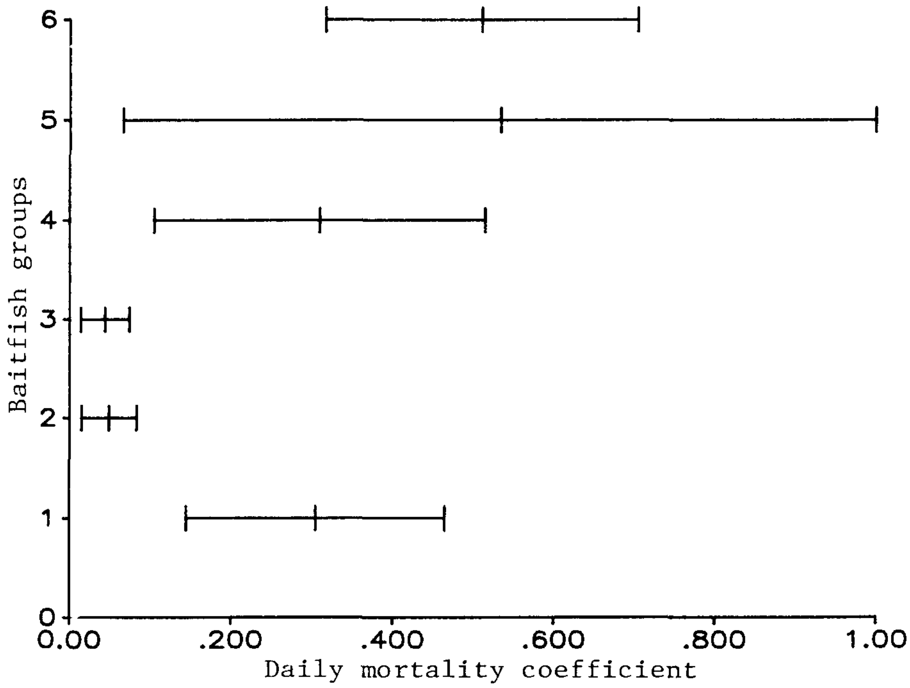
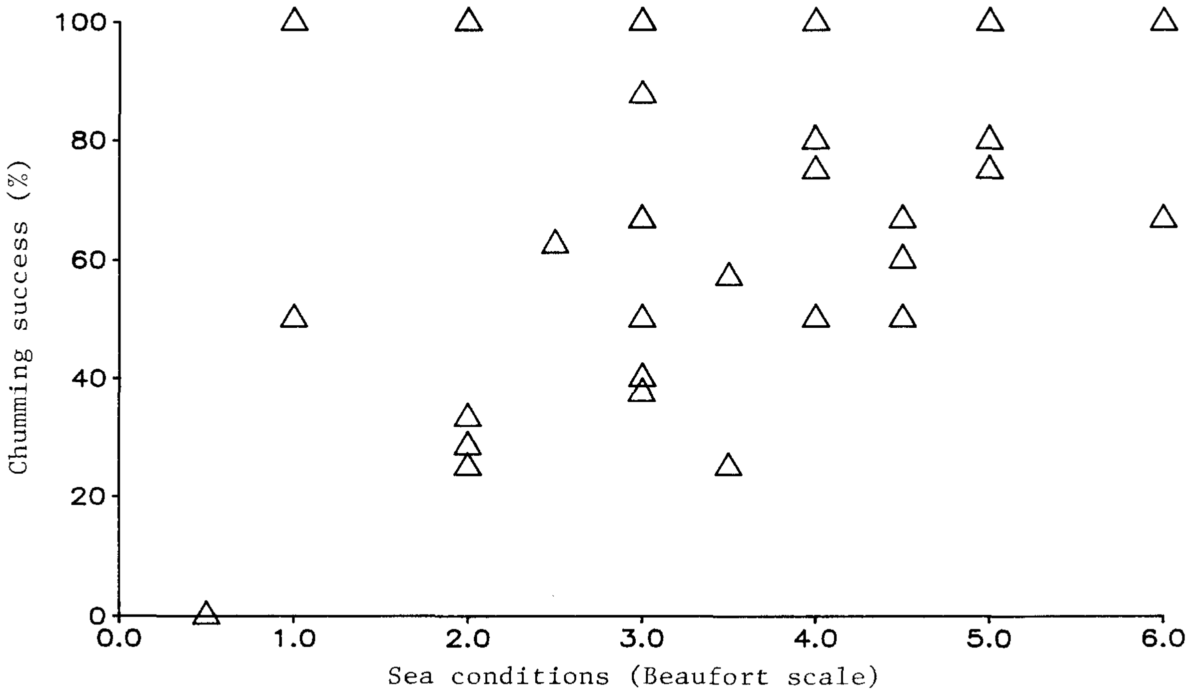


Figure 3. Means (middle bar) and 95 per cent confidence limits on the means for percentage of bait carried that was used as chum (upper), and for daily mortality coefficients (lower), for each baitfish group. Baitfish groups are: sprats, 1; milkfish, 2; mollies, 3; hardyheads, 4; sardines, 5; anchovies, 6.

SARDINES

R = 0.339
N = 37



MOLLIES

R = -0.563
N = 17

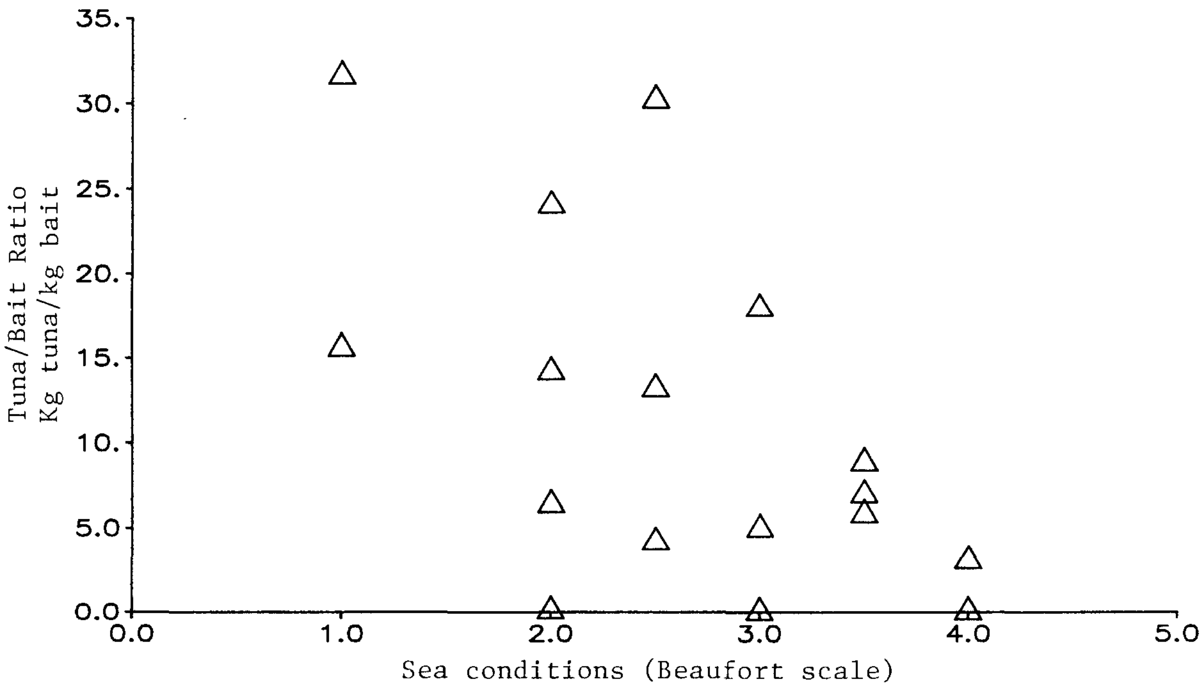
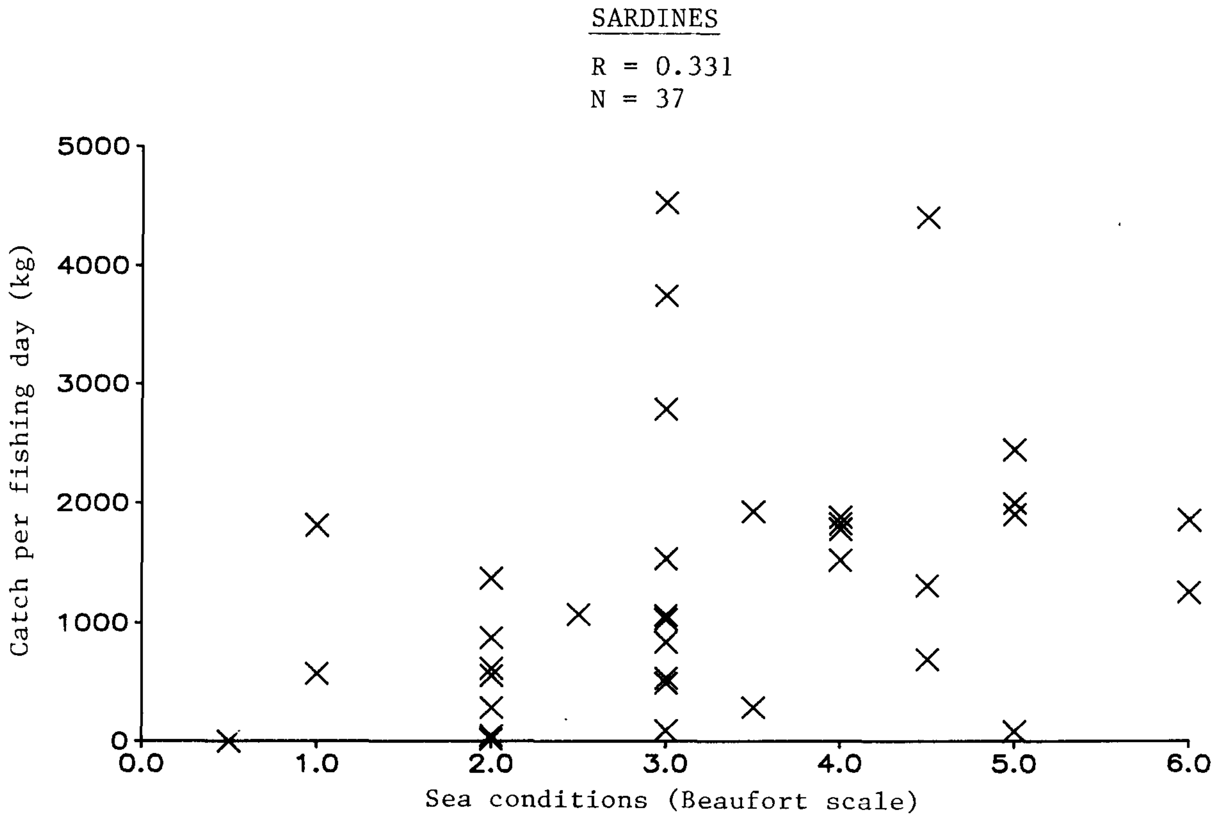


Figure 4. Plots of chumming success versus sea condition for sardines, and tuna/bait ratio versus sea condition for mollies. R is the correlation coefficient; N is the sample size.



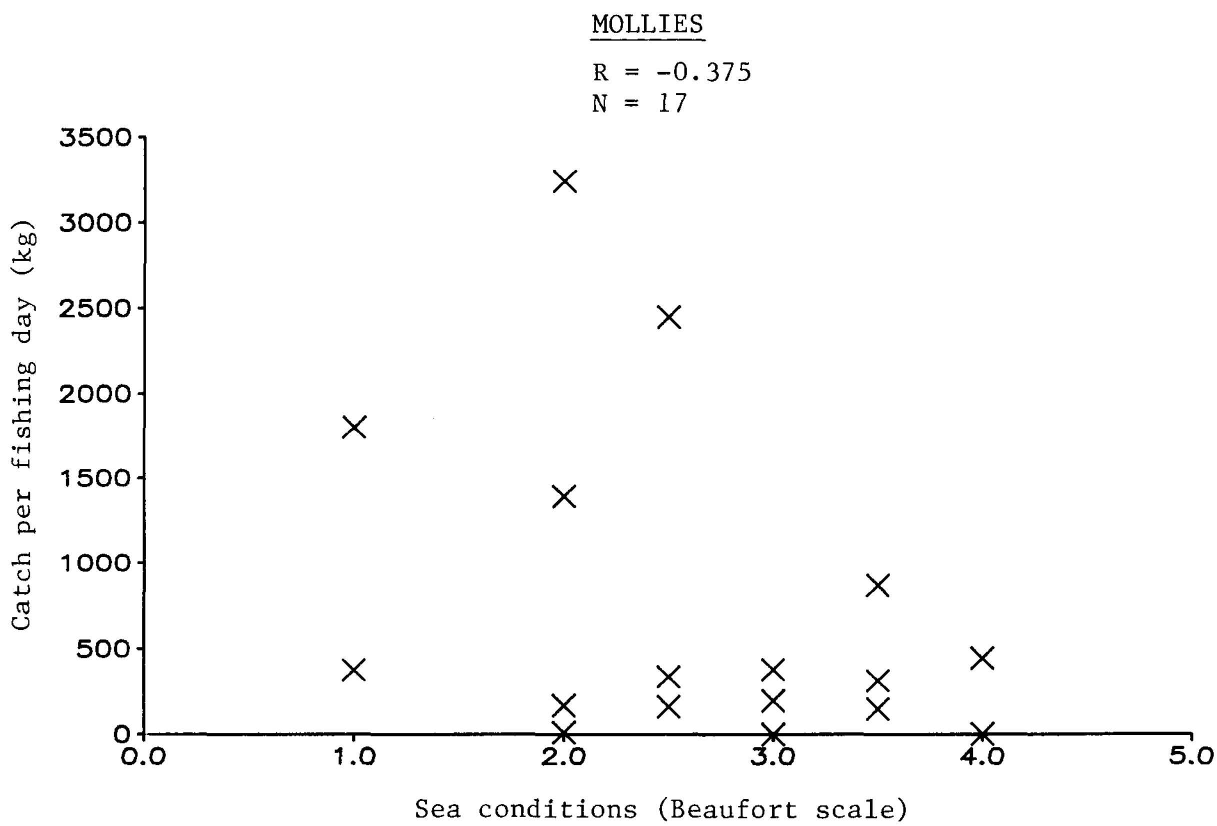
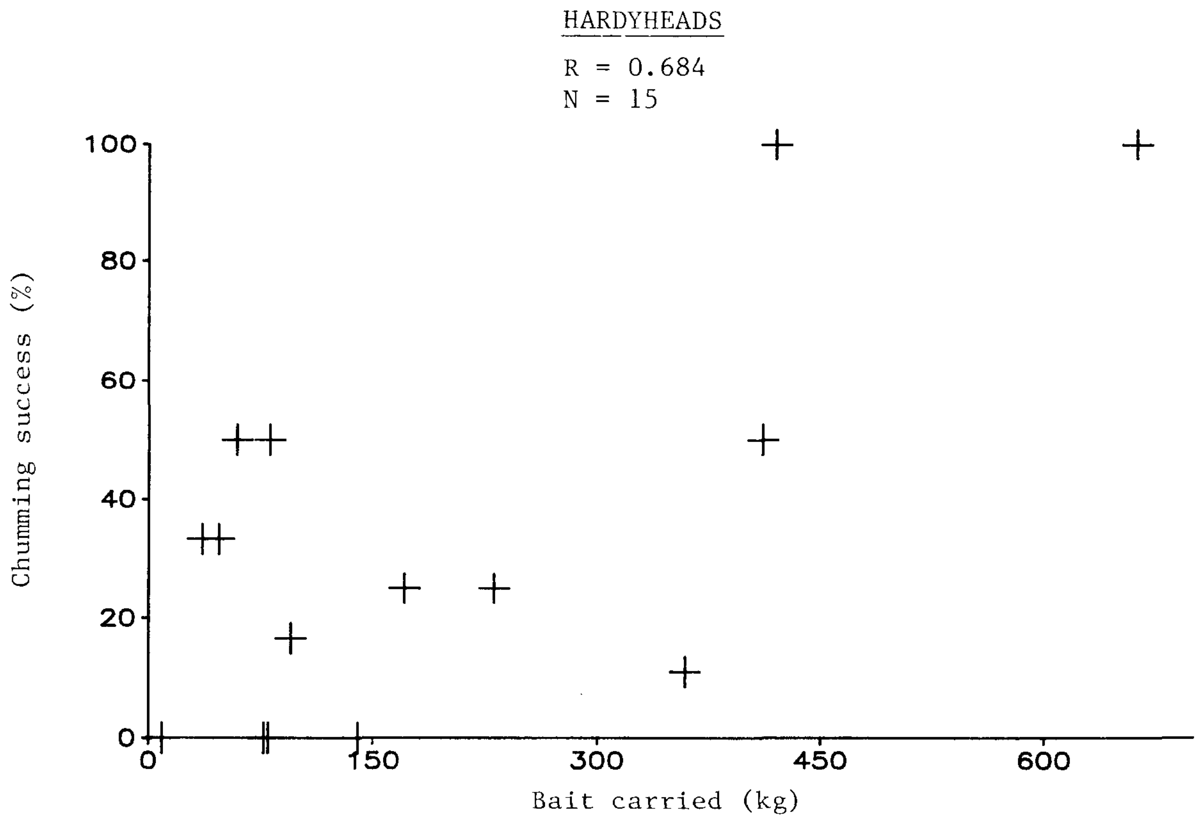


Figure 5. Plots of tuna catch per fishing day versus sea condition for both sardines and mollies. R is the correlation coefficient; N is the sample size.



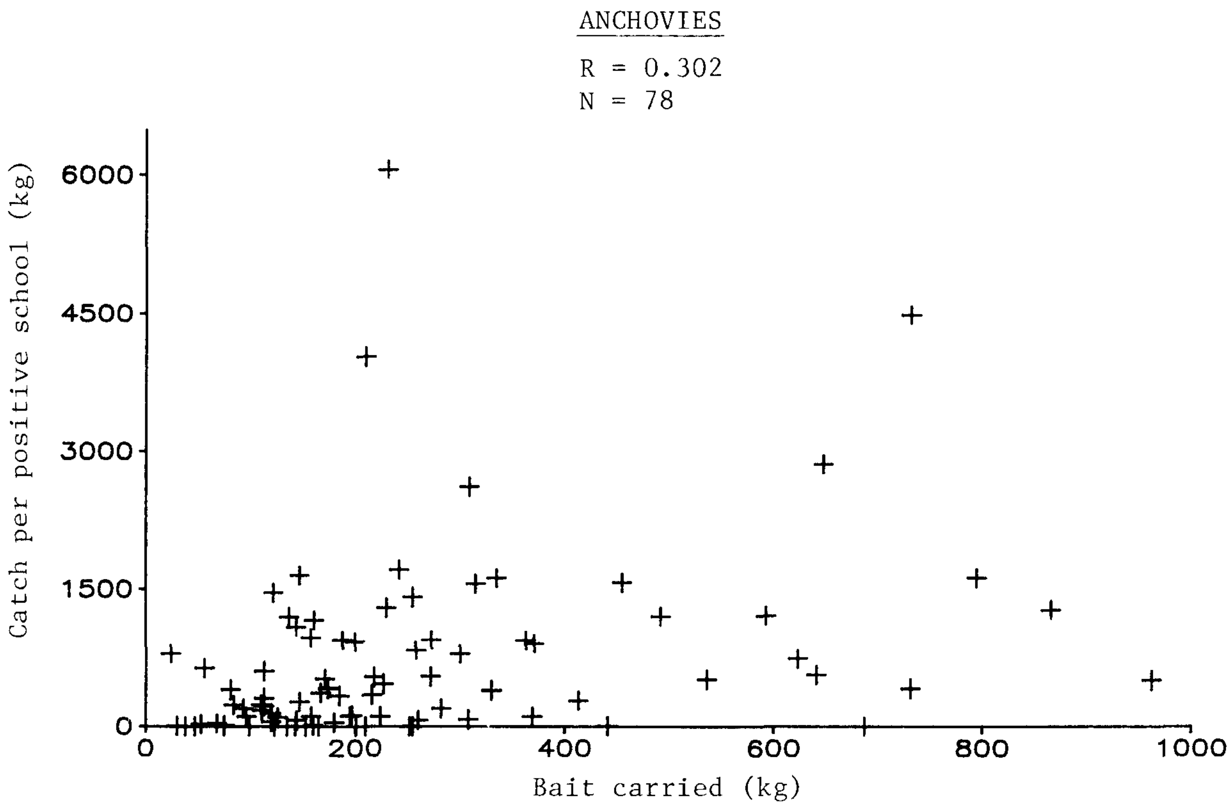
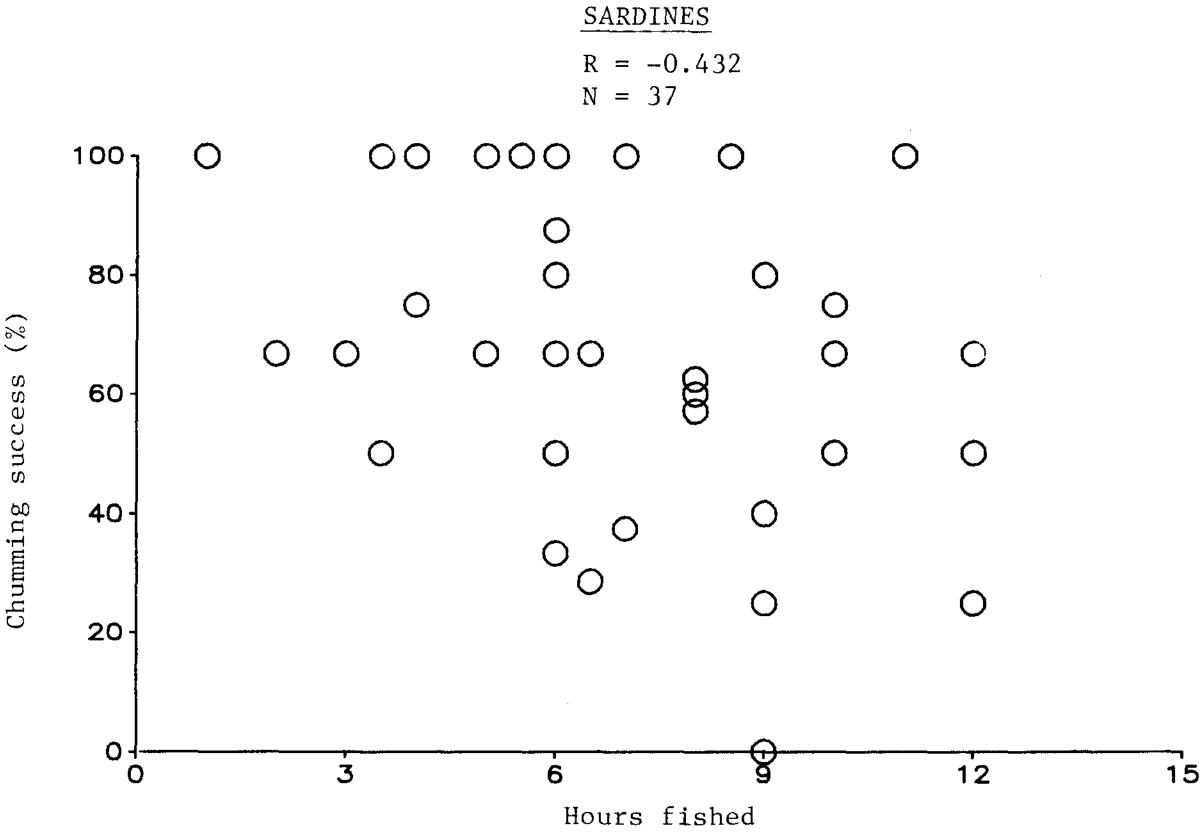


Figure 6. Plots of chumming success versus bait carried at commencement of fishing for hardyheads, and tuna catch per positive school versus bait carried for anchovies. R is the correlation coefficient; N is the sample size.



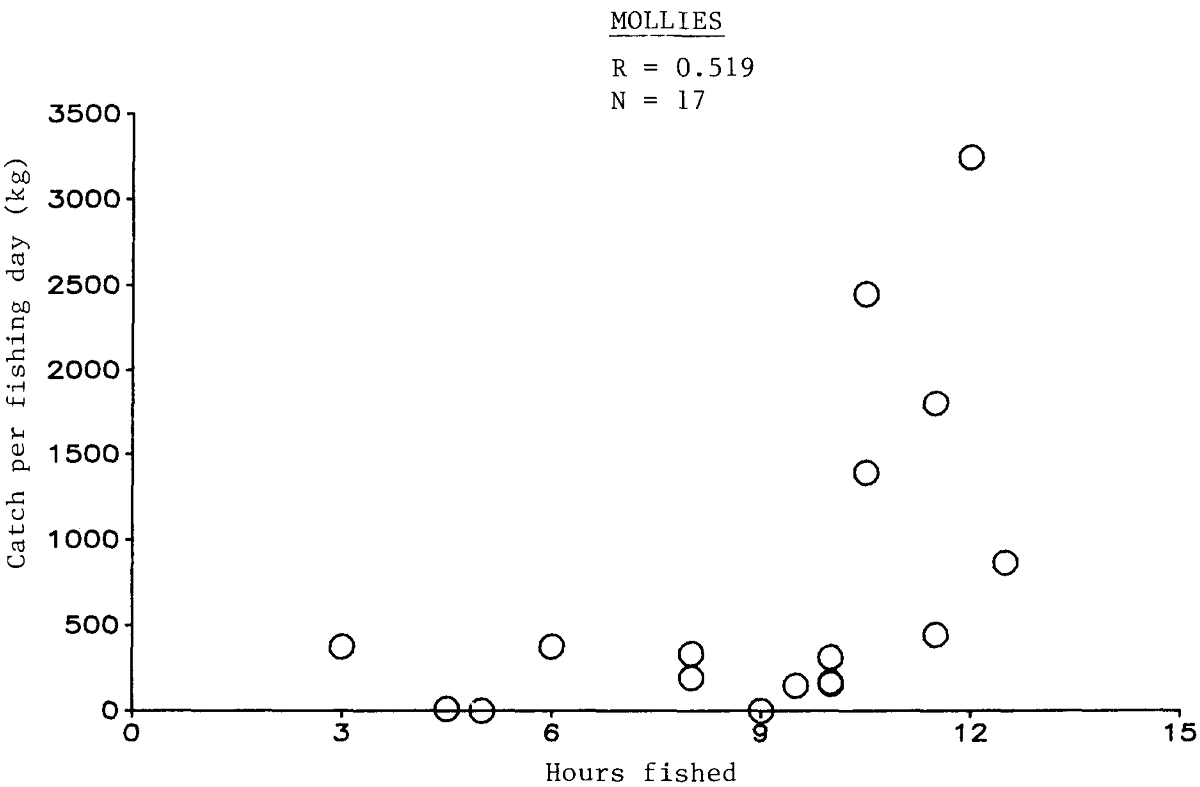
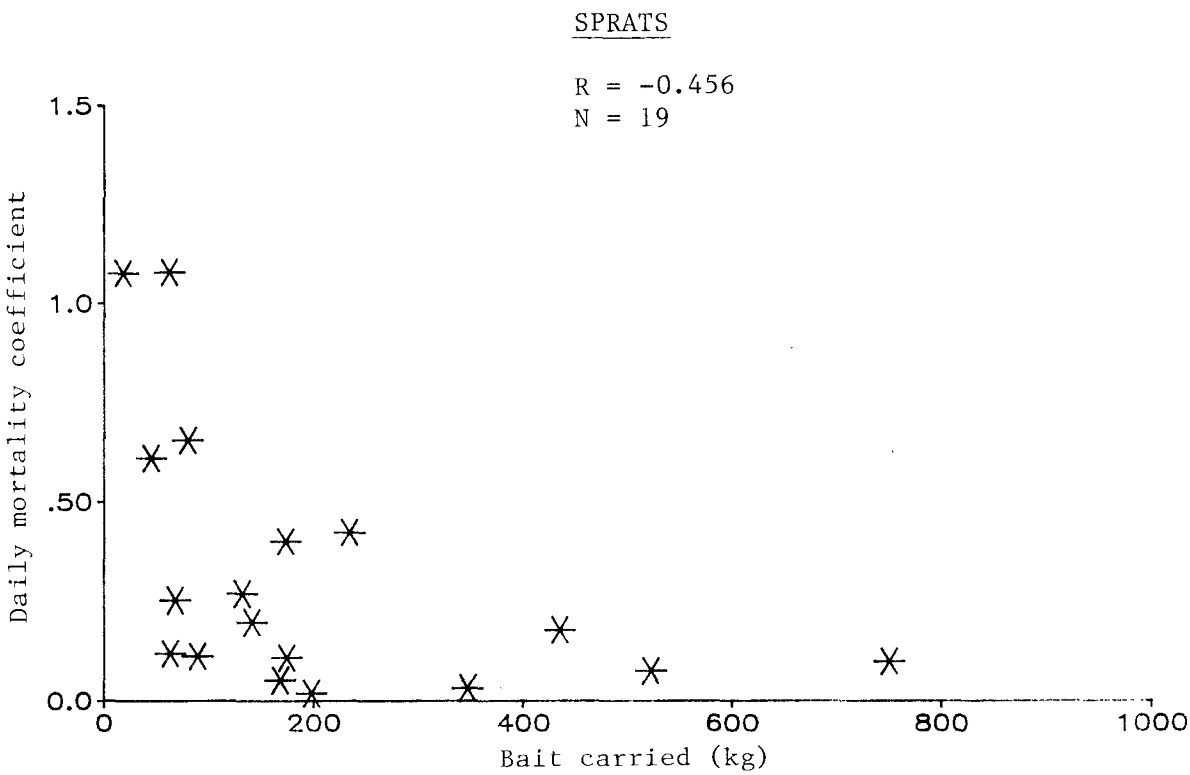


Figure 7. Plots of tuna catch per day versus hours fished per day for mollies, and chumming success versus hours fished per day for sardines. R is the correlation coefficient; N is the sample size.



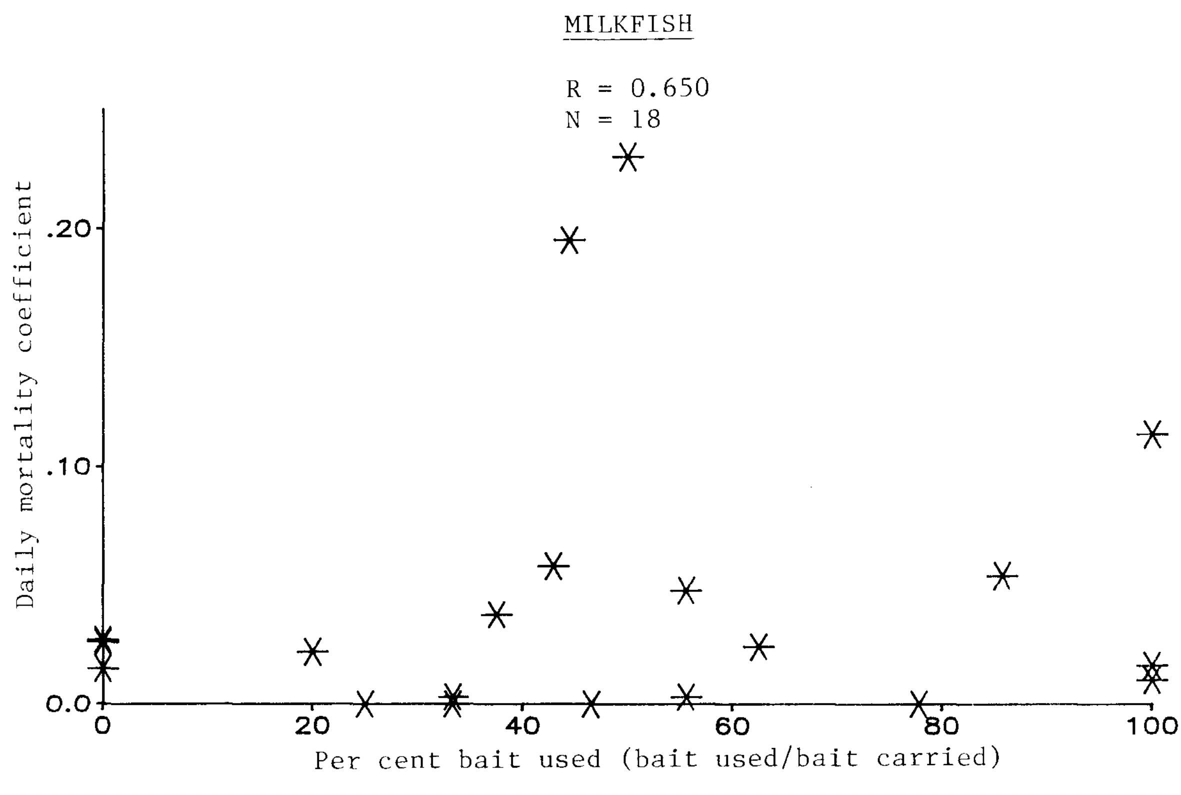


Figure 8. Plots of daily mortality coefficient versus bait carried for sprats, and daily mortality coefficient versus percentage of bait carried that was used as chum for milkfish. R is the correlation coefficient; N is the sample size.