22

Sources of variability in catch per trip for the flyingfish, *Hirundichthys affinis*, fishery in Barbados

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Abstract: This study investigates the reliability of catch per trip as an index of abundance in the Barbados day-boat flyingfish (*Hirundichthys affinis*) fishery by investigating effects of variation in boat, gear, trip and fisherman characteristics, as well as effects of environmental factors, on trip frequency, catch and catch per trip. Trip frequency was the best predictor of total catch. The number of trips landing at Speightstown was lower for boats with higher catch per trip. This suggests that successful boats either fish more often or land at alternate sites more often. Catch per trip was not correlated with either boat age, boat length or boat horse power; and was not correlated with fishing gear power (effective net area). Moreover, effects of daily variation in the environmental variables measured (rainfall, temperature, cloud cover, wind speed, relative humidity, and luminescence) on trip frequency, total catch and catch per trip were either statistically insignificant or negligible. However, catch per trip was highest for fishermen with the most fishing experience, and was highest for fishermen who returned latest to mooring (longest trip duration). A quantitative socio-economic investigation should now be conducted to determine whether fishermen could increase their total catch, and hence total income, by increasing seasonal trip frequency and daily trip duration.

INTRODUCTION

Overview of the flyingfish fisheries of the eastern Caribbean

For the past three centuries, the economies of the islands of the eastern Caribbean have been based primarily on agriculture, with sugar cane being the crop of greatest importance. Faced with increasing population sizes, declining prices for traditional agricultural exports, a rising public expectation for a higher standard of living and a consequent increase in agricultural and non-agricultural imports, the now politically independent islands have increasingly turned to marine fisheries to help meet their social and economic goals. With an increased emphasis on marine fisheries came a steady increase in the size, power and overall capability of fishing vessels, and an improvement in the effectiveness of fishing gear, in many eastern Caribbean islands. The consequence has been an increase in fishery yields. Consumption of fish products has also increased, rising by two-thirds over the twenty year period 1960-1980 (FAO 1988). An increasing export market, and increased local consumption, have in turn led to further development of fisheries, with the principal emphasis being on oceanic pelagic fishes, such as tuna, dolphin, kingfish, billfish and flyingfish.

Flyingfish, and specifically *H. affinis*, is the major component of the catch in many islands of the eastern Caribbean (Mahon *et al*. 1986). It has been exploited in the region since the 1700s (Storey 1983). Commercial fisheries for *H. affinis* are now established in Tobago, Grenada, St. Lucia, Barbados, Dominica, Martinique and off the north east coast of Brazil (Oxenford 1986). In addition to *H. affinis*, the fishery also occasionally captures *H. speculiger*, *H. rondeletii* and a limited number of *Cypselurus heterurus*, *C. comatus* and *C. cyanopterus* (Storey 1983, Jones 1984, Khokiattiwong 1989).

Despite improvements in vessels and gear, flyingfish fisheries remain largely artisanal in most islands. The boats used vary in size from 14 ft (4.3 m) open canoes and pirogues (in St. Lucia, Grenada and Dominica) to 50 ft (15.2 m) partially covered launches (in Barbados, Tobago and Dominica). The power supply varies from inboard diesel engines to outboard petrol engines. Gillnets, dip nets and handlines are used in all the fisheries, along with some form of fish aggregating device (FAD).

Historical review and current status of the Barbados flyingfish fishery

The three most significant developments in the Barbados flyingfish fishery over the past 50 years have been the transition from sails to inboard engines, the introduction of gillnets, and a gradual increase in boat size. The increase in boat size has been accompanied in recent years by an ongoing transition from smaller boats making daily trips (day-boats) to larger boats staying at sea for several days per trip (ice-boats) (Hunte and Oxenford 1989). The transition from sails to engines, the increase in boat size and the change in boat type have allowed a considerable expansion of the area fished, resulting in a trend of increasing catch in the flyingfish fishery.

Sails to engines

The traditional vessels used in the flyingfish fishery were sailboats and row boats (Brown 1967). Their use was continued until the early 1950s when there was apparently a decline in the number of fish being caught near the coast. This initiated the change from sail to inboard engines, an innovation which extended the fishing range of the vessels and resulted in an increase in catches of motorised vessels compared to sailboats (Brown 1967). Despite the increased range and catch that accompanied motorisation, initially the development was slowly accepted, since fishermen were largely untrained in the use and maintenance of engines. In 1952, only five percent of the fleet was powered by inboard engines.

The transition to motorisation was rapidly accelerated by the extensive destruction of the sailboat fleet by hurricane Janet in 1955. This necessitated a major rebuilding programme, and provided the opportunity to increase the number of boats with engines. By 1956, one third of the vessels were motorised, and by 1959 almost the entire fleet of 450 boats was motorised (Brown 1967).

Gillnets

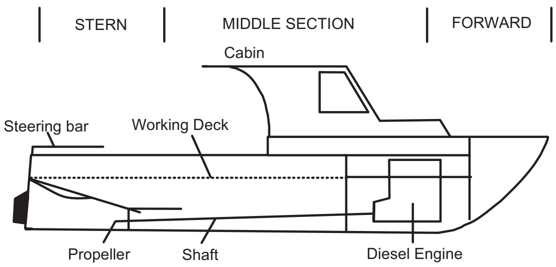
Traditionally flyingfish were caught by scooping up fish with elliptical dip nets about 1 m by 1 m. Fish were often attracted by chumming (bait baskets of rotting fish), and fish aggregating devices (FADs), known locally as screelers, which were typically composed of dead plant material, (e.g. palm or coconut fronds), rope, and pieces of sacking inter alia. The screelers attract flyingfish by providing a surface for spawning. The gillnet was introduced in the 1951-1952 fishing season. Fish swim into the net, but if an appropriate size, can only pass part way through. Backing out of the net is prevented by the net twine slipping behind the gill. Following research conducted by D. Wiles (Hall 1955), gillnets with a mesh size of 1 7/8" (4.8 cm) were initially found to provide best catches by fish numbers and total weight in the Barbados flyingfish fishery.

By the end of 1952, over half the fishing fleet had been equipped with gillnets and by 1953 the entire fleet was so equipped. The result was a marked increase in flyingfish catches. Today, monofilament nylon gillnets with mesh sizes of 1 1/2" to 1 5/8" (3.8-4.1 cm) are used in the fishery (Harding 1986), and screelers continue to be used. Handlines and dipnets are still employed during periods of high fish abundance.

Boat size and type

Following transformation to motors, there has been a gradual increase in engine power, paralleled by an increase in average boat size (from 6.8 m in 1961 to 8.8 m in 1986, McConney 1987, Hunte and Oxenford 1989). Fishing is now conducted from launches known locally as day-boats (Figure la), or ice-boats (Figure 1b).

(a) Day-boat (10 m)



(b) Ice-boat (15 m)

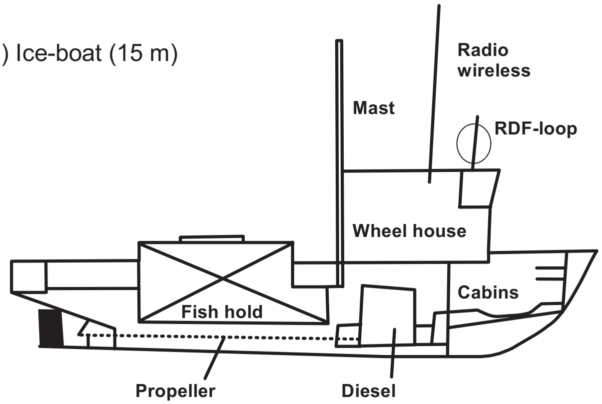


Figure 1. A comparison of (a) day-boat and (b) ice boat designs (After McConney 1987).

Day-boats vary in size from 7 m to 10 m; have partially covered decks, are outfitted with 22 to 225 hp engines, and return to landing sites daily (Jones 1984). Ice-boats are 12 m to 15 m in length, have 120 hp to 215 hp engines, have ice holds with total capacities of 8 to 10 tons and remain at sea several days before returning to port (Jones 1984, Hunte and Oxenford 1989).

Ice-boats were first introduced in 1978. By 1989, there were 82 ice-boats and 463 day-boats in the fishing fleet (Mahon 1989). Ice-boats have the capacity to fish up to 400 miles off the island, but fish mainly in the triangle between Tobago, Grenada and Barbados. Day-boats continue to fish 5 to 15 miles (9-28 km) off the coast of Barbados, within sight of the island. The introduction of the ice-boats, along with the gradual increase in size of the day-boats, has accompanied by a rapid increase in flyingfish catch (Hunte and Oxenford 1989)

Landing sites

Fish are currently landed at three primary landing sites: Bridgetown Fisheries Complex (BFC) on the south west coast, Oistins on the south coast and Speightstown on the north coast (Figure 2). A primary landing site at Bay Street was closed upon the opening of BFC. The landing site at Oistins was completed in 1983 and designed to service 80 fishing boats, while the BFC, completed in 1989, can accommodate approximately 150 boats. Both of these sites have docking, refrigeration, fuel supply and other support facilities. There are also seven secondary landing sites, with sheds and slabs for cutting fish, and a number of tertiary sites which are beach and bay areas where boats are moored or beached (Figure 2, Bell *et al*. 1988).

Data collection

Information on weight of flyingfish landed by individual vessels has been recorded at Speightstown, Oistins and Bay Street fish markets since 1958. Prior to 1983, flyingfish were counted and converted to weight at a rate of 3 fish / lb (7 fish / kg) (McConney 1983). Presently, all species are weighed and recorded on a daily basis by the Market Assistants at the primary sites. These data provide a continuous and reliable time series of data on catch rate and flyingfish abundance for the flyingfish fishery.

Use of catch, effort and catch per unit effort data

Analytical models for the assessment of fishery stocks require information on a number of life history parameters, e.g. age, growth and mortality rates. It is often difficult to obtain reliable information on these variables. However, there are assessment models, such as surface production models, which require only catch and effort statistics. Thus catch and effort statistics constitute the minimum requirements for a simple assessment of a fishery (FAO 1980).

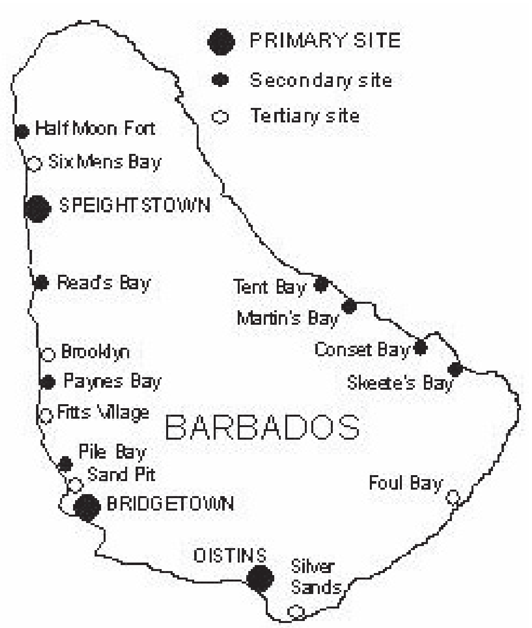


Figure 2. Fish landing sites in Barbados (adapted from Bell *et al.* 1988).

The term "catch" is often used synonymously with "landings". More strictly, landings refer to the weight of fish and fish products brought ashore, whereas catch, or nominal catch, refers to the live weight equivalent of the landings (FAO 1980). The two terms are equivalent where all catch is brought ashore. However, when a portion of the catch is discarded before docking, the landings may be lower than the catch. In this study, catch will be used as defined above, i.e. live weight equivalent of the landings, unless otherwise stated.

Higher catches may indicate increased fish abundance, but may also result from longer fishing hours or more fishing gear, i.e. increased fishing effort. Information on fishing effort is therefore necessary if catch statistics are to be used to provide information on the abundance of stocks. Examples of units of effort include number of boat days, number of hooks set, number of boat trips and quantity of gillnets set.

Catch and effort data are often combined to produce a catch per unit effort (CPUE) statistic. CPUE is strictly an index of availability of the fishery resource. Availability describes the degree to which the fish stock is vulnerable to capture. It varies, inter alia, with abundance of the fish and with variation in their susceptibility to the gear. Susceptibility to the gear is referred to as catchability. An accurate estimate of fishing effort, and if possible an indication of whether there is variation in catchability, are therefore invaluable in following changes in abundance through the CPUE index (Rothschild 1977).

Reliability of CPUE as an index of abundance

Constraints on estimating unit fishing effort

Many vessel and fisherman characteristics can influence the quantity of fish taken by a vessel per unit time or per trip, and hence influence the accuracy of vessel time or trip as a unit of fishing effort. These include the size and age of the vessel, its storage capacity, the skill of the crew and the availability of technological aids (FAO 1980, O'Brien and Mayo 1988, Oxenford 1985). Many of these fleet characteristics will tend to improve with time, leading to increased effective fishing effort with time. Gulland (1983) has emphasized that this must be accounted for when using CPUE as an index of abundance over time, since it will lead to overestimates of abundance in later years (see also O'Brien and Mayo 1988). Finally, weather conditions may also influence effective fishing effort, since weather affects trip decisions, trip duration, the area fished and the efficiency of vessel and gear operations (Gates 1984).

Variation in catchability

Even assuming an accurate estimate of fishing effort, the relationship between catch, fishing effort and fish abundance, embodied in the concept of catchability, is complex and can significantly affect the reliability of CPUE as an index of abundance (Winters and Wheeler 1985). Increasing fishing effort should lead to increased fishing mortality, where fishing mortality is defined as the proportion of the stock taken by the fishery, and is used synonymously with the term "catch rate". The simplest assumption is that one unit of fishing effort (f) removes a constant proportion of the stock, and is therefore directly related to fishing mortality (F) by a constant (q) which is called the catchability coefficient, i.e. $F = qf$. Catchability may therefore be defined as the fraction of a fish stock that is caught by a defined unit of effort (Ricker 1975), and is a measure of the susceptibility of fish to the fishing gear. Typically, as effort increases, there will be a proportional increase in catch provided that the fraction of the population susceptible to capture by a unit of effort (i.e. the catchability coefficient) remains constant.

The above relationship assumes that q is constant and thence that there is a linear relationship between fishing effort and catch. The reliability of CPUE as a measure of abundance is therefore affected by the extent to which the catchability coefficient, q, may vary. For most fisheries, there will be a range of efforts for which q may remain approximately constant. However, this may not be true at high levels of effort because of competition between units of effort and/or changes in response of the fish to the fishing activity. Catchability may also change with stock abundance. For example, a declining stock may often be associated with increasing catchability, so that the observed decline in CPUE underestimates the actual fall in stock abundance (Gulland 1983). Finally, variation in fish behaviour, often triggered by variation in environmental factors, may lead directly to variation in q, or indirectly through temporal or spatial changes in fish distribution (O'Brien and Mayo 1988).

Environmental effects on abundance and catchability

Environmental variability is a major cause of variation in availability of fish resources (CPUE), since it may affect both abundance and catchability of fish (Cushing 1983). Catches in different fisheries have been shown to be correlated with river discharge (Mahon 1986, Mahon 1990), wind-induced circulation, residual drift, water stability and eddies, large-scale weather systems, major oceanographic events, and temperature (Cabiio *et al*. 1987), flood, pollution, turbidity (Marais 1988), turbulence, food and predation (Anthony and Fogarty 1985), water transparency and salinity (Marais 1988). Water temperature and wind have received particular attention in this context.

Temperature affects the rate of metabolic processes and thus can directly affect survival, growth, recruitment, feeding rates and distribution of marine organisms. Temperature can also have indirect effects on production in higher trophic levels by influencing primary and secondary production (Fogarty 1988). It can therefore influence the availability of critical food types at various developmental stages or, by reducing growth rate, leave young susceptible to predators over a longer period (Everhart and Youngs 1981). Temperature may also affect the distribution or abundance of a predator, and therefore have a secondary effect on prey (Anthony and Fogarty 1985). Finally, temperature may act primarily as a proxy variable, i.e. an indicator of other changes in the environment with more direct effects on fish, e.g. as an indicator of advective changes of water masses (Laevastu and Hayes 1981), or as an indicator of upwelling areas (Anthony and Fogarty 1985).

Where data on water temperatures are unavailable, air temperatures may be used in correlation analyses with catch data, since there is some correlation between air and sea temperatures. For example, the difference between the two in the Atlantic Ocean ranges from negligible in July to slightly lower air temperatures than sea temperatures in January (Van Loon 1984). The mechanisms of interactions between oceans and atmosphere are the subject of ongoing research.

Wind may influence the availability of fish in several ways, one of which is its production of surface gravity waves and orbital currents. Variation in wind speed and, direction may cause oscillations which are strongly confined to the surface layer. This results in large vertical shears which in turn cause instabilities and generate turbulence (Hasse and Dobson 1983). Turbulence and waves can influence vertical movement and distribution (Laevastu and Hayes 1981), since fish tend to avoid the upper layers of the sea during adverse weather.

Environmental effects on spawning behaviour of fish may influence their immediate availability as well as their ultimate abundance. Current speed and direction may show daily, lunar and seasonal periodicity (Anthony and Fogarty 1985), and fish spawning is often correlated with the periodicity. For example, many coastal fish spawn at times of the month and locations that favour current-driven transport of their pelagic eggs and pelagic larvae offshore where predation is reduced (Johannes 1978, Hunte and Cote 1989, Hunt von Herbing and Hunte 1991). Moreover, seasonal spawning may occur at times of the year when prevailing winds or offshore currents are at their weakest, thereby reducing the transport of larvae long distances from their origin (Johannes 1978). Mahon *et al*. (1982) and Lao (1989) have suggested that eddies could serve to reduce dispersal of larvae and juveniles from the vicinity of islands until they are capable of actively swimming against the current.

Objectives

Variation within the unit of effort and variation in catchability will constrain the reliability of CPUE as an index of abundance in all fisheries, and variation in environmental factors can influence both unit effort and catchability. Removing these effects, and hence improving the reliability of CPUE, is difficult. A major constraint is that almost nothing is typically known about the allocation of effort by individual vessels, and some of the variables which affect this, such as skill of crew, are difficult to quantify. A second constraint is that little is typically known about effects of environmental factors on catchability. Neither variation within unit effort, nor effects of environmental factors on unit effort or catchability, has previously been investigated for the flyingfish fishery in Barbados.

The principal objective of the present study is to investigate the reliability of catch per trip as an index of abundance in the flyingfish fishery in Barbados. The approach is to quantitatively investigate sources of variation in catch, trip and catch per trip for day-boats in Barbados. Specifically, the study investigates the reliability of catch per trip as an index of abundance by investigating (a) effects of variation in characteristics of boats, gear, and trip duration on trips, catch and catch per trip, and (b) effects of environmental variables on trips, catch and catch per trip.

METHODS

This study examined a number of variables which could be contributing to variability in catch per trip for the flyingfish fishery in Barbados. To do so, it was necessary to develop a data set which included both catch and effort variables, as well as several potentially relevant environmental parameters. It was decided to focus on the Speightstown fleet as a representative sample of the Barbadian fleet, since this fleet has historically placed primary emphasis on flyingfish fishing, and since the time series of data available for this fleet is long and among the best recorded. All of the catch and effort data used in this study are from the Speightstown fleet. Current fishing practices were also investigated by questionnaire to assist in identifying all sources of variability within the “trip” variable, and to more generally facilitate the interpretation of the data. The information on fishing practices was obtained from the Speightstown fleet, as well as from other fishing fleets in Barbados.

Current fishing practices

A questionnaire survey was the principal technique used to obtain information on fishing practices of Barbadian flyingfish fishermen. Questionnaires were distributed and administered by the researcher, thereby allowing direct contact with the fishermen and facilitating the acquisition of information additional to that obtained through the questionnaire, as appropriate.

To maximize the effectiveness of questionnaire surveys, it is important to structure questions such that most information obtained can be quantitatively analyzed. Moreover, it is important to ensure that biases arising from variation in availability of participants at the time of interviewing, which cause the sub-sample interviewed to be non-representative of the total sample, are minimized.

Questionnaire structure

The questionnaire developed allowed for both multiple-choice and free response answers. The questionnaire was pre-tested on ten fishermen and revised in response to problems detected. The final version of the questionnaire is presented in Appendix 1.

The questionnaire was divided into four sections as described below.

Fishing boat characteristics

This section investigated general characteristics of the vessel, including boat type, engine power, construction material and presence of navigational and safety equipment (Appendix 1).

Fishing skills

This section attempted to investigate the skill of the fishermen based on fishing experience, persons from whom fishing skill had been learned and formal training received (Appendix 1).

Fishing strategy

In this section, the questions attempted to obtain information on fishing strategies employed in the fishery. Questions therefore included the number of years spent fishing with the same boat, type and quantity of gear used, the frequency of hauling and resetting nets at sea, the duration of a normal trip, and the species of fish targeted. Since 11 Speightstown fishermen were interviewed, this information on gear and trip characteristics could be quantitatively related to the catch and effort for 11 of the 30 Speightstown boats analyzed. To further interface the questionnaire information with that obtained from the detailed analysis of factors affecting fishing effort and flyingfish abundance, questions relating to factors which fishermen associate with flyingfish abundance, and factors used in determining whether a fisherman fishes on any particular day, were also asked (Appendix 1).

Sampling techniques

A total of 65 of the estimated 1,000 day-boat fishermen in Barbados were interviewed. An attempt was made to distribute interviews among sites in proportion to the number of vessels landing at that site, but the final distribution (Table 1) was partly determined by the availability of fishermen at landing sites during the time of interviewing. Thus there was proportionately high sampling at the primary landing sites (Oistins, Speightstown and Bridgetown Fishing Complex) and proportionately low sampling at secondary and tertiary sites. The numbers of interviews at Speightstown have been combined with the neighbouring sites of Six Men’s Bay and Half Moon Fort, since a number of fishermen had recently re-located their base from Speightstown to the neighbouring sites. At some sites, such as Skeete’s Bay, interviews were conducted at the fishermen’s homes or at community-based recreational centres, rather than at the landing site.

Table 1. Number and percentage of interviews conducted, based on landing sites.

Landing site	Day-boats (n=65)	
	Number	Percent
BFC	6	9.2
Conset Bay	4	6.2
Oistins	29	44.6
Read’s Bay	3	4.6
Skeete’s Bay	7	10.8
Speightstown/Six Men’s Bay/Half Moon Fort	11	16.9
Tent Bay	5	7.7

Fishing sites were visited in the afternoon, and interviews were conducted as soon as fishermen were available. One-on-one interviews were conducted in all cases. Attempts were made to make questions as concise as possible and to present them in terms familiar to the fishermen. Questions were restated whenever necessary; and comments that were not specific responses to the questions asked were also noted. Only one fisherman from each boat was interviewed. Each interview took approximately 30 minutes.

Catch and effort data

Daily (but interrupted) records for individual boats were obtained for the flyingfish fishery for the period November 1986 to July 1988 from market records at the Speightstown landing site and from on-site interviews with fishermen at the time of landing. Interviews were conducted three days each week for six months in each of the two fishing seasons surveyed (1986-1987 and 1987-1988). Information supplied by fishermen was validated by market receipts. The number of flyingfish landed by each boat was noted and divided by three to produce an approximate weight in pounds (Best, Market Superintendent, pers. comm.). This was converted to a weight in kilograms.

Day-boats generally fish Monday to Friday, occasionally on Saturdays, and rarely on Sundays. Data were therefore generally unavailable for Saturdays and Sundays. Fish brought into the market by means other than boats (speculator inputs) were excluded from the catch information. Trips where no flyingfish were landed were not included in the analysis, since it could not be determined whether flyingfish were not landed due to unsuccessful fishing or because there was no fishing effort directed at flyingfish. Whether other species of fish were landed in addition to flyingfish was noted, but their weight was not recorded.

The data were aggregated at different levels to examine variability in catch/trip The individual daily catch records were tabulated by boat to produce a total catch per boat for the survey period. Catch per trip for a boat was calculated by dividing the total amount of flyingfish landed in a given period by the total number of successful trips made during that period. Daily catch per trip for all boats landing at Speightstown was calculated by dividing the total daily catch by all boats by the total number of trips made.

Catch per trip data showed seasonal variation. To investigate effects of boat characteristics on catch per trip the data were detrended before performing the analyses. The month1y average for the variable was calculated and used as a monthly seasonal index for that variable. This index was then subtracted from each daily data point (see Pankratz 1983).

Boat characteristics

Data on boat age, boat dimensions, and engine power for each boat landing at Speightstown during the survey period were obtained from the Fishing Boat Registers at the Fisheries Division (Appendix 2). Year of first registration was taken as an indication of boat age. Length was used as an index of size of the boat.

Environmental data

Daily air temperature, wind speed, wind direction, relative humidity, rainfall and cloud cover for the period January 1986 to December 1988 were obtained from the Caribbean Meteorological Institute, Husbands, St. James and the Meteorological Department, Grantley Adams International Airport. Moon luminescence data for the period January 1986 to December 1988 were obtained from the Caribbean Meteorological Institute.

Daily air temperature was calculated as the mean of the daily maximum and minimum temperatures. Wind speed was used as an indication of the intensity of the easterly Trade Winds across the topical Atlantic. These winds drive the major surface currents which affect the eastern Caribbean (Mahon 1990). Total daily rainfall, average daily cloud cover, and relative humidity were used as further indicators of climatic conditions which may affect the flyingfish fishery.

The environmental variables all showed seasonal variation. To determine the effect of these variables on daily catch and effort, it was therefore necessary to first remove this seasonality before performing any analyses. The monthly average for the variable was calculated and used as a monthly seasonal index for that variable. This index was then subtracted from each daily data point. This differencing method of deseasonalising data is often used with time series analyses (Pankratz 1983) and allows for adjustment for seasonal variation without removing general trends or cyclical movements.

Data analysis

Simple and multiple regression analysis, simple and partial correlation analyses and analyses of variance (ANOVA) were the chief data analysis tools used. Regression analysis allows for the summary of data and quantifies the nature and strength of the relationships among variables. Multiple regression allows for an examination of the relationship among one dependent variable and one or more independent variables. Like simple regression, multiple regression uses least squares to estimate the regression model.

Analyses of variance assess the effect of one qualitative factor on one (one-way ANOVA) or two (two-way ANOVA) dependent (response) variable(s). ANOVA is robust, operating even with considerable heterogeneity of variances, and with considerable deviations from the assumption of normality. Particularly at large sample sizes, the validity of the analysis is affected only slightly by deviations from normality.

Partial correlation analyses measure the relationship between two variables while controlling for the possible effects of other variables. The analysis is useful for uncovering hidden relationships and detecting spurious relationships.

In dealing with the environmental data, a principal components analysis was used to summarise the variation in the highly correlated environmental parameters, and thereby develop a composite "environmental" variable.

The 95% significance level was chosen in all analyses to test the null hypothesis (no significant differences) since relatively small differences in mean catch/trip can produce statistically significant results. The database was established using the DBase for DOS, a relational database management program, which allows for the easy cross referencing and data linking required.

RESULTS

General characteristics of catch and trips at Speightstown

Thirty eight different day-boats landed fish at Speightstown during the period November 1986 to July 1988. Reliable data on boat characteristics and catch were available for 30 of these boats. The characteristics of each of these 30 boats are provided in Appendix 2. Most boats made fewer than 20 successful trips that were landed at Speightstown over these two fishing seasons, but a few boats made over 100 successful trips (Figure 3a). Together the 30 boats made a total of 901 successful trips landed at Speightstown over the two seasons, producing a total of 96,180 kg of flyingfish. On 83% of these trips, only flyingfish were landed (called flyingfish trips), and these trips accounted for 91,010 kg of the total weight of flyingfish landed. On the other 17% of trips (called mixed trips), flyingfish as well as other pelagic species were landed, the other pelagics being primarily shark, dolphin and kingfish. Most boats landed less than 2,000 kg of flyingfish at Speightstown over the two seasons, but a few boats landed over 10,000 kg of flyingfish (Figure 3b). The modal catch per trip was 101-150 kg (Figure 3c).

Mean catch per trip was significantly higher for flyingfish trips than for mixed trips across the two fishing seasons (flyingfish trips 125.1 kg; mixed trips 118.4 kg; comparison of means, $t = 5.42$, $p < 0.001$). This indicates that a tendency to target other pelagics on some flyingfish trips could compound investigations of effects of boat, gear, gear use and trip characteristics on catch per trip in the flyingfish fishery. Consequently, only the 83% of fishing trips that landed exclusively flyingfish have been used in subsequent analyses in this study.

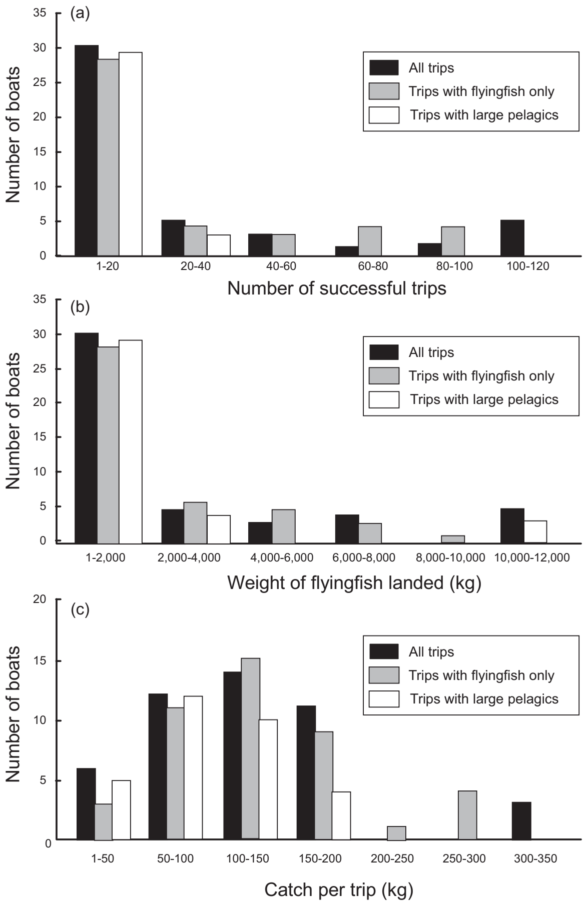


Figure 3. (a) Number of successful trips, (b) weight of flyingfish landed, and (c) catch per trip, for boats landing at Speightstown, 1986-1988.

The seasonal trends for catch, fishing trips and catch per trip for trips landed at Speightstown were similar to the seasonal trends described for the whole fishery. Catches and the number of trips are lowest between August and November and highest between December-January and May-June (Figures 4 a, b). The seasonal variation in fishing effort appears to track seasonal variation in fish availability, since catch per trip is also highest between December-January and May-June (Figure 4c). A one-way analysis of variance indicated that catch per trip varied significantly among days across the fishing season (ANOVA, $F = 1.84$, $p < 0.0001$).

There was a general decline in the total number of trips landed at Speightstown from 1986 to 1988 (Figure 4a), and a similar, although less consistent decline in weight of flyingfish landed (Figure 4b). For example, between January and June, the total number of trips made was 724 for 1986, 505 for 1987 and 372 for 1988. Total catch in these months was 69,000 kg for 1986, 44,000 kg for 1987 and 36,500 kg for 1988. Mean catch per trip between January and June was 95.3 kg for 1986, 87.1 kg for 1987 and 98.1 kg for 1988, i.e. catch per trip remained relatively constant or showed a slight increase over the study period (Figure 4c).

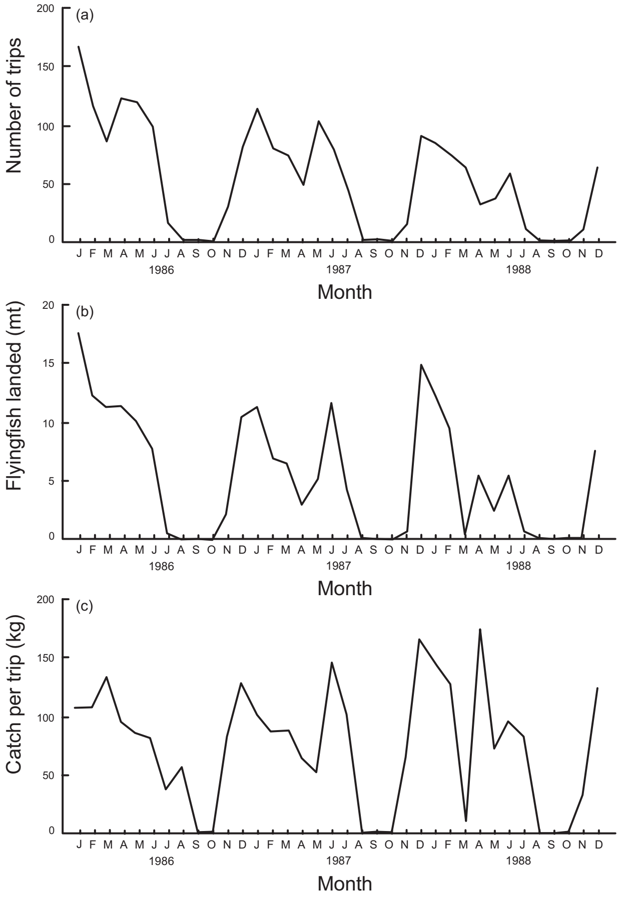


Figure 4. (a) Total number of trips, (b) total weight of flyingfish landed, and (c) monthly catch per trip, for boats landing at Speightstown, 1986-1988.

Variation in trip, boat and gear characteristics

Variation in trip frequency, catch and catch per trip between boats

There was considerable variation among boats in the number of fishing trips/landings at Speightstown over the two fishing seasons (Figure 5a). Consistent with this, the total flyingfish catch varied substantially between boats over the two seasons (Figure 5b). Ninety four percent of the variation in catch between boats was explained by the variation in trip frequency among boats (linear regression analysis, $r = 0.97$, $p < 0.0001$). Despite this strong correlation of catch with trip frequency, catch per trip did vary significantly among boats across the two fishing seasons (one way ANOVA, $F = 2.56$, $p < 0.0001$; Figure 5c). There was a significant negative correlation between the number of trips/landings at Speightstown and catch per trip across boats (linear regression $r = -0.43$, $p < 0.02$). This indicates either that boats which are most successful on a per trip basis, fish less often or that boats which are most successful on a per trip basis land at alternate sites more often. Consistent with this, and with the strong correlation between catch and trip frequency, total catch was also negatively correlated with catch per trip across boats, but the correlation was not statistically significant (linear regression, $r = -0.28$, $p = 0.13$).

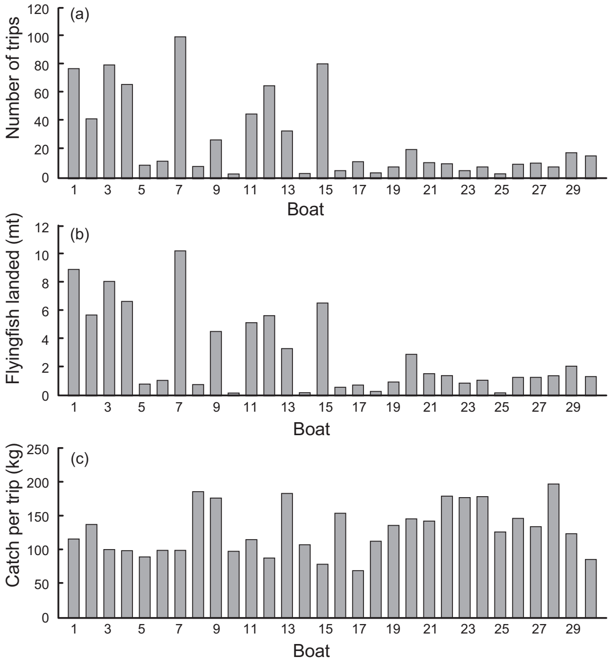


Figure 5. (a) Number of fishing trips, (b) weight of flyingfish landed, and (c) catch per trip, for individual boats landing at Speightstown, 1986-1988.

Variation in boat characteristics

Age, length and horse power

There was considerable variation in boat age in the Speightstown day-boat fleet, boats ranging in age from 1 year to 25 years, with a modal age of 11-15 years and a mean age of 13.4 years (Figure 6a).

There was also considerable variation in boat length in the Speightstown day-boat fleet, boats ranging in length from 24 to 34.5 ft (7.3-10.5 m), with a modal length of 30-32 ft (9.2-9.8 m) and a mean length of 29.5 ft (9.0 m) (Figure 6b).

Engine power in the Speightstown day-boat fleet ranged from a minimum of 22 hp to a maximum of 165 hp, with a modal hp of 20-50, and a mean of 50.23 hp (Figure 6c).

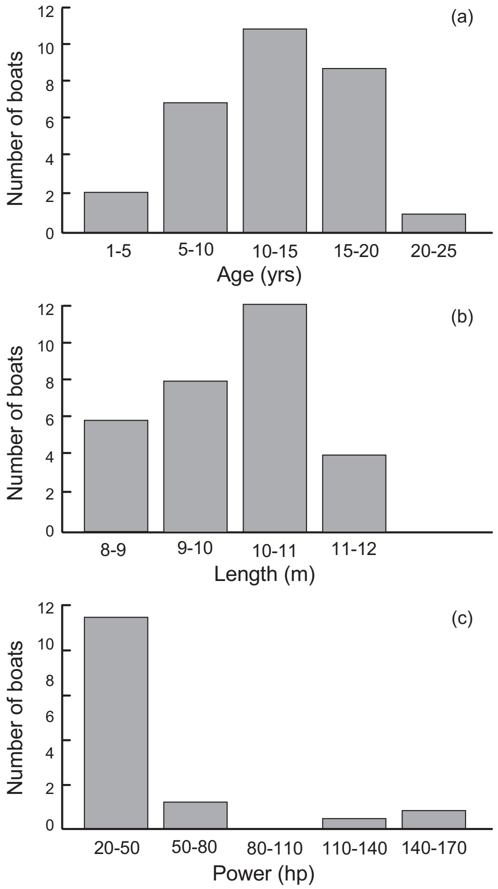


Figure 6. (a) Age, (b) length, and (c) engine power of boats in the Speightstown fishing fleet.

Inter-relationships of boat characteristics

Boat length was not correlated with boat age in the Speightstown day-boat fleet (linear regression, $r = 0.148$, $p = 0.435$), probably because older boats have been gradually lengthened over time. There was no correlation between boat length and engine power in the fleet (linear regression, $r = 0.101$, $p = 0.594$). However, the lack of correlation appears to be generated by a single small boat with large engine power. When this boat is omitted from the analysis, boat length is positively correlated with engine power (linear regression, $r = 0.697$, $p < 0.0001$). Newer boats had significantly larger engines (linear regression, $r = -0.364$, $p < 0.05$).

Variation in gear and gear use characteristics

Type, size and number of nets used

Most fishermen interviewed used gill nets (99.0%), dip nets (91.85%) and hand lines (99.0%) to harvest flyingfish. Gill nets are responsible for most of the fish captured on any fishing trip, but the precise proportion of fish taken by the different gear types is unknown. Most fishermen set two gill nets simultaneously on each fishing trip, but the number set ranges from 1 to 5 (Table 2).

Table 2. Number of gill nets set simultaneously by fishermen.

No. of nets set	Frequency (%)
1	3.1
2	58.5
3	23.1
4	13.8
5	1.5

The stretched mesh size of gill nets used ranged from 1.5" to 1.625", with most fishermen using 1.625" mesh. About 50% of the fishermen interviewed do not change the mesh size of their nets during the fishing season, the other 50% fish with smaller mesh nets towards the end of the fishing season when mean fish size is apparently smaller (Oxenford *et al*. 1993).

The gill nets used ranged from 5 ft to 12 ft (1.5-3.7 m) in depth (Table 3), from 29 ft to 40 ft (6.1-12.2 m) in length (Table 4) and from 90 to 400 ft^2 (8.4-37.2 m^2) in area (Table 5). The mean net depth was 6.49 ft (2.0 m) , the mean length was 30.27 ft (9.2 m) and the mean net area was 196.44 ft^2 (18.3 m^2). The effective net area was calculated for each boat as the area of each net summed across all nets simultaneously set. Effective net area ranged from 120 ft^2 to 1,320 ft^2, with a mean of 520.03 ft^2 (48.3 m^2) (Table 6). Effective net area for a boat is considered the best index of fishing gear power for that boat.

Navigational equipment

All boats were equipped with citizens band (GB) radios, and over 90% had compasses. Only 61.5% of the boats were equipped with very high frequency (VHF) radios, and only 16.7% were equipped with single side band/short wave (SSB) radios. Only 6.2% of the boats had radar, and none of the boats had satellite navigation equipment. Most fishermen claimed that their boats were equipped with flares. Since navigational equipment is essentially a safety strategy, and is not an integral part of the procedure of targeting and harvesting flyingfish, effects of variation in navigational equipment between boats on differences in catch per trip were not investigated in this study.

Table 3. Depth of nets used by Speightstown fishermen

Depth of net	Frequency (%)
5.0 ft (1.5 m)	27.7
6.0 ft (1.8 m)	27.7
7.0 ft (2.1 m)	4.6
8.0 ft (2.4 m)	18.5
10.0 ft (3.1 m)	7.7
11.0 ft (3.4 m)	4.6
12.0 ft (3.7 m)	7.7
34.0 ft (10.4 m)	1.5

Table 4. Length of nets used by Speightstown fishermen.

Length of net	Frequency (%)
20.0 ft (6.1 m)	7.7
25.0 ft (7.6 m)	9.2
30.0 ft (9.1 m)	60.0
35.0 ft (10.7m)	4.5
40.0 ft (12.1 m)	18.5

Table 5. Area of nets used by Speightstown fishermen.

Area of net	Frequency (%)
80.0-144.0 ft^2 (7.4-13.4 m^2)	25.0
144.0-208.0 ft^2 (13.4-19.3 m^2)	37.5
208.0-272.0 ft^2 (19.3-25.3 m^2)	18.8
272.0-336.0 ft^2 (25.3-31.2 m^2)	2.1
336.0-400.0 ft^2 (31.2-37.2 m^2)	10.4

Fishing experience

Most fishermen interviewed had been fishing for less than 20 years, the range being 1 year to 55 years (Figure 7). Fishing skills were primarily learned from friends (37.8%) or family members (28.6%), but about 17% of the fishermen had attended training courses and 16.3% claimed to be self-taught.

Inter-relationships of gear, gear use and boat characteristics

The length of time that fishermen had been fishing was negatively correlated with boat size (linear regression, r = -0.65, p = 0.008) and with boat engine power (linear regression, r = -0.69, p = 0.05), either indicating that more experienced fishermen prefer to fish smaller, less powerful boats, or that older (typically more experienced) fishermen are fishing smaller, less powerful boats as a historical ownership legacy.

Table 6. Effective area of nets used by Speightstown fishermen.

Effective area of net	Frequency (%)
80.0-328.0 ft^2 (7.4-30.5 m^2)	33.3
328.0-576.0 ft^2 (30.5-53.5 m^2)	35.4
576.0-824.0 ft^2 (53.5-76.6 m^2)	18.8
824.0-1072.0 ft^2 (76.6-99.6 m^2)	2.1
1072.0-1320.0 ft^2 (99.6-122.7 m^2)	10.4

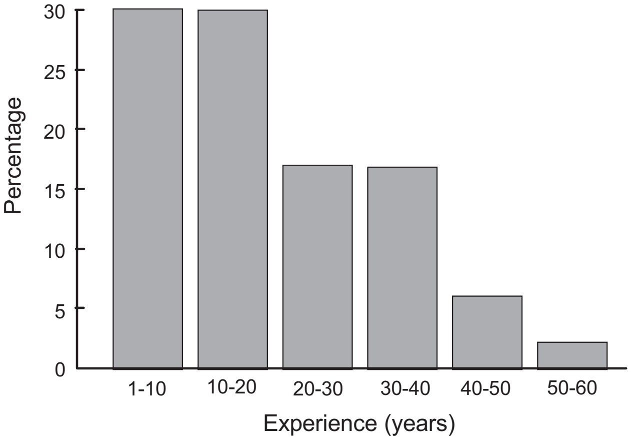


Figure 7. Experience as full-time fishermen for day-boat fishermen in questionnaire survey.

Fishermen with more experience tended to use a larger effective fishing area of nets (i.e. more fishing gear power), but the correlation was not statistically significant at the small sample size available (linear regression, r = 0.602, p = 0.11). Gear power was not significantly correlated with either boat age (linear regression, r = 0.481, p = 0.23), boat length (linear regression, r = -0.224, p = 0.59) or boat horse power (linear regression, r = -0.321, p = 0.44).

Variation in trip characteristics

Duration of trip

Given favourable conditions, most day-boat fishermen indicated that they left “early in the morning”, usually between 4:00 am and 5:00 am, and returned “late in the evening”, usually between 2:00 pm and 6:3 0 pm. It was not possible to obtain information on absolute duration of trips in this study. However, an indication of the relative duration of trips was obtained by recording the sequence in which the boats returned to mooring on each fishing day, and ranking each boat by its return sequence. Each boat was therefore given a sequence number from 1 to 30 on each fishing day. On days on which all of the 30 study boats did not fish, the sequence number was weighted to be a rank out of 30. The sequence number differed significantly between boats across the two fishing seasons (one-way ANOVA, F = 5.166, p < 0.001), indicating that the boats differed significantly in the duration of their fishing trips.

Location of fishing area

Most fishermen were reluctant to provide information on their exact fishing locations. However, the majority (71.4%) stated that their fishing location remained relatively constant, typically within a 10 km radius, throughout the fishing season. Moreover, the fishermen noted that the location in which they fished was also used by most of the other boats in the Speightstown fleet. It therefore seems unlikely that boat-specific differences in fishing location could be contributing significantly to boat-specific differences in catch per trip.

Inter-relationships of trip, gear and boat characteristics

The landing sequence of boats was not correlated with either boat age (linear regression, r = 0.076, p = 0.688), boat length (linear regression, r = 0.064, p ~ 0.734) or boat engine power (linear regression, r = 0.015, p = 0.935). There was some indication that fishermen with the most experience tend to return later to mooring, but the correlation was not statistically significant (linear regression, r = 0.46, p = 0.18). Consistent with this, since fishermen with more experience tend to use more fishing gear power, there was some indication that boats with the greatest fishing gear power return later to mooring, but the correlation was again not statistically significant (linear regression, r = 0.52, p = 0.12).

Effects of variation in trip, boat and gear characteristics on catch, trip frequency and catch per trip

Effects of variation in boat characteristics on catch, trip frequency and catch per trip

The number of fishing trips landing at Speightstown over the two fishing seasons surveyed was not correlated with boat length (linear regression, r = 0.083, p = 0.664. However, there was some indication that older boats may make fewer trips/landings (linear regression, r = -0.291, p = 0.12). Consistent with this, since older boats have smaller engines, there was some indication that less powerful boats may make fewer trips/landings (linear regression, r = 0.298, p = 0.11).

Consistent with the tendency for older, less powerful boats to make fewer trips, and with the fact that trip frequency is a strong predictor of total catch, total catch was negatively correlated with boat age (linear regression, r = -0.355, p = 0.054) and positively correlated with boat engine power (linear regression, r = 0.356, p = 0.054) across the two fishing seasons. Total catch was not significantly correlated with boat length (linear regression, r = 0.129, p = 0.499).

Although weak effects of boat characteristics on trip frequency and on total catch were evident, no effects of boat characteristics on catch per trip were detected. Catch per trip was not correlated with either boat age (linear regression, r = -0.087, p = 0.649), boat length (linear regression, r = 0.046, p = 0.808) or boat engine power (linear regression, r = -0.081, p = 0.67). The detection of significant effects of boat characteristics on catch per trip could in principle be constrained by the strong seasonal effects on catch per trip observed for all boats. The catch per trip data were therefore seasonally detrended, and regression analyses of detrended catch per trip on boat characteristics were conducted. However, detrended catch per trip was again not correlated with either boat age, boat length or boat horse power (linear regression: age, r = -0.309 p = 0.078, length, r = -0.090, p = 0.669, horse power, r = -0.057, p = 0.786).

Effects of variation in gear and gear use characteristics on catch, trip frequency and catch per trip

The frequency of fishing trips landed at Speightstown made was not significantly correlated with fisherman experience (linear regression, r = -0.314, p = 0.36). There was some indication that trip/landing frequency was lower for boats with greater fishing gear power (effective net area), but the correlation was not statistically significant (linear regression, r = -0.48, p = 0.16). Consistent with these results, since trip frequency explains most of the variation in total catch, total catch was not significantly correlated with either fisherman experience (linear regression, r = -0.207, p = 0.56) or fishing gear power (linear regression, r = -0.423, p = 0.24). Interestingly, catch per trip was significantly higher for fishermen with most fishing experience (linear regression, r = 0.621, p = 0.05), but there was no detectable correlation between catch per trip and fishing gear power (linear regression, r = 0.204, p = 0.573).

Effects of variation in trip characteristics on catch, trip frequency and catch per trip

The frequency of fishing trips landing at Speightstown was negatively correlated with the landing sequence number assigned to boats (linear regression, r = -0.544, p = 0.02). This indicates that either boats which return late to mooring make fewer fishing trips or that boats which return late to mooring are landing more frequently at alternate sites. Consistent with this, given that trip frequency explains most of the variation in total catch, total catch was negatively correlated with the landing sequence of boats (linear regression, r = -0.345, $p < 0.06$), i.e. boats which return late to mooring have a lower total catch. Interestingly, there was significant variation in catch per trip as a function of landing sequence (one-way ANOVA, F = 9.95, $p < 0.001$). Catch per trip was higher for boats returning to mooring later (using mean catch per trip value and one mean landing sequence for each boat (linear regression, r = 0.223, p = 0.24) using all trips for all boats (r = 0.321, $p < 0.001$), indicating that catch per trip increases with trip duration.

Effects of environmental variables on trip characteristics and catch per trip

Seasonal trends in environmental variables and trip characteristics

Mean daily rainfall per month ranged from 0 to 1.3 mm over the 3 year period January 1986 to December 1988. Rainfall was highest between August and December and lowest between January and July. Fish availability, and hence trip frequency and monthly catch, was highest between December and June, i.e. the flyingfish season largely coincides with the months of lowest rainfall.

Mean daily cloud cover per month ranged from 4 octares to 6 octares (an octare is a proportion of 8) and was lowest between December and February each year. The months of lowest cloud cover are therefore a subset of the months of highest flyingfish availability (December-June).

Mean daily wind speed per month ranged from 6.8 to 10.5 knots, with values bring highest between March and May in most years. Months of highest wind speed are therefore a subset of the months of highest flyingfish availability (December-June).

Mean daily relative humidity per month ranged from 66 to 82%. Monthly humidity was lowest in the early half of the year, i.e. January to May, when rainfall is low and wind speed is high. Much of the flyingfish season (December-June) therefore coincides with months of low relative humidity.

Mean daily temperature per month ranged from 25°C to 28°C, with temperatures being highest between April and September and lowest between December and February. Monthly temperature therefore showed no clear coincidence with flyingfish availability and the flyingfish fishing season (December-June).

It is evident from the above that the flyingfish season coincides with months of lowest rainfall, and that the months of lowest cloud cover, lowest relative humidity and highest wind speeds all occur within the flyingfish season. However, these observations need not imply that any of those environmental factors causally influence seasonal flyingfish availability.

Daily trends in environmental variables and trip characteristics

Fishermen's perspectives

The fishermen interviewed cited weather conditions as the major factors determining whether or not to fish on a given day (Figure 8). Other factors identified were water colour (flyingfish availability was considered to be highest when water colour is green), moon phase (flyingfish availability was considered highest around full moon), current market prices and the recent success of other fishermen (Figure 8). In the context of weather conditions, little or no rainfall, low to moderate swells and weak to moderate currents were considered to be good conditions for flyingfish fishing. Fishermen claimed that these were good conditions, not only because they were least dangerous, but because they were more conducive to larger catches.

Daily interrelationships of environmental variables

All of the environmental variables investigated showed strong seasonal variation. To investigate correlations between environmental variables on a daily basis, the data sets for each of the environmental variables were first seasonally detrended as described. The detrended data on any given day is the value of the parameter on the day relative to its monthly mean. A number of the environmental variables were weakly but significantly correlated. Daily detrended rainfall was positively correlated with daily detrended cloud cover, relative humidity and wind speed; and cloud cover was positively correlated with relative humidity and wind speed (Table 7). Daily detrended temperature was not correlated with any of the other environmental variables measured (Table 7). A principal components analysis was used to reduce the correlated environmental variables to a single composite "environmental" variable. Since the environmental variables were only weakly correlated, the composite "environment" variable, represented by the first principal component of the analysis, explained only 28% of the variance in the environmental variables. The composite "environment" variable was therefore not used to explore effects of the environmental variables on trip frequency, catch and catch per trip.

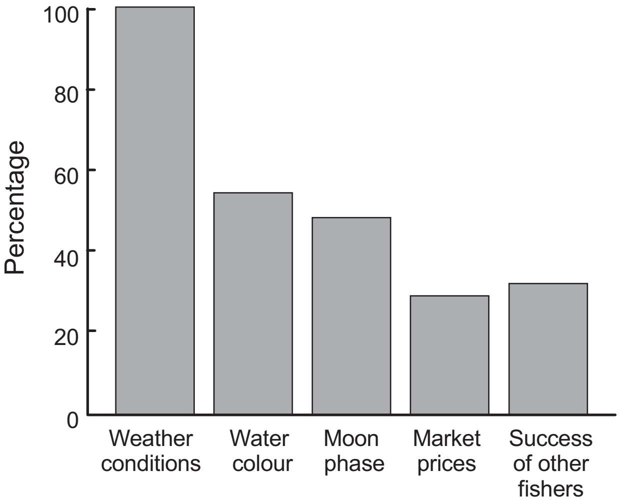


Figure 8. Predetermining factors for going fishing.

Daily effects of environmental variables on trip frequency, total daily catch, and catch per trip

Since the environmental variables investigated, as well as trip frequency, total catch and catch per trip, all showed strong seasonal variation, correlations between environmental variables and trip and catch variables on a daily basis were examined using data which were seasonally detrended.

Effects of daily variation in environmental variables on daily variation in trip frequency, total catch and catch per trip were either insignificant or negligible, as detected by simple linear regressions (Table 8). Daily trip frequency was not influenced by either daily rainfall, temperature, cloud cover or relative humidity, but there was a statistically detectable effect of daily wind speed on daily trip frequency (Table 8). However, daily variation in wind speed explained a negligible proportion (about 1.3%) of the daily variation in trip frequency (Table 8). Reflecting the fact that total catch is primarily driven by trip frequency. Total daily catch was also not influenced by daily rainfall, temperature, cloud cover or relative humidity, but there was a weak statistical effect of daily wind speed on daily total catch (Table 8). However as with trip frequency, daily variation in wind speed explained a negligible proportion (about 1%) of the daily variation in total catch (Table 8).

Daily catch per trip was not affected by daily rainfall, temperature, or wind speed (Table 8). Weak statistical effects of daily cloud cover and daily relative humidity were detected, but these explained only about 0.9% of the variation in daily catch per trip in both cases (Table 8).

Effects of luminescence on daily trip frequency, daily total catch and daily catch per trip were also investigated. Linear regression analysis detected a statistically significant effect of luminescence on trip frequency (Table 8). However, luminescence explained a negligible proportion (about 2.7%) of the variation in daily trip frequency (Table 8). No effects of luminescence on either total daily catch or daily catch per trip were detected (Table 8).

DISCUSSION

General fishing practices

The flyingfish fishery of Barbados is a major component of the island's fisheries, landing on average 2,505 mt annually (1980-1989) and accounting for approximately 57% of the total fish landings and 64% of the pelagic landings. The fishery employs an estimated 6,000 people and the annual landed value of the flyingfish catch is in excess of BDS$ 8 million wholesale and BDS$ 11 million retail (Willoughby 1993).

In many ways, the Barbadian flyingfish fishery has changed little over the past two decades (see Storey 1983). The major change is that ice-boats have now been established as an integral part of the fishery and make up approximately 19% of the fleet. The fishing fleet currently comprises approximately 500 wooden day-boats and 80 ice-boats constructed of fibre glass or wood. Although preliminary economic analyses suggest that ice-boat fishing pays higher wages to captain and crew than day-boat fishing (Hunte and Oxenford 1989), the longer fishing range of ice-boats has caused increasing tension with neighbouring fishing countries, and is likely to constrain the rate of transition of day-boats to ice-boats in the Barbados fishing fleet. At present, the traditional day-boats, which dominate the Speightstown fleet and are the focus of the present study, remain the principal vessel type for harvesting flyingfish in Barbados. More than three decades of catch and trip data exist for the day-boat flyingfish fleet in Barbados. These data are potentially invaluable in providing long-term trends in abundance of flyingfish in the eastern Caribbean, in investigating inter-annual variability in abundance of flyingfish, in generating stock-recruitment relationships for flyingfish, and in conducting stock assessments for flyingfish in the eastern Caribbean. However, despite their potential importance, no attempt has been made to investigate the reliability of catch per trip as an index of abundance of flyingfish in the Barbados flyingfish fishery. Against this background, the objective of the present study was to investigate the reliability of catch per trip as an index of abundance in the flyingfish fishery in Barbados by investigating (a) effects of variation in characteristics of boats, gear and trip duration on trip frequency, catch and catch per trip, and (b) effects of environmental variables on trips, catch and catch per trip.

A potential constraint on the reliability of catch per trip as an index of flyingfish abundance that was identified in the present study is the relative allocation of fishing effort to flyingfish compared to other pelagics on fishing trips which target both fish categories. Catch per trip of flyingfish was significantly higher on trips that exclusively targeted flyingfish than those which targeted flyingfish and other pelagics (mixed trips). The precise allocation of effort between flyingfish fishing and fishing for other pelagics on mixed trips is unknown.

Table 7. Results of correlation analyses between environmental variables on a daily basis (n = 1020) (r = correlation coefficient, p = probability of obtaining r).

Variable		Temperature	Cloud cover	Relative humidity	Wind speed
Rainfall	r	-0.041	0.258	0.136	0.061
	p	0.193	0.000	0.000	0.054
Temperature	r		0.038	-0.039	-0.029
	p		0.222	0.219	0.355
Cloud cover	r			0.198	0.082
	p			0.000	0.009
Relative humidity	r				0.042
	p				0.182

Table 8. Results of simple linear regressions of daily trips, daily catch and catch per trip on daily values for environmental variables (n = 320 for all except luminescence where n = 141) (r = correlation coefficient, p = probability of obtaining r).

Variable		Total daily trips	Total daily catch	Daily catch/trip
Rainfall	r	0.072	0.089	0.090
	p	0.193	0.114	0.106
Temperature	r	-0.033	-0.023	0.006
	p	0.554	0.686	0.921
Cloud cover	r	0.040	-0.056	-0.098
	p	0.479	0.317	0.081
Relative humidity	r	0.005	0.020	0.094
	p	0.924	0.718	0.095
Wind speed	r	0.112	0.100	0.029
	p	0.045	0.075	0.601
Luminescence	p	0.051	0.107	0.779
	r	0.163	0.135	0.024

Variation in this will therefore generate unexplained variation in catch per trip of flyingfish as an index of flyingfish abundance, and a consistent change in this parameter over time would lead to biased interpretations of changes in flyingfish abundance as indicated by catch per trip. In the present study, to facilitate investigations of boat, gear, trip and environmental characteristics on catch per trip, only fishing trips which exclusively targeted flyingfish (83% of the trips made by the Speightstown fishing fleet) have been analysed.

There was considerable variation between boats in the number of trips landing at Speightstown, total catch and catch per trip. Ninety-four percent of the variation in total catch was explained by variation in trip frequency. Interestingly, the most successful boats, as indicated by the highest catch per trip, either made the fewest trips or landed most often at alternate sites. The considerable variation in trip frequency evident between boats, and the strong correlation between total catch and trip frequency, suggest that boats could increase their total catch by fishing more frequently. This in turn may suggest that fishermen do not fish such as to maximize total catch and hence total income, but fish only as often as necessary to achieve some necessary or acceptable income level. Alternately, fishermen may fish, not to maximize total catch and income, but to maximize income per unit of labour/time, within the constraint of requiring a certain minimum total income. If market value per fish landed is lower at higher total catch, the increment in income for every increment in labour/time effort will decrease at higher total catches. One strategy for alleviating this would be to land at alternate sites, particularly if the catch to be landed was large. There was some evidence in this study to suggest that successful boats seek alternate landing sites more often than less successful boats. The observation that, over the two years of the present study, as catch per trip appeared to increase slightly, the number of trips landing at Speightstown declined is also of interest in this context. Possible effects of these socio-economic factors on controlling trip frequency and total catch within and between fishing seasons require quantitative investigation.

Effects of boat characteristics

Few effects of boat specifications on trip and catch characteristics were detected in this study. The older boats in the fleet have smaller engines, and there was some indication that older boats and less powerful boats make fewer fishing trips and hence have smaller total catches. A partial correlation analysis and a multiple ANOVA indicated that boat age and boat power may independently have similar strength effects on trip frequency and hence total catch (partial correlation: for boat age on trips, r = -0.205; for boat power on trips, r = 0.215). The lower trip frequency and total catch for older boats with smaller engines could partly result from more "down time" (i.e. maintenance/repair time) for such boats, but "down time" was not specifically investigated in this study. Interestingly, fishermen who have been fishing for longer, and may on average therefore be older, use less powerful boats; and fisherman age could therefore in principle be contributing to the lower trip frequency observed for less powerful boats. However, although the correlation between trip frequency and fisherman experience in this study was negative, it did not approach statistical significance (p = 0.38). Most importantly in the context of the principal objectives of this study, catch per trip was not correlated with either boat age, boat length or boat engine power across the range of age, length and power present in the Speightstown fleet. This suggests that variation in boat characteristics is not contributing to variation in catch per trip for the Speightstown fishing fleet.

Effects of trip characteristics

The principal trip characteristic likely to affect catch per trip is trip duration. It was not possible to obtain information on absolute trip duration in this study, but an indication of relative trip duration was obtained by recording the sequence in which the boats returned to mooring on each fishing day. Note that relative trip duration is itself only an index of relative fishing duration (i.e. time spent fishing), since fishing duration (time spent fishing), fishing location and boat speed will all generate variation in trip duration.

Boats differed significantly in landing sequence in this study. Moreover, an important result of the study is that boats returning later to mooring had higher catch per trip, perhaps indicating that fishing duration is a significant source of variation in catch per trip in the Speightstown flyingfish fleet. Interestingly, the landing sequence of boats was not predicted by any of the boat characteristics investigated, i.e. by boat age, length or engine power. There was some indication that boats which returned late to mooring carried greater fishing gear power (effective net area). Greater fishing power could therefore, in principle, explain the higher catch per trip observed for boats which returned to mooring later. However, simple linear regression could detect no effect of gear power on catch per trip (r = 0.204, p = 0.73). Moreover, when effects of landing sequence on catch per trip were controlled by partial correlation analysis, the correlation between catch per trip and fishing gear power was further weakened (r = 0.111). This suggests that it is trip duration (landing sequence) *per se* which contributes significantly to catch per trip.

Trip duration, as indicated by landing sequence, could simply be a product of individual fisherman preference. The observation that catch per trip can be increased by increasing trip duration, and that trip duration differs significantly between boats, may again suggest that fishermen do not fish such as to maximize total catch and hence total income. It is again more consistent with the suggestion that they fish only long enough to achieve some necessary or acceptable income level, or that they fish so as to maximize income per unit of labour/time. The market value per unit fish landed typically decreases towards the end of each fishing day. Hence, the increment in income for every increment in time spent at sea will decrease with increasing trip duration. Possible effect of these socio-economic factors on trip duration, and hence on catch per trip, require quantitative investigation.

Effects of gear and gear use characteristics

The gear use characteristic investigated in the context of its effect on catch per trip was fisherman experience; and catch per trip did increase significantly with fisherman experience in this study. This could be the consequence of greater fishing skill *per se*, or because more experienced fishermen use more effective boats, more effective gear or fish for longer. In the context of boat characteristics, simple linear regression could detect no effects on catch per trip. Moreover, more experienced fishermen were typically using smaller, less powerful boats, and hence their higher catch per trip is unlikely to be the consequence of the boat characteristics that they use. Indeed, the positive correlation between fisherman experience and catch per trip, and the negative correlation between fisherman experience and boat length and power, could mask effects of boat length and power on catch per trip. However, when the effect of fisherman experience on catch per trip was controlled by partial correlation analysis, boat length and boat power remained insignificantly correlated with catch per trip (length, r = -0.007; power, r = -0.252).

In the context of gear power (effective net area), simple linear regression could detect no effect on catch per trip. Consequently, although there was a tendency for more experienced fishermen to use greater gear power, this is unlikely to be the cause of the higher catch per trip achieved by the more experienced fishermen.

In the context of trip duration characteristics, there was a weak tendency for more experienced fishermen to return later to mooring, and catch per trip was higher for boats returning later to mooring. Longer trip duration could therefore in principle explain the higher catch per trip of experienced fishermen. However, when the effects of landing sequence on catch per trip were controlled by partial correlation analysis, catch per trip remained positively correlated with fisherman experience (r = 0.511, $p < 0.05$). This, and the results discussed above all suggest that skills which emerge from fishing experience *per se* are contributing to higher catch per trip.

Effects of environmental factors

An analysis of seasonal variation in environmental variables indicated that flyingfish availability, and hence the flyingfish fishing season, coincides with months of lowest rainfall, and that the months of lowest cloud cover, lowest relative humidity and highest wind speeds all occur within the flyingfish season. However, it is important to appreciate that this need not imply that any of these factors causally influence the observed seasonal variation in flyingfish availability. Seasonal variation in flyingfish availability appears to be determined by the timing of the annual life cycle of flyingfish. Flyingfish spawn between December and June, with heaviest spawning in May-June (Storey 1983, Oxenford *et al*. 1994). The non-availability of flyingfish between June and December is best explained by heavy adult post-spawning mortality (Oxenford *et al*. 1993, Oxenford 1994) and by the fact that juveniles born in a given year are not large enough to be taken by the commercial fishing gear until about December (Oxenford *et al*. 1994). It is of course quite possible that the seasonal timing of the flyingfish life cycle, and hence ultimately the timing of availability of flyingfish to the commercial gear, is determined by seasonal variation in environmental variables. For example, Oxenford *et al*. (1994) have shown that the growth rate of juvenile flyingfish increases with increasing temperature, and have suggested that heavy spawning in May and June may be timed to coincide with months of highest temperature.

Interviews with fishermen indicated that they perceived weather conditions as being important in determining whether or not to fish on a given day. They identified little or no rainfall, low to moderate swells and weak to moderate currents as being good conditions for flyingfish fishing, both in the context of safety at sea and of higher catches. They also considered flyingfish catches to be highest around full moon. These perspectives were largely not supported by an analysis of effects of daily variation in environmental variables on daily trip frequency and daily catch per trip. No effect of either daily rainfall, temperature, cloud cover, or relative humidity on daily trip frequency could be detected; and daily wind speed explained a statistically significant but negligible (1.2%) proportion of daily variation in trip frequency.

Effects of environmental variables on catch per trip could, in principle, result either from effects on trip duration or from effects on catchability. However, no effect of either daily rainfall, temperature or wind speed on daily catch per trip could be detected; and daily cloud cover and relative humidity explained only negligible proportions of the variation in daily catch per trip (about 0.9% in both cases). It is possible that the fishermen's perspective that rainfall influences the success of flyingfish fishing is based more on their appreciation that flyingfish are most available, and hence most heavily fished, in the drier months of the year, rather than on daily effects of rainfall on availability within the dry (flyingfish) season.

One assertion of fishermen that was weakly supported by the results of this study is that moon phase affects flyingfish availability and hence fishing trip frequency; specifically, that flyingfish are most available and fishing trips are most common around full moon. It is not implausible that flyingfish catchability could vary with moon phase, since the method of catching flyingfish strongly depends on their spawning habits and specifically their apparent preference for spawning on floating material, and since many tropical fish species are now known to exhibit lunar variation in spawning effort (e.g. Johannes 1978, Hunte and Cote 1989, Hunt von Herbing and Hunte 1991). Indeed, Hall (1955) has previously reported a steady increase in flyingfish catches towards and immediately following full moon in experimental fishing for flyingfish off Barbados. In the present study, a statistically significant effect of luminescence on trip frequency was detected, but luminescence explained only about 2.7% of the variation in daily trip frequency; and no effect of luminescence on daily catch per trip was detected.

In summary, these results suggest that effects of daily variation in environmental variables on catch per trip, and hence on either catchability or trip duration, are negligible in the flyingfish fishery in Barbados. Moreover, no significant effects of boat or gear characteristics on catch per trip could be detected. Most of the variation observed in daily catch per trip appeared to result from variation in fisherman experience and variation in how long fishermen were prepared to remain at sea (daily trip duration).

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APPENDIX 1: QUESTIONNAIRES FOR FISHERMEN

The Eastern Caribbean Flyingfish Project, sponsored by the IDRC and conducted from Bellairs Research Institute, is currently in its third year. Its purpose is to investigate the life history and factors influencing the abundance of the flyingfish in the region. This component of the project seeks to determine the contribution of fishermen to this industry.

SECTION 1 - FISHING BOAT CHARACTERISTICS	
1. Name of vessel:	2. Reg. No.
3. Construction of boat: [ ]wood [ ]fibreglass [ ]steel [ ]concrete	
4. Navigational/safety equipment: [ ]VHF [ ]compass [ ]Satnav [ ]SSB [ ]radar sextant	
SECTION 2- FISHING SKILL	
5. How many years have you been a full-time fisherman?	years
6. How many years have you been fishing this particular vessel?	years
7. From whom did you learn your skill?	
8. Have you ever attended any fishery training courses?	[ ] Yes [ ] No
SECTION 3- FISHING STRATEGY	
GEAR: 9. What fishing gear do you use? [ ] gillnet [ ] dipnet [ ] handline [ ] other	
10. How many nets do you usually set at once?	
11. Do you change the mesh size through the season? [ ] Yes [ ]No	
12. Gear characteristics net 1 net 2 net 3 (a) stretched mesh size (b) net hang (c) depth of net (d) Length of net	
13. How long have you used these gears? (a) gillnet (b) dipnet (c) hand line	
14. If there has been a change, what brought about this change?	
FACTORS AFFECTING TRIPS: 15. How often during the fishing season do you go out to fish?	
16. Are there any predetermining factors for your going out? [ ] wait for other fishermen to go out [ ] water colour [ ] observe the catch of another fisherman [ ] moon phase [ ] weather conditions [ ] market prices [ ] other:	
17. Average time of departure	
18. Average time of arrival	
19. (a) How long do you stay out ________ hrs	
(b) Is it a fixed period of time or is it determined by the catch?	[ ] Fixed [ ] Catch
20. What factors do you associate with high flyingfish abundance? [ ] water colour [ ] floating material [ ] other:	
21. Which fish are the main contributors to the catch? [ ] flyingfish (%) [ ] shark (%) [ ] dolphin (%) [ ] other:	
22. Do you [ ] fish for a particular species of fish or [ ] just catch what is available	
23. What do you do during the "off-season' for flyingfish (July - October)?	

INFORMATION OBTAINED FROM FISHERIES DIVISION
1. Name of boat: 2. Reg. no.
3. Type of boat: [ ] day-boat [ ] ice-boat
4. Construction of boat: [ ] wood [ ] fibreglass [ ] steel [ ] concrete
5. Navigational safety equipment: [ ] VHF [ ] compass [ ] satnav [ ] SSB [ ] radar [ ] sextant
6. (a) Year of first registration: (b) Number of years in fleet:
7. (a) Length: (b) Beam:. (c) Draught:
8. (a) Type of engine: (b) Power: hp
9. (a) Landing site: (b) Mooring site:

APPENDIX 2. CHARACTERISTICS OF VESSELS IN THE SPEIGHTSTOWN FISHING FLEET (1986-1988)

Boat	Age (years)	Length (ft)	Engine power (hp)	Number of trips	Catch per trip (kg)
1	10	31.5	44	76	116
2	9	26	165	41	138
3	1	26	165	80	100
4	11	32.5	80	66	99
5	17	26	44	8	92
6	8	29	29	11	99
7	13	31	44	100	100
8	10	25	29	4	187
9	9	32.5	44	26	174
10	15	31	27	2	99
11	11	30.4	44	44	116
12	15	28	44	65	86
13	12	34.5	80	18	181
14	11	34.5	120	2	109
15	16	30	30	81	79
16	4	24.8	30	4	152
17	15	27	22	10	70
18	25	32.3	80	3	114
19	19	29	29	7	138
20	8	31	44	20	147
21	18	31	44	11	143
22	15	27.5	41	8	179
23	13	31	44	5	179
24	17	27	29	6	179
25	8	27.5	29	1	126
26	19	30	30	9	146
27	19	29	44	9	133
28	15	32	44	7	194
29	19	24	22	17	121
30	20	30.5	44	15	87
Mean	13	29.4	52.2	25.2	129
SD	5	2.8	36.5	28.7	35
Min	1	24	22	1	70
Max	25	34.5	165	100	194