TECHNICAL REPORT SERIES TR-E-6

Klima, E. (1989) Review of Ecuadorian Offshore Shrimp Fisheries and Suggestions for Management and Research. In: Olsen, S. and Arriaga, L., editors. A Sustainable Shrimp Mariculture Industry for Ecuador. Narragansett, RI: Coastal Resources Center, University of Rhode Island

A SUSTAINABLE SHRIMP MARICULTURE INDUSTRY FOR ECUADOR

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International Coastal Resources Management Project

The University of Rhode Island

Review of Ecuadorian Offshore Shrimp Fisheries and Suggestions for Management and Research

Revisión de la Pesquería Ecuatoriana del Camarón Costero y Sugerencias para su Manejo e Investigación.

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Resumen

En la pesca de arrastre del camarón blanco entre 1965 y 1979, las capturas de Penaeus occidentalis comprendieron entre el 50 y el 60% de los desembarques totales de camarón blanco, siendo la especie más importante en la pesca con buques de arrastre. En segundo lugar se ubicó la especie P. stylirostris (25 - 45%) y finalmente P. vannamei (6%). A este respecto debe anotarse que se observó amplias variaciones anuales en la composición por especies de las capturas.

La Captura por Unidad de Esfuerzo (CPUE) (captura anual promedio por buques) en los primeros años varió grandemente, desde 352 lb/día (1956-1957) hasta 143 lb/día (1958-1959). En general, la CPUE fue de alrededor de 200 lb/día en la zona de Esmeraldas y 177 - 120 lb/día en el Golfo de Guayaquil, entre 1961 y 1964. Desde 1973 hasta 1982, la CPUE ha sido más o menos estable, fluctuando alrededor de 120 lb/día. Un aumento significativo fue observado en el año de El Niño de 1983, cuando la CPUE saltó a 345 lb/día, pero luego cayó a niveles bajos de 78 y 68 lb/día.

Se ha supuesto que el Golfo de Guayaquil es el principal lugar de cría para P. vannamei y tal vez para otras especies de camarón blanco. Igualmente, se piensa que el tamaño y la persistencia del área de cría puede estar determinada por la influencia de las corrientes de aguas frías y cálidas. Somers demostró una relación estrecha entre la cantidad de lluvias y la CPUE: conforme aumentan las lluvias también lo hacen las CPUE. Sin embargo, esta relación encontrada está dominada por la presencia de El Niño de 1983, que mostró gran cantidad de lluvias y muy alta CPUE.

El autor analiza a continuación aspectos referidos a la información científica para manejo, las necesidades de datos estadísticos y el manejo actual de las pesquerías, incluyendo la implantación de vedas. Finalmente presenta varias recomendaciones, tales como: Ampliar el programa de recolección de datos estadísticos (capturas, esfuerzo de pesca, composición por especies y por tallas de las capturas comerciales, catura artesanal de postlarvas), efectuar estudios independientes para evaluar las acciones de manejo y determinar el reclutamiento y distribución de postlarvas y juveniles del camarón, así como estudios de marcación-recaptura para determinar los límites de los "stocks".

Introduction

The Ecuadorian offshore trawl fishery commenced in 1952, according to Cobo and Loesch (1966). Between 1954 and 1975 the fishery fluctuated from a high of 8,700 m.t. in 1969 to a low of around 5,000 m.t. in 1964, with production fairly stable at around 6,000 metric tons. Since 1976, with the inception of the culture industry, accurate information on total production is not available for the offshore trawl fisheries. However, the number of vessels has gradually increased to approximately 250-300 in 1985.

Predominant Species

Cun and Marin (1982) estimated that *Penaeus occidentalis* comprised between 50 percent and 60 percent of the white shrimp catch from 1965 to 1979, and is the most important species to the trawl fishery. The second important species is *Penaeus stylirostris* which constituted between 25 percent and 45 percent of the catch during the 1965 through 1979 period; *P. vannamei* was of only minor importance in the Gulf of Guayaquil and other areas, contributing on the average approximately 6 percent of the catch. It should be noted, however, that there appears to be considerable annual variation in the species caught by the offshore fishery. In some years, such as 1973 and 1977, *P. vannamei* comprised 12 percent of the total catch, and in 1979, 21 percent of the commercial catch was made of this species. McPadden (personal communication) shows that in 1985, *P. vannamei* made up at least 30 percent of the white shrimp catch in the Gulf of Guayaquil (Table 1).

Two other species, *P. californiensis* and *P. brevirostris*, do not appear to be a major part of the offshore catch, possibly because these species are found farther offshore, and the fishery may not operate in offshore waters as readily as in the nearshore waters. There appear to be two principal fisheries: one north of the port of Manta with both white and brown shrimp as main components, and the other south of Manta, composed mostly of white shrimp. The interchange of shrimp and stock delineation between the two areas is unknown.

CPUE

Detailed information on monthly catch-per-unit effort (CPUE) by commercial double-rigged trawlers is available from 1973 to the present, but annual CPUE estimates from 1956 to 1972 are limited. The data from June 1973 to the present are based on interviews with vessel captains in the Gulf of Guayaquil. Charles McPadden (personal communication) has used this data to clearly demonstrate the measures of relative abundance from 1973 to 1986. In addition, monthly mean size and length frequency distribution by species is available in raw form, but has not been analyzed in any depth. The monthly length frequency distributions by species are supposedly available but not in a computer format, so they cannot be easily analyzed to determine periods of peak recruitment.

In 1986 Ian Somers (personal communication), U.N. Food and Agriculture Organization (FAO) consultant from Australia, evaluated the impact of the postlarval and offshore shrimp fisheries on the long-term recruitment (adding to harvestable population) of major commercial species of shrimp, with particular reference to *P. vannamei*. Findings of both Somers and this author (1986) show that total annual production statistics are based on export records and do not distinguish between farm and sea production. A series of production estimates were made by Somers and, although none of these appears to be reliable, they may be adequate to depict an overall upward trend in production and the number of vessels in the offshore fishery. Somers identifies the production estimates by various researchers throughout this time frame (Figure 1).

The annual CPUE per boat in the early years of the fishery was relatively high but varied greatly, ranging from a high of 352 lbs/day in 1956-57 to approximately 143 lbs/day in 1958-59 (Table 2). Generally, the annual CPUE was about 200 lbs/day in the Esmeraldas region and 177 to 120 lbs/day in the Gulf area between 1961 and 1964. Total annual CPUE has been more or less stable from 1973 through 1982, fluctuating around 120 lbs/day (Figure 2). A significant increase in catch was noted in the El Niño year (1983) where the CPUE jumped to 345 lbs/day and thereafter dropped to low levels of 78 and 68 lbs/day.

Recently the British Mission under Charles McPadden instituted two major programs for data collection. First, in November 1985 an observer-at-sea program was initiated in which observers participate in fishing trips each month from the ports of Posorja, Guayaquil and Manta, and every other month from Esmeraldas. Information is collected on the catch-per-tow, hours fished, areas fished and species composition. Second, in February 1986, a logbook system was initiated throughout the country. Information will be obtained on catch-per-tow by area and time fished. The best data base on the shrimp fishery available for analysis is the information obtained from interviews on catch and fishing effort. Reliable information is not available on total catch or total fishing effort.

CPUE and El Niño

The El Niño year (1983), was phenomenal in that the offshore fishery CPUE increased dramatically, probably as a result of increased spawning activity, better survival of juveniles and good recruitment to the offshore fishery. Immediately after the El Niño, in January 1984, monthly CPUE dropped to pre-El Niño year levels. Since that time, the CPUE appears to have decreased each month and has continued to decrease through 1985.

Somers (1986) has separated the annual CPUE for the 1984-1986 period into all species and *P. vannamei*. The total average annual catch rate for 1984-1985 was 73 lbs/day, well below the average 113 lbs/day for the 1973-1979 time frame. The specific catch rate for *P. vannamei* was 23 lbs/day in 1984-1985, considerably greater than the average 13 pounds per day for 1973-1979. The initial catch rate for all species for the first few months in 1986 was 126 lbs/day, which is similar to the earlier catch rates for 1973-1979, but somewhat lower than earlier years (1961-1964) in the fishery.

Since March 1985, McPadden has obtained information on CPUE for white and brown shrimp. This data reveals that the monthly CPUE for white shrimp decreased to a level below 40 lbs/day, whereas brown shrimp monthly CPUE peaked in September 1985 at over 110 lbs/day.

Managing Recruitment

The Ecuadorian government initiated a closed season from December 1985 to January 1986. After the season opened, the CPUEs were at least two times higher than before the closed season. However, it is disturbing that the CPUE before the closure period continually declined to extremely low levels. If these data represent what is actually happening in the fishery and reflect the availability and abundance of white shrimp, regulations to reduce fishing mortality should be considered.

Somers (1986) indicated that there was insufficient evidence to demonstrate any significant declines in recruitment to the offshore fishery. However, the current CPUE levels (less than 40 lbs/day) are extremely low compared to any other world penaeid fisheries for the type of vessels that are presently being utilized off Ecuador, and has declined precipitously from the initial CPUEs after the fishery had stabilized between 1961 and 1964.

If the percentages of species composition are correct, as identified by McPadden, there has been a significant increase in *P. vannamei* captured as reflected in the increased CPUE for this species in the last few years; however, the decline in the other species should cause concern. A significant cause for the decline in CPUE other than overfishing may be reduction in the mangrove areas that are used as nursery areas by larval and juvenile shrimp (Zimmerman and Minello, this volume). Alvarez (this volume) indicates that 10.6 percent of the mangrove area has been lost in the last ten years in Ecuador.

McPadden has also been able to estimate the number of postlarvae delivered to mariculture ponds by the artisanal fishery, but there is considerable uncertainty concerning these values. Maugle (personal communication) indicates that up to 50 percent of the caught larvae die before they reach the pond, therefore the estimates are probably low by at least half. There appears to be a peak of postlarvae production at around 4 billion individuals (i.e. perhaps 8 billion) in 1984, declining somewhat after that. McPadden (1985) indicates that the catch estimates of postlarvae in 1985 were slightly lower than the corresponding estimates for 1984. He has also pointed out that the postlarval fishery involves at least 90,000 participants, and he has clearly identified a need for accurate monitoring of this fishery to determine recruitment levels both in the postlarval and offshore stocks.

Biological Influences on Fisheries

Water Temperature

It is hypothesized that the Gulf of Guayaquil is a prime nursery area for *P. vannamei* and perhaps other white shrimp species. McPadden (1985) indicated that juvenile white shrimp are found predominantly in the Gulf of Guayaquil, whereas mature animals have not generally been observed in this area. The size and persistence of the nursery area may be dictated by the influence of the warm or cool currents. The movement of warm water (26°C) from the north into the Gulf of Guayaquil during September, October and November probably enhances spawning for white shrimp as well as transporting larvae into the Gulf. If the warm water area is large enough and lasts long enough, spawning and recruitment will probably be very good. However, if the cooler southern currents with temperatures of 22°C to 23°C confine the warm water areas during this period, spawning and survival of larvae and juveniles are negatively affected. Further, if the cold southern water penetrates the Gulf, the juveniles may migrate north toward the Esmeraldas area during the April-May period.

Rainfall

Somers has demonstrated a close relationship between rainfall and CPUE (Figure 3). Low rainfall results in low CPUEs; as rainfall increases, so does CPUE. However, this relationship is dominated by the El Niño phenomenon of 1983 and its corresponding high rainfall and high CPUE. The correlation is extremely good at the lower and mid-level of the scale and implies a linear relationship with relatively low levels of rainfall (up to 2,000 mm per year). This relationship indicates that recruitment from 1973 to 1984 was influenced more by environmental conditions than by other factors. Overfishing does not appear to be a major factor in the success of year-class strength.

Fishery Management and Scientific Information

Governments have prime responsibility for conserving marine resources and ensuring that marine stocks are available to future generations in the same quantities as to the present generation. U.S. President Theodore Roosevelt said, "The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value."

Resource managers share this responsibility. They must, of course, prevent recruitment overfishing and certainly minimize growth overfishing (i.e., harvesting animals before the maximum population of that year-class is achieved). Difficulty arises most often in allocation of the resources between competing user groups. Managers must utilize the best scientific information available, as well as input from the industry and consumer groups. Obviously, there is a need for information exchange among scientists, managers, the harvesters and enforcement (Figure 4).

The acceptability of management decisions depends on the flow of information, therefore it is important that significant input be provided by the users of the resources. Various methods may be used to provide industry input. For example, special panels may be established as advisory groups to government officials making management decisions. In the United States, having citizen advisory groups is a legal requirement during development of management plans for federal waters (Leary, 1985).

At the opposite end of the continuum is a system headed by an industry czar who controls all management decisions with little or no user input. Regardless of which management system is eventually used, it is important that good scientific information be available for the decision makers. Therefore, it is recommended that Ecuador consider expanding the program initiated by McPadden to collect statistical information on the shrimp industry from logbooks and interviews of vessel captains regarding catch, effort, CPUE and species composition. Also, a comprehensive program to collect other fishery-dependent data as well as fishery-independent data should be implemented.

Fishery-Dependent Data

The following fishery-dependent data is critically needed for management decisions:

- total catch
- fishing effort
- size composition and species composition of the commercial catch

While it might be impossible to take a regular census of the offshore fishery, some type of sampling program is required to provide accurate total catch and fishery effort information. A special study should be conducted to determine the appropriate experimental design, methodology and approach for a country-wide sampling program to collect the necessary fishery statistics.

The key to implementing a sampling program to estimate total catch and effort is to make recording the number of vessel trips mandatory. Of course, cooperation of the industry is critical; without assurance from the government that the confidentiality of the data will be maintained, it will be impossible to obtain this cooperation. It is also necessary to establish field stations at major unloading ports, such as Esmeraldas, Manta, Bolivar and Guayaquil. These field stations could be manned by a small team of data collectors and research scientists who would obtain fishery catch statistics.

Equally important is the collection of accurate information on the artisanal postlarvae fishery, including the quantity of each species of postlarvae caught monthly, areas fished and the number of individuals involved. Sampling the artisanal postlarvae fishery on a regular basis could also be conducted from the field stations.

Fishery-Independent Surveys

A major question concerning the stocks of shrimp off Ecuador is the interchange between the Esmeraldas and the Gulf of Guayaquil. A well-planned study could be conducted by tagging shrimp in either or both areas and obtaining recoveries from the fleet. This information would need to be supplemented with the amount of fishing effort deployed in both areas, as well as the effort expended in areas between the Gulf of Guayaquil and Esmeraldas. Finally, the collection of tag recoveries would be enhanced by the establishment of field stations.

Fishery-independent surveys to monitor the shrimp populations in the fishery grounds are expensive but do provide long-term information on status and trends of the major species. For example, such surveys conducted once or twice a year would be useful for evaluating effects of shrimp closures (Matthews, 1982). The current program to monitor the distribution and abundance of postlarvae and juvenile shrimp in the Guayaquil estuary should be continued, and expanded to other areas of the coast.

Management of Ecuadorian Fisheries

The two shrimp closures recently imposed by Ecuador appear to have been successful, but without a system of statistics on total catch, fishing effort, CPUE, as well as size composition and species composition of the commercial catch, it is impossible to accurately assess the effects of closures (Nichols, 1982; Klima et al, 1982; Poffenberger, 1982; and Mathews, 1982). Without such evidence, it will also be unlikely that continued industry support for periodic closures will be available, though sometimes, even with good information, the political whims of various user groups may be swayed because of selfish interests.

Establishing a permanent, long-term program to collect fisheries statistics from the offshore fishery and the postlarval fishery will form a data base for evaluating both. Without that type of data base, it will be difficult to determine if recruitment overfishing is occurring. The fishery-dependent data bases can also be used to analyze trends of both the postlarval and offshore fisheries and determine the impact on the major shrimp stocks of Ecuador.

Although recruitment overfishing does not appear to be a serious problem, the fishery's low CPUEs in 1984 and 1985, and the switch in species composition from *P. occidentalis* and *P. stylirostris* to

P. vannamei are of some concern. The Ecuadorian government should consider a method of imposing a limited entry system since there seem to be enough vessels to capture the amount of shrimp currently being harvested. Any increase in fishing effort or number of vessels will only decrease CPUE and the per boat share of the resource. The government should also consider continuing the experimental closures. The rationale behind this is that a reduction in fishing mortality will not hurt the fishery and, in fact, may be a long-term benefit. The timing of the closure should be altered to coincide with peak recruitment of juvenile shrimp in the fishery.

Long-term planning is essential to the well-being of the shrimp industry of Ecuador. The author recommends that a management and research plan be jointly developed by the government and shrimp industry to identify goals and objectives and to describe possible management actions that will ensure a viable fishery. Implementation of the plan will require adequate financial resources for management, research and enforcement.

Summary

It is the responsibility of the Ecuadorian government to develop a long-term plan for the management of their shrimp fisheries. Included in this plan should be implementable goals, objectives and financial support not only for management and enforcement, but for research as well. To these ends, the British Mission is working to develop such a plan.

The closed season and area restrictions imposed in 1985 to 1986 by the government appear to have been successful because of the increased CPUE immediately following the closure. Unfortunately, there is inadequate data to determine whether the increased CPUE was due to the reduction of fishing effort which allowed an increase in biomass through population growth, or, conceivably, because of an increase in recruitment which allowed the delayed harvest to be larger and more profitable. Nevertheless, the closed season and area concept should probably continue, if only because it reduces fishing effort.

A sound statistical data collection system should be developed not only to evaluate closures, but also to evaluate conditions of the stocks and to provide advice for future management actions. The collection of fishery statistics should and must be considered confidential data and should only be released in summary form to protect individuals. Fishery-independent surveys may also be needed to evaluate management actions and determine recruitment and distribution of postlarval and early juvenile shrimp, as well as conducting mark-recapture studies to determine stock boundaries. Joint planning and development of such programs between industry and the Istituto Nacionale de Pesca (INP) will accelerate supported implementation of these programs.

Finally, consideration should be given to limiting future expansion of the offshore shrimp fleet by developing some form of limited entry system.

Table 1

Penaeus vannamei, *P. stylirostris*, and *P. occidentalis*, expressed as percentage of these species total catch in the Gulf of Guayaquil in 1985.

	P. stylirostris	*P. vannamei*	*P. occidentalis*
March	33	35	35
April	25	30	44
May	28	34	38
June	27	52	21
July	34	40	26
August	25	33	42
September	60	25	15
October	37	38	35
November	33	44	23
December	39	24	37

(Source: McPadden, personal communication)

Table 2

Total catch in millions of pounds, fishing effort in thousands of days fished, and CPUE for white shrimp for the Gulf of Guayaquil and Esmeraldas.

Area	Year	Total Weight, millions of pounds	Fishing Effort, thousands of days fished	CPUE lbs/day
	1956-57	2.94	8.4	352
	1957-58	3.60	12.6	286
Gulf and Esmeraldas	1958-59	2.78	19.4	143
	1959-60	3.19	16.1	198
	1960-61	2.60	12.3	212
	1961-62	2.39	12.4	191
	1962-63	2.33	14.1	165
	1963-64	2.08	15.4	185
Esmeraldas	1961-62	0.88	3.4	248
	1962-63	0.88	4.3	206
	1963-64	0.84	5.1	164
Gulf	1961-62	1.59	9.1	177
	1962-63	1.45	9.9	147
	1963-64	1.24	10.3	120

(Cobo and Loesch, 1966)

Figure 1. Total estimated shrimp production and number of shrimp vessels for Ecuador.

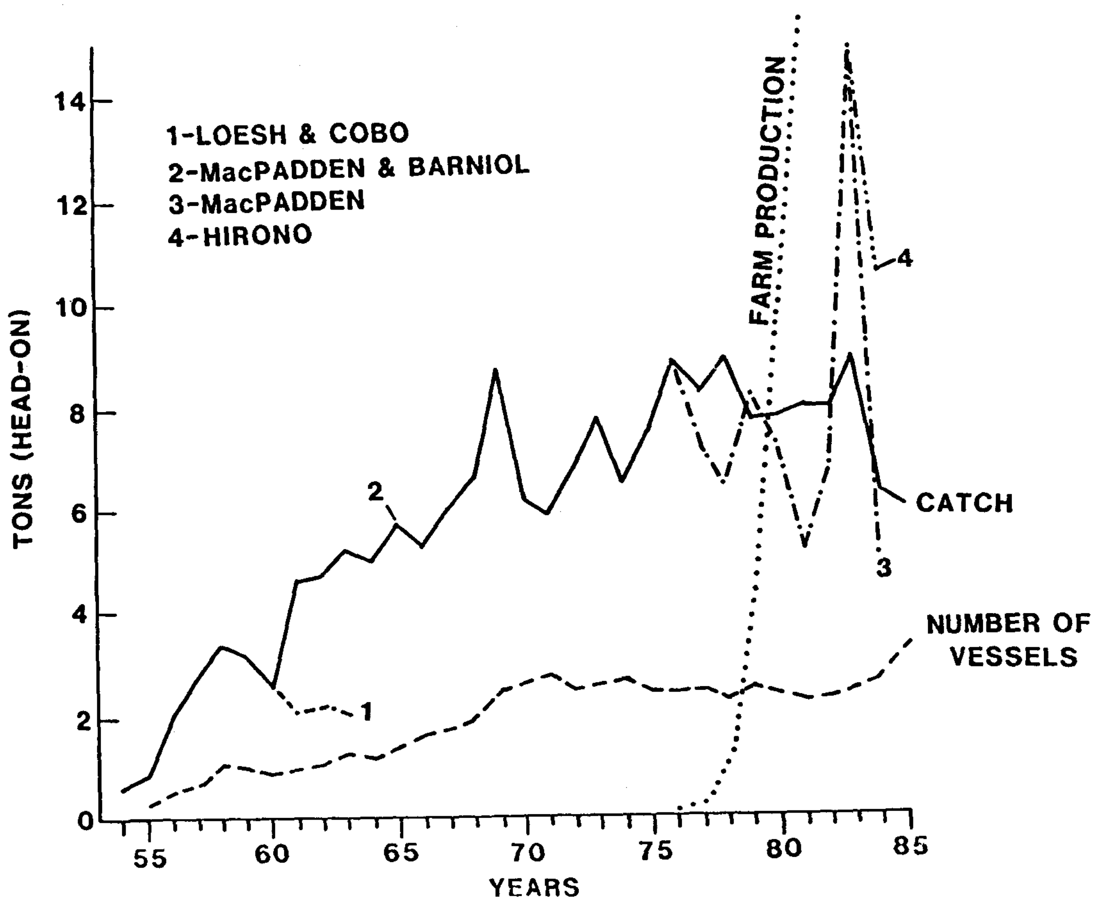


Figure 2. Monthly catch per unit effort (lbs head-off) for all shrimp species and *P. Vannamei* in the Gulf of Guayaquil from 1973 to 1985.

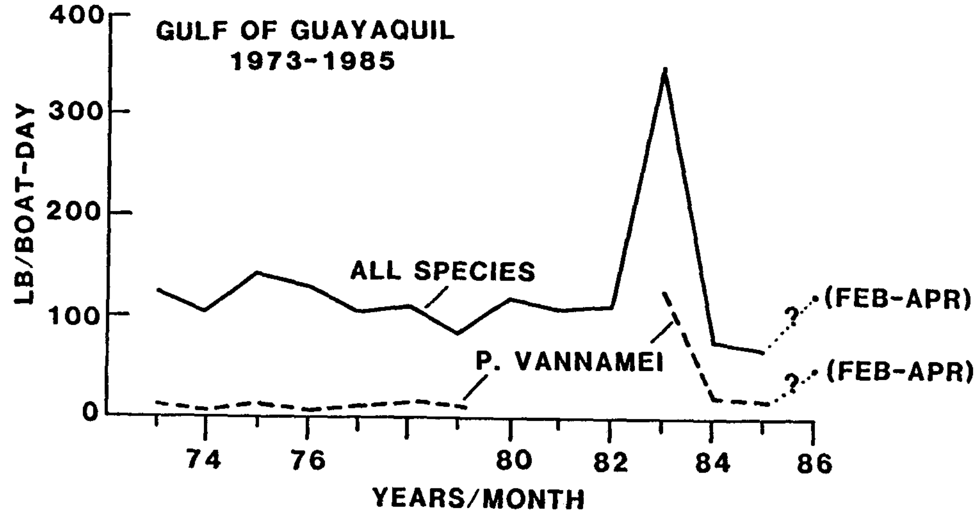


Figure 3. Relationship between rainfall (mm) and CPUE (kg/day, heads-off) in the Gulf of Guayaquil (CPUE = 22.2 + 0.034 rainfall; r^2 = .88).

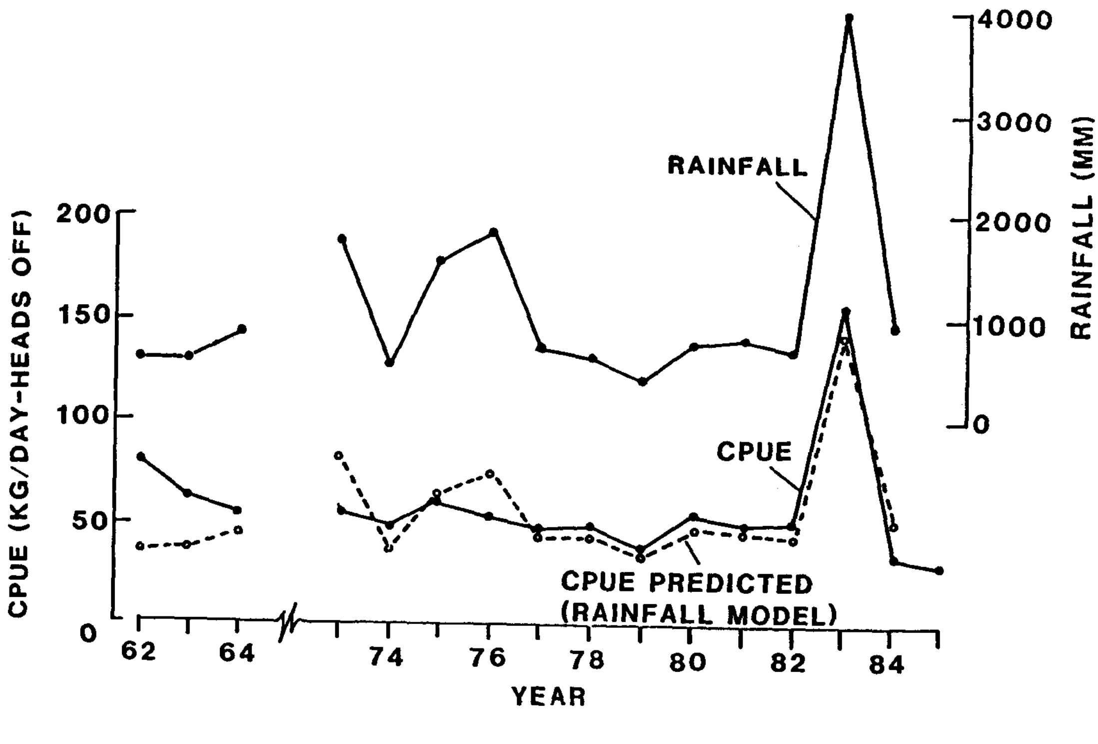
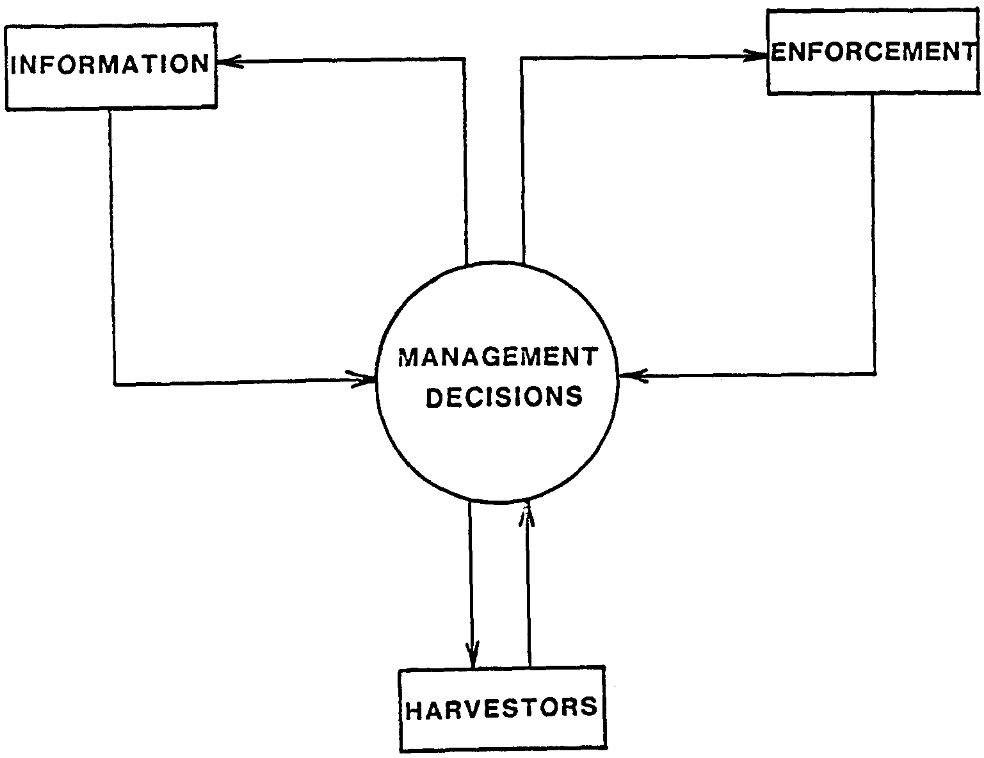


Figure 4. Information flow used to make fishery management decisions.



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