10 SHRIMP AND FINFISH FISHERIES IN SURINAME

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10.1 General background

The stock assessment work programme of the Fisheries Department of Suriname has been established in accordance with recognised fisheries management priorities. Current management issues have been discussed by representatives of all stakeholder groups (fishermen, fish processors, fish merchants, exporters, the public sector, etc) during a two-day national workshop on fisheries management in January 1998. The following major issues were identified:

- There is a lack of control and surveillance at sea, which results in very poor enforcement of any management measures. This increases the risk of overfishing of some of the resources. This situation also has a bearing on the quality of the data that are collected for stock assessment purposes, since no reliable information can be obtained on illegal fishing activities.
- The shrimp fishery exhibits strong yield fluctuations from year to year. The total annual landings have varied in recent years from 2 000t to more than 3 000t tail weight. In addition, fishing companies are affected by a sustained decline of the yields since 1995. Average catch per fishing day, which used to fluctuate around 100kg tail weight, has decreased to less than 50kg since September 1996. Investigation is required to find out to what extent natural causes like recruitment fluctuations, environmental causes, etc. explain this change, as opposed to the impact of fishery related causes (too much effort, competition of other fleets) and/or other human causes.
- The major recent development in the finfish fisheries is the entry of new fleets, generally larger vessels equipped with trawls of various types. These vessels compete with pre-existing (mostly small-scale) fishermen for some fish species and they also target other species that were only lightly exploited before. A multi-fleet and multi-species approach is appropriate to investigate these issues.
- A seabob fleet has also developed recently. Since it operates in the shallow coastal zone, it competes with other fleets exploiting resources in that area. The new seabob fleet faces complaints from the shrimp fishery, as well as from various parts of the small-scale fisheries that exploit seabob and finfish. Investigations on the mutual impacts of all these activities are important to management.

10.2 Collection of data for stock assessment

There are four main programmes through which the Fisheries Department is collecting the information required for the assessment of the resources.

- Through a **Fisheries Information System**, data on landings and effort are regularly collected. For the small-scale fisheries, where many different small fishing units land at numerous places, the system is based on a network of field enumerators. The companies operating larger vessels (this includes all types of trawlers and the vessels using vertical lines) are requested to submit their data after each trip.
- There is an **observer programme** that aims at the collection of information on bycatch and fishing grounds on board of fishing vessels. It also collects biological samples (finfish and seabob).
- There is a **sampling programme** on shore, recording biological data on selected species (finfish, seabob and shrimp).

- **Economic information** has only been recorded on an irregular basis for specific studies.

Priorities have also been set in the species to be assessed. Although the situation of all major commercial species ultimately has to be elucidated and then monitored, analyses focused in 1998 on the following:

- **Shrimp:** specific assessments are under way for the two major species sustaining the fishery, brown shrimp (*Penaeus subtilis*) and hopper shrimp (*Penaeus brasiliensis*).
- **Seabob:** *Xyphopenaeus kroyeri*.
- **Finfish:** most attention is given to the species that are significant in the trawl catches. Of particular interest are the species caught by several types of gear, like sea trout (*Cynoscion virescens*), other species of the family Sciaenidae and lane snapper (*Lutjanus synagris*).

10.3 Shrimp fishery

10.3.1 Port samplings

Port sampling at the processing plants was resumed in March 1996. It produces data on the species/gender and size composition of the monthly shrimp landings. This information will complement similar data covering the years 1985 to 1991. Based on the observations of these two periods and the landings by commercial size categories, similar compositions will be calculated for the periods in which there was no sampling (before 1985 and from January 1992 to February 1996). A continuous database will then become available.

10.3.2 Length–based cohort analysis by month

A length–based cohort analysis has been applied to monthly data on the second period of data (1996-1998), updating the 1998 workshop results (which covered the first period). The parameters used were the same as previously used (Table 10.1).

Table 10.1 Growth and mortality parameters used in a length based cohort analysis of the important species in the shrimp fishery

	L_∞ (mm tail)	K (month^{-1})	M (month^{-1})
P. subtilis F	136	0.0885	0.146
P. subtilis M	110	0.0924	0.146
P. brasiliensis F	144	0.1000	0.146
P. brasiliensis M	133	0.1000	0.146

It should be noted that the most recent results are provisional, as the figures on landings provided by some of the fishing companies still need to be completed and verified.

The brown shrimp fishing mortalities exhibit a similar seasonal pattern in both periods, being about twice as high in the second part of each year as in the first part (Fig. 10.1). The fishing mortality level also seems to be similar between the periods 1985-91 and 1996-98. Hopper shrimp (*P. brasiliensis*) mortalities in the 1996-98 period are also comparable with the values found in the earlier period (Fig. 10.2).

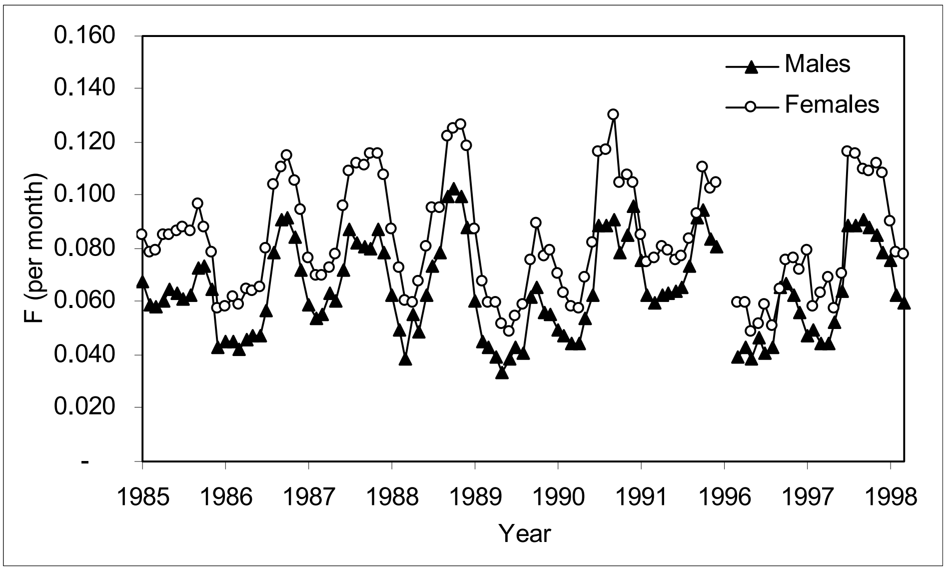

Figure 10.1 Monthly fishing mortalities, *P. subtilis*, Suriname, 1985-1998

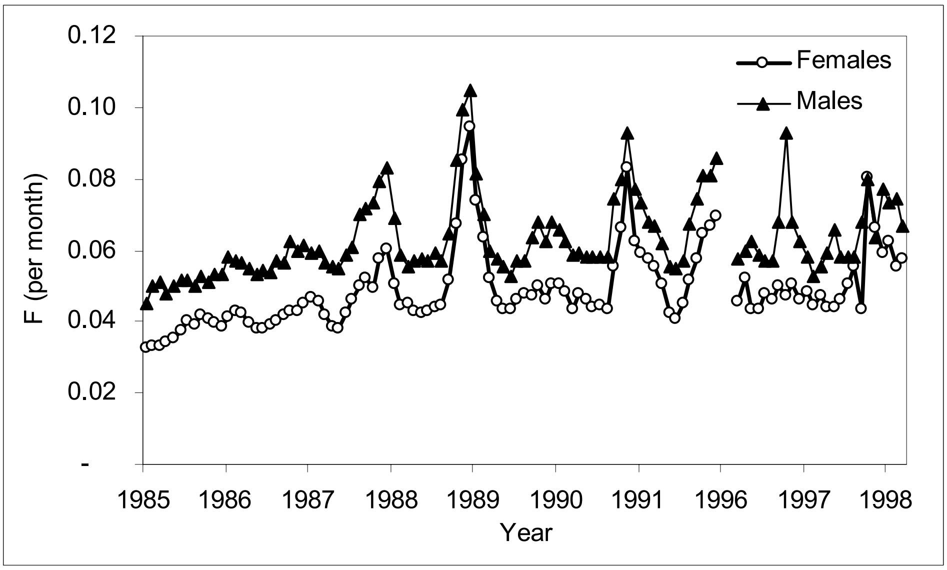

Figure 10.2 Monthly fishing mortalities, *P. brasiliensis*. Suriname, 1985-1998

The biomass estimates, however, appear much lower for the 1996-98 period than in 1985-91. This is most visible in the case of the brown shrimp (Fig. 10.3). These brown shrimp biomass estimates also show relatively high variability from month to month. For *P. brasiliensis*, a decrease in the biomass estimates is observed only in the second part of the second period (1997, Fig. 10.4).

10.3.3 Multi-fleet analysis

Two components can be distinguished in the shrimp trawling fleet, the Korean and Japanese fleets. Korean and Japanese companies have differing strategies and fishing grounds and they exert different mortalities on the shrimp species. In addition to these two fleets, the seabob vessels are also catching some brown shrimp. A multi-fleet analysis including these three components could help estimate the extent to which the seabob fleet may affect the shrimp fishery and provide insights on the interactions between the two shrimp trawler fleets.

A length-based cohort analysis has been carried out since the last workshop on the total female brown shrimp landings of the three fleets. The size composition of the Korean and the Japanese components was taken from the average numbers landed, by month, over the years 1985-1991. The composition of the seabob fleet landings was the results of samples carried out on board of the vessels in 1997 and 1998. The three length compositions differ (Fig. 10.5).

The fishing mortalities from LCA were used in a Thompson-Bell model to run simulations to see how catches would change with changing fishing mortality. The fishing mortalities were multiplied by a range of constants, first all together and then to one fleet at a time while the mortalities of the two other fleets were kept constant. These simulations suggested that:

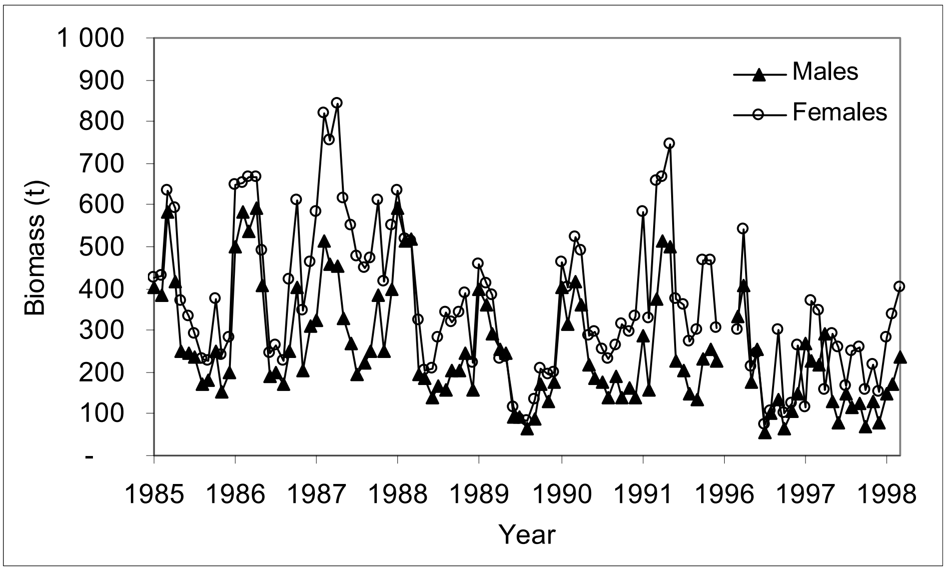

Figure 10.3 Monthly average biomass, *P. subtilis*, Suriname, 1985-1998

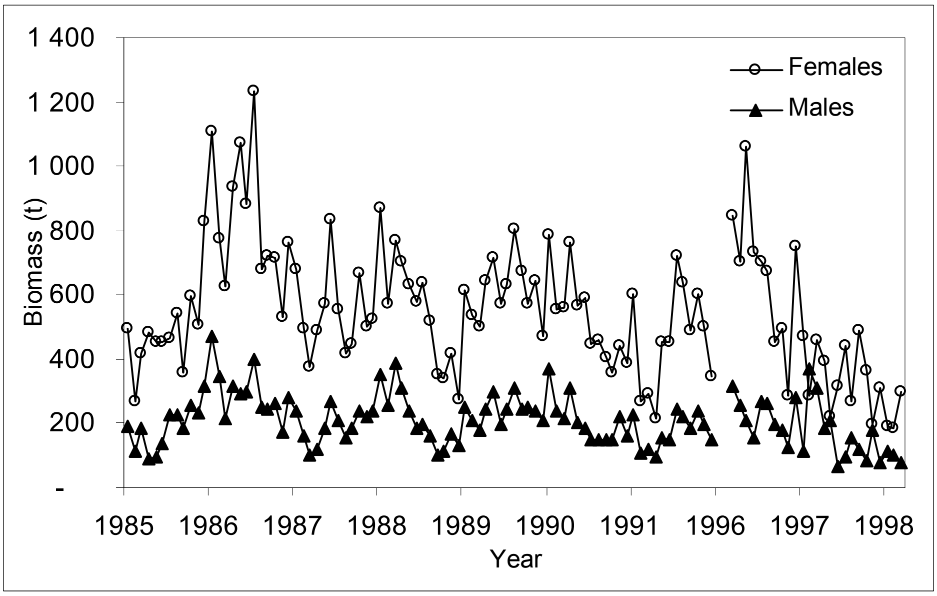

Figure 10.4 Monthly average biomass. *P. brasiliensis,* Suriname, 1985-1998

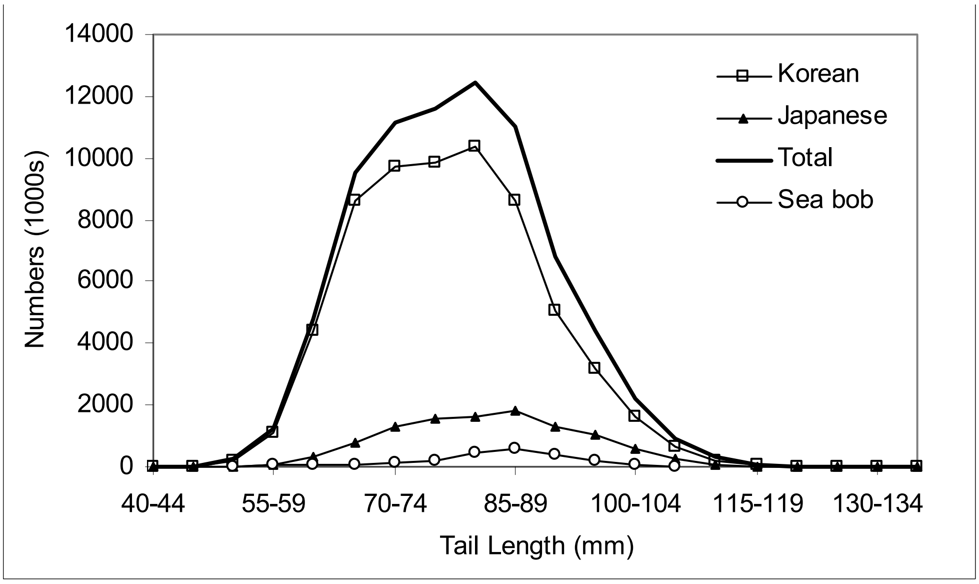

Figure 10.5 Length frequency distribution of *P. subtilis* female catch by fleet.

Table 10.2 Fishing mortality estimates from LCA for the three fleets fishing *P. subtilis*. The total calculated fishing mortalities were divided into components allocated to the three fleets, proportionally to their contribution to the landings in each size

Size range		Total F	Fishing Mortality by fleet		
Min	Max		Korean	Japanese	Seabob
40	45	**0.00**	0.00	0.00	0.00
45	50	**0.00**	0.00	0.00	0.00
50	55	**0.03**	0.02	0.00	0.00
55	60	**0.14**	0.12	0.01	0.00
60	65	**0.57**	0.52	0.04	0.00
65	70	**1.25**	1.14	0.10	0.01
70	75	**1.72**	1.50	0.19	0.02
75	80	**2.18**	1.86	0.29	0.04
80	85	**3.09**	2.58	0.40	0.11
85	90	**4.04**	3.17	0.66	0.21
90	95	**4.05**	3.04	0.79	0.22
95	100	**4.68**	3.38	1.10	0.20
100	105	**4.90**	3.54	1.24	0.12
105	110	**4.86**	3.42	1.34	0.10
110	115	**4.87**	3.50	1.37	0.00
115	120	**4.90**	3.52	1.37	0.00
120	125	**4.10**	2.95	1.15	0.00

- Further increases in the total effort (fishing mortality) would not lead to an increased value of the landings (Fig. 10.6).
- The seabob fleet does not seem to affect the shrimp fishery much. This is mainly due to the fact that volumes of small sizes caught by this fleet appear relatively insignificant (Fig. 10.7).
- An increase in fishing mortality by the Korean fleet would decrease the brown shrimp yields of the other fleets, as well as the total landed value (Fig. 10.8).
- Increasing the fishing mortality by the Japanese fleet would also decrease the yields of the other two fleets, but it would not cause a notable decrease in the total value. The gain of larger shrimp caught by the Japanese fleet would offset the loss of the less valuable, smaller shrimp caught by the Korean fleet (Fig. 10.9).

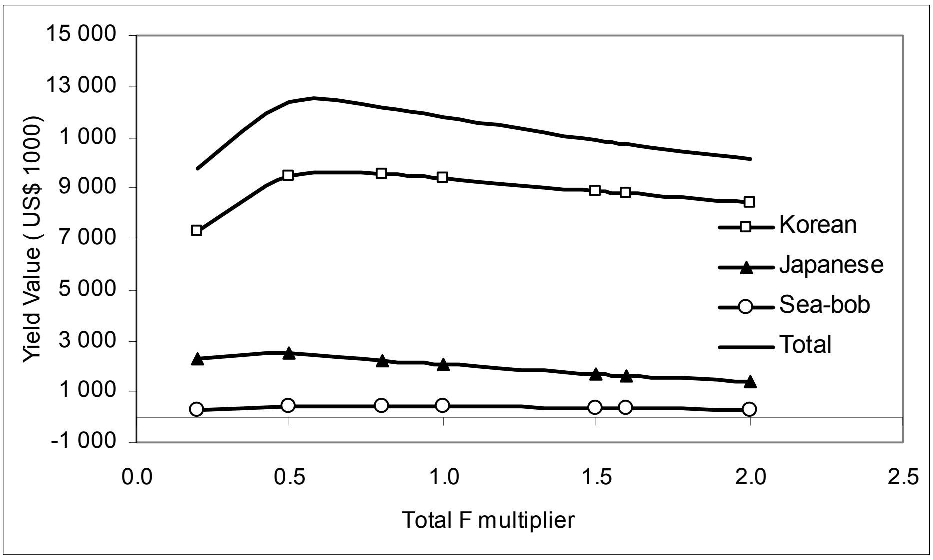

Figure 10.6 Yield value (*P. subtilis* female) by fleet vs fishing mortality multiplier

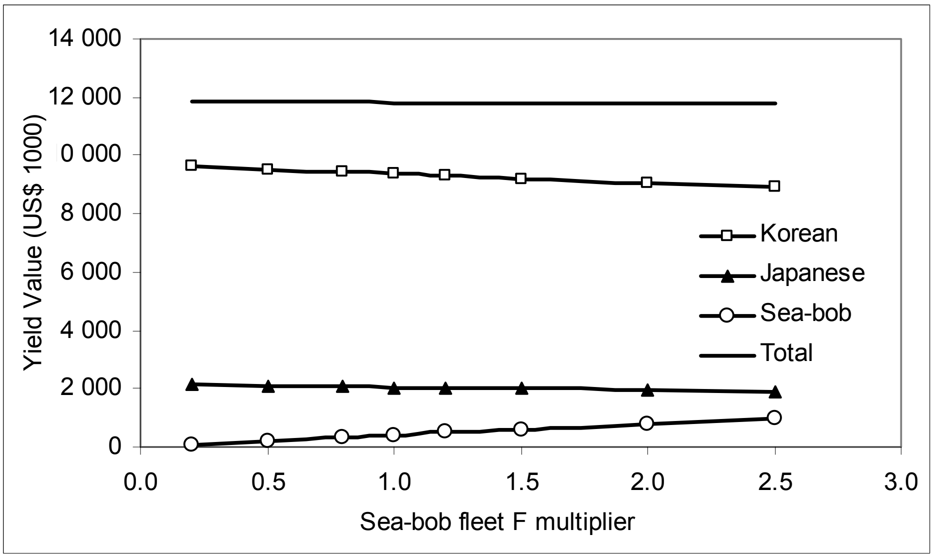

Figure 10.7 Yield value (*P. subtilis* female) by fleet vs seabob fleet F multiplier

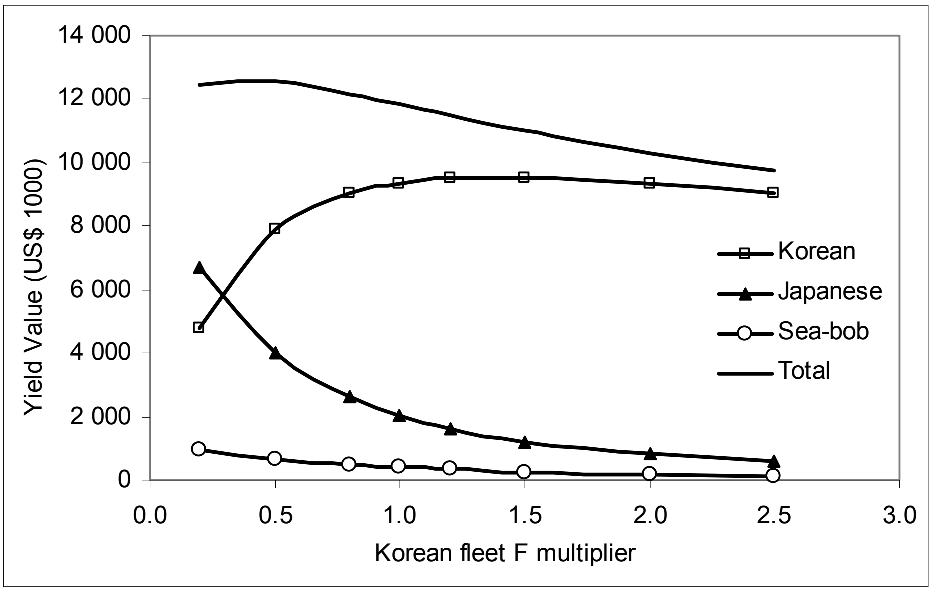

Figure 10.8 Yield value (*P. subtilis* female) by fleet vs Korean fleet F multiplier

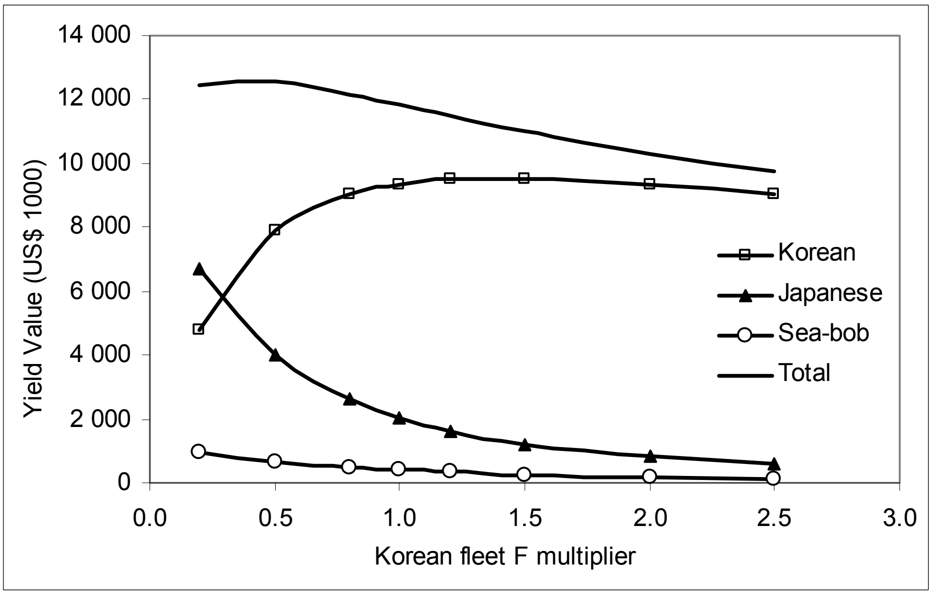

Figure 10.9 Yield value (*P. subtilis* female) by fleet vs Japanese fleet F multiplier

These are preliminary observations and it should be pointed out that the size distribution of the landings by the seabob fleet, which is a key to this analysis, is based on samples. It therefore only covers a limited portion of the operations (however, covering an entire year). In addition, inter-annual variations are of course not accounted for and it would be advisable to repeat the analysis based on separated annual data.

The proportion of brown shrimps in the seabob trawlers catch probably varies from trip to trip, even from haul to haul, showing peaks in delimited seasons and areas, depending on recruitment. It is also possible that trawlers licensed for seabob could target brown shrimp at times when seabob yields are low. These cases may be easily missed by a sampling programme covering more or less one out of twenty landings, yet they might have an impact on the overall size distribution of brown shrimp caught by seabob vessels. We also expect a large year-to-year variability because there are years with and without strong brown shrimp recruitment peaks, so analyses based on a particular year's data may give substantially different results.

10.4 Seabob Fishery

10.4.1 General description of operations

The first fishing company started operating in 1996 and a second one joined the fishery in 1997. Today, they have fleets of 15 and 8 vessels respectively, which are former shrimp trawlers with freezers replaced by ice holds. The gear is an adapted shrimp trawl, with a higher vertical opening and a lighter headrope. Detailed information on the operations, fishing grounds, are being recorded by observers.

10.4.2 Data collection on efforts and landings

Landing reports are requested from the companies, on a trip-by-trip basis, including dates leaving and arriving from port, seabob landed by commercial grades and other components of the landings (finfish and ungraded shrimp).

Factory samples

Seabob has been sampled during the unloading at the first processing plant (one boat per month). The purpose was to assess the presence of brown shrimp in the seabob landings. The components of the samples (seabob, other shrimp and fish by species) were weighed and all *Penaeus* shrimp was measured (as far as possible). The seabob itself, however, proved to be too damaged at the time of landing to be measured.

Sampling on board

Observers on board seabob trawlers collected a seabob sample from every haul during on average one trip per month. The treatment of these samples at the laboratory included measuring all seabob and brown shrimp and recording the weights of all components, by shrimp and finfish species. An analysis based on these length frequency distributions could not been completed in time for the workshop.

10.4.3 Impact on Penaeus shrimp species

Amounts and size composition of shrimp catch by seabob trawlers were estimated from observers samples and landing reports. *P. subtilis* and *P. schmitti* were reported in small quantities. According to these provisional results, the impact of the seabob fleet on shrimp populations appears quite small (see 10.3).

10.5 Finfish fisheries

Catch and effort data are recorded at landing by enumerators for the small-scale fisheries, whereas trawl fishing companies are requested to report the same data after every trip. Biological information (length frequency compositions for the main species) has been recorded on board trawlers, but the collection of biological data on shore (for finfish landed by small-scale fishermen) has not succeeded due to a lack of staff. Assessments have been undertaken on lane snapper (*Lutjanus synagris)* and sea trout (*Cynoscion virescens*).

10.5.1 Assessment of lane snapper (Lutjanus synagris)

Lane snapper (*Lutjanus synagris*) has only recently gained importance in the landings in Suriname. It is one of the target species of the recently developed fleet of finfish trawlers (called “kotters”, 5 vessels under Dutch flag). It also forms part of the bycatch of the shrimp trawlers and in 1998, a third fleet (2 larger mid-water trawlers under Korean flag, called “Osito”) has taken part in the harvest. There is therefore a good case for multi-fleet analysis with 3 fleets.

Growth and mortality parameters have not been estimated in this sub-region (Brazil-Guyanas shelf). Estimates from other areas of the Atlantic Ocean (Brazil, Cuba, Mexico) were found in FishBase. In order to allow for a first analysis, the following values for the length-weight relationship and growth parameters were selected among those proposed by this database:

$$a = 0.0427 \; ; \; b = 2.72$$

$$L_\infty = 55 \text{ cm}$$

$$K = 0.28 \text{ yr}^{-1}$$

The equation of Pauly provided an estimate for the natural mortality M (setting the sea temperature at 27º gave M = 0.65 yr^{-1}).

The size composition and the landings by the two finfish trawler fleets were calculated from the samples measured on board both types of vessels in the course of 1998 and from accurate reports on the 1998 landings. Similar data are not available over the same period for lane snapper taken as a bycatch by the shrimp fishery. For the purpose of this analysis, a length frequency distribution and an estimate of the landings by this fleet dating from 1991 was used. The landings in numbers by size for each fleet are shown in Fig. 10.10.

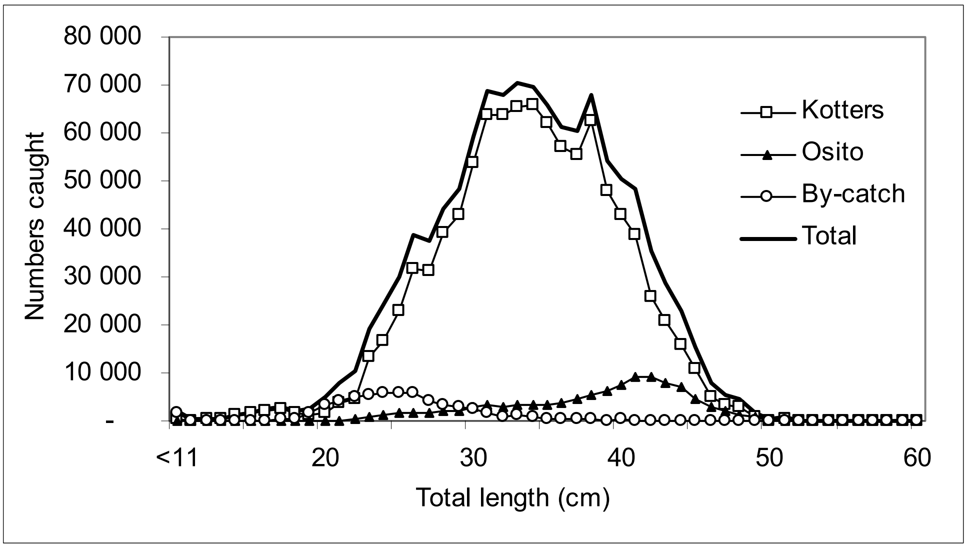

Figure 10.10 Estimated numbers of *L. synagris* caught by length class in 1998 for Kotters and Osito fleets and in 1991 for shrimp bycatch

A catch curve analysis was carried out on these catch data and a fishing mortality F=0.494 $year^{-1}$ was estimated. A Beverton and Holt per recruit analysis was used to estimate yield per recruit (Fig. 10.11) and biomass per recruit (Fig. 10.12). YPR appears to be currently below its maximum level, unless the selectivity (which has not been estimated) is assumed to be such that length at first capture is under 15 cm, which is not supported by the estimates of fishing mortalities by size (Table 10.2). BPR is estimated to be, in the current situation, around a third of the pristine level.

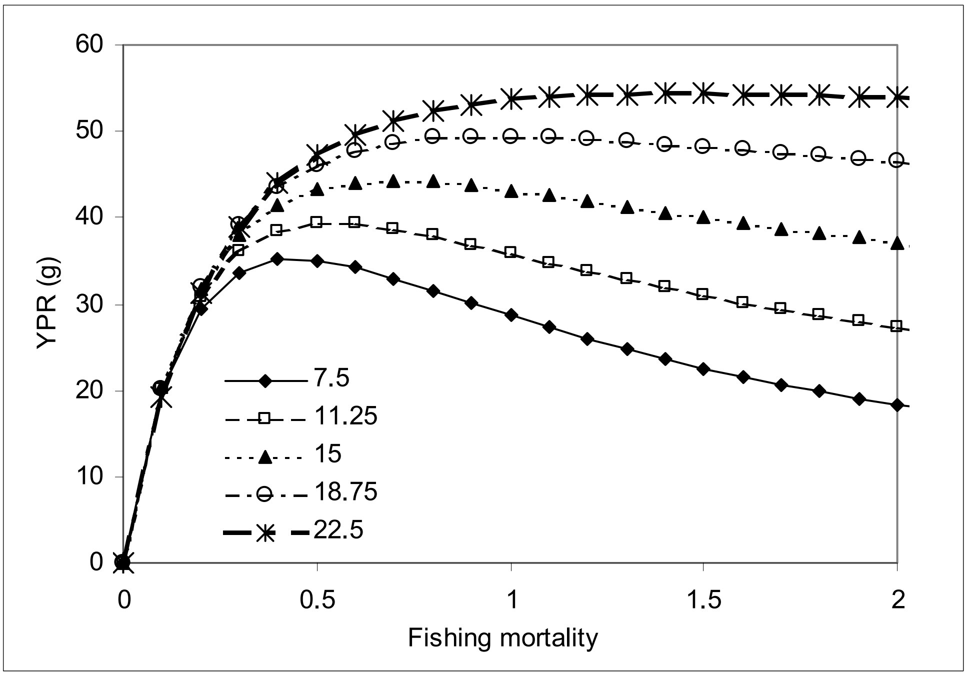

Figure 10.11. Yield per recruit under different lengths at first capture (cm) of *L. synagris*, based on 1998 data

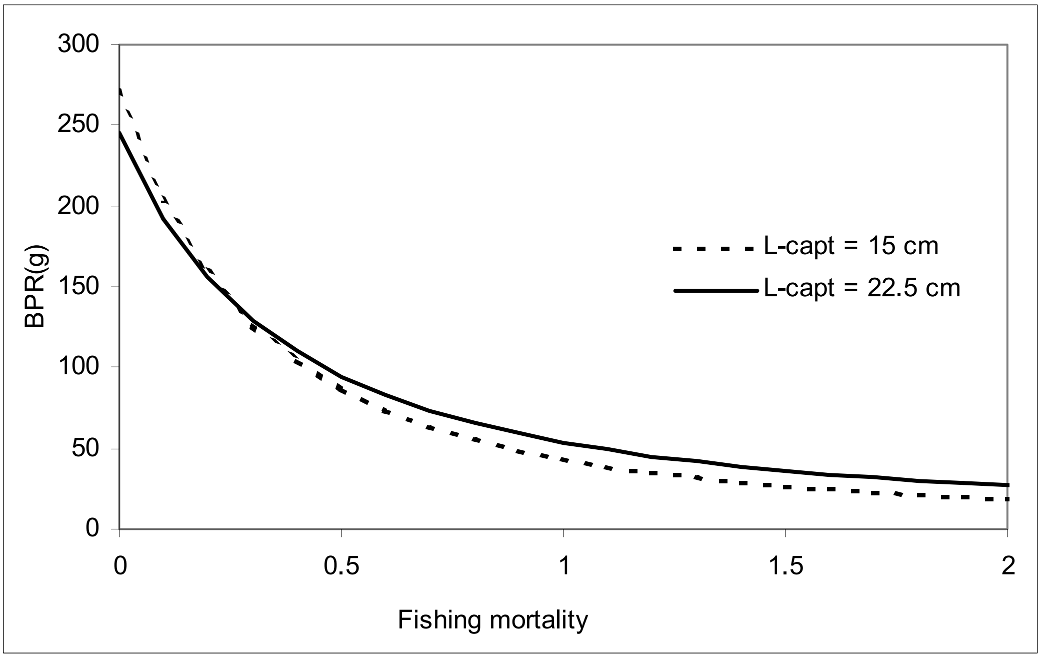

Figure 10.12 Stock biomass per recruit of *L. synagris*, based on 1998 data

Table 10.2 Results from a length-based cohort analysis estimating fishing mortality by length class. The distribution of the F by size into fleet components was estimated based on contribution of each fleet to the landings to each size

Size range		Fishing mortality				Size		Fishing mortality			
Min	Max	Total	Kotters	Osito	Bycatch	Min	Max	Total	Kotters	Osito	Bycatch
11	20	0.00	0.00	0.00	0.00	37	38	0.33	0.31	0.02	0.00
20	21	0.01	0.00	0.00	0.00	38	39	0.44	0.41	0.03	0.00
21	22	0.01	0.00	0.00	0.01	39	40	0.42	0.39	0.03	0.00
22	23	0.02	0.01	0.00	0.01	40	41	0.47	0.42	0.06	0.00
23	24	0.03	0.02	0.00	0.02	41	42	0.57	0.48	0.08	0.00
24	25	0.04	0.03	0.00	0.01	42	43	0.54	0.43	0.10	0.00
25	26	0.06	0.04	0.00	0.01	43	44	0.58	0.43	0.15	0.00
26	27	0.08	0.06	0.00	0.01	44	45	0.63	0.45	0.18	0.00
27	28	0.08	0.07	0.00	0.01	45	46	0.60	0.42	0.18	0.00
28	29	0.10	0.08	0.00	0.01	46	47	0.45	0.32	0.13	0.00
29	30	0.12	0.10	0.01	0.01	47	48	0.45	0.29	0.16	0.00
30	31	0.16	0.14	0.01	0.01	48	49	0.56	0.35	0.21	0.00
31	32	0.19	0.18	0.01	0.01	49	50	0.38	0.26	0.12	0.00
32	33	0.21	0.20	0.01	0.01	50	51	0.16	0.09	0.07	0.00
33	34	0.24	0.23	0.01	0.00	51	52	0.40	0.09	0.31	0.00
34	35	0.26	0.25	0.01	0.00	52	53	0.21	0.17	0.04	0.00
35	36	0.28	0.26	0.01	0.00	53	54	0.53	0.37	0.16	0.00
36	37	0.30	0.28	0.02	0.00						

A Thompson-Bell model used fishing mortalities for each length class (Table 10.2) to simulate the effect of varying fishing mortality. The mortalities were multiplied by a range of constants, first all together, then separately to one fleet at a time while the mortalities of the other two fleets were kept constant. The results, expressed in total weight caught, suggest that:

- Increasing the total effort could lead to substantial increases in total landings (Fig. 10.13). The "Osito" fleet, however, would experience a reduction in its harvests, unlike the two other fleets. This would coincide with a gradual elimination of the larger sizes that make up most of the "Osito" catch.
- The "kotters" fleet dominates the fishery so much that it is unaffected by the other fleets (Fig. 10.15, 10.16). On the contrary, an increase of the effort of the "kotters" fleet would be detrimental for the "Osito" fleet (Fig. 10.14).
- Shrimp bycatch, even though removing mainly juveniles from the fishing grounds, does not seem substantially to affect the fishery (Fig. 10.15). This observation relies on our assumption that this species does not make up a large portion of the bycatch and that the information on size composition and volumes collected almost 10 years ago is still valid.

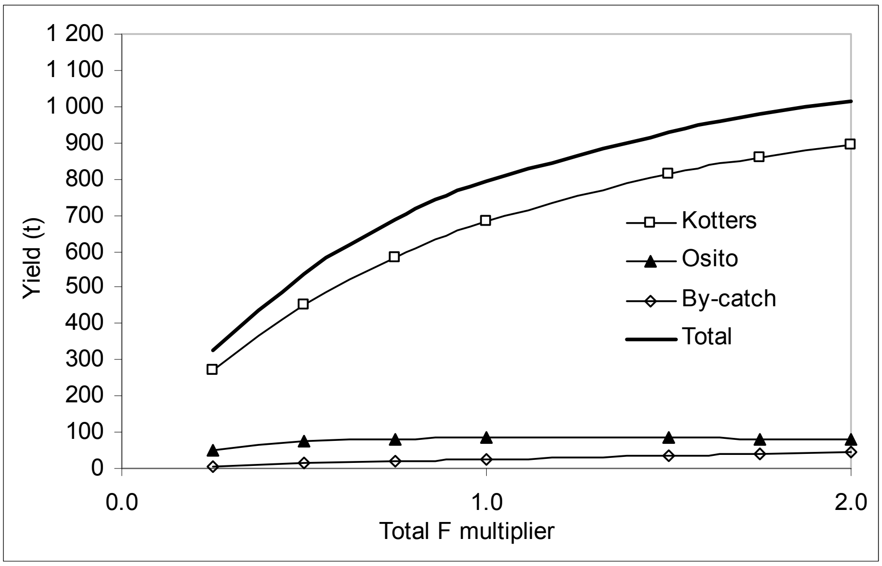

Figure 10.13 Yield in weight of *L. synagris* vs F multiplier for all fleets

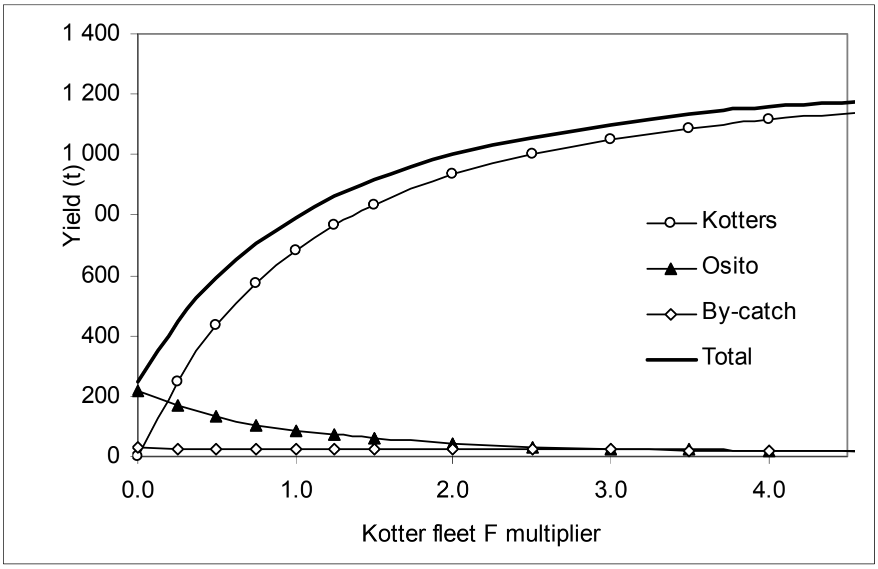

Figure 10.14 Yield in weight of *L. synagris* vs F multiplier for Kotters fleet only

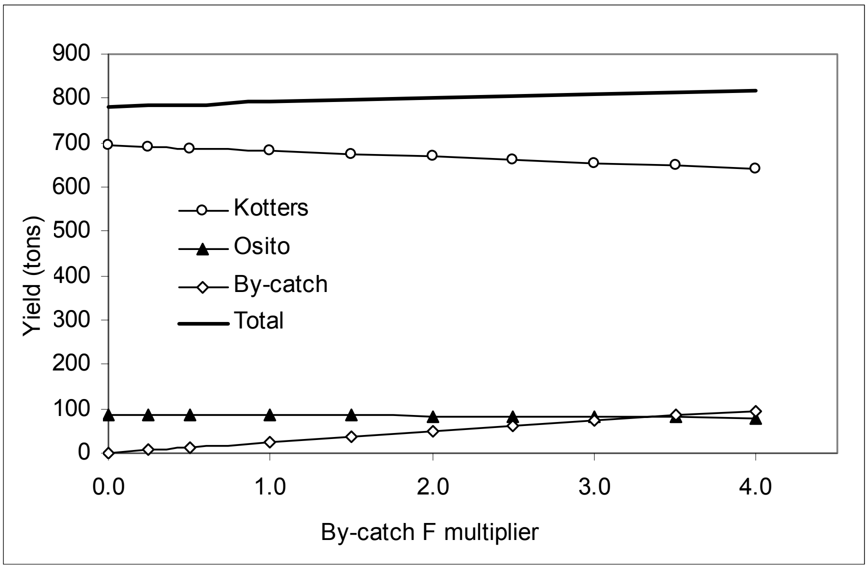

Figure 10.15 Yield of *L. synagris* vs F multiplier for the bycatch fleet only

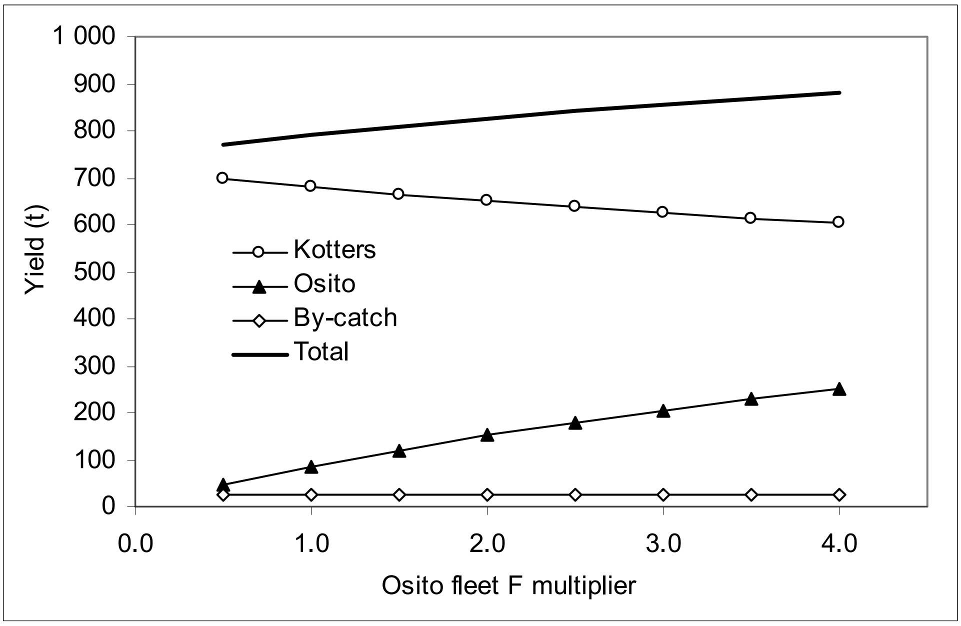

Figure 10.16 Yield in weight of *L. synagris* vs F multiplier for the Osito fleet only

10.5.2 Assessment of sea trout (Cynoscion virescens)

Cynoscion virescens is a major commercial species in Suriname. It is a demersal fish, distributed in coastal waters to depths of around thirty meters. It is caught by a number of gears, the most important being trawls, drifting gillnets and Chinese seines. Among the trawlers, the same fleets as for lane snapper can be distinguished viz. the Korean (or “Osito”) and the Dutch (or “kotters”) fleets.

The Kotter fleet uses bottom trawls, while the Korean fleet uses mid-water trawls. In recent years, the catches have decreased, leading to concern about the status of the resource. This assessment focused on the trawl fleet, on which most data were available.

Table 10.3 Fleet characteristics of the Dutch “kotters” and Korean “Osito” vessels catching *Cynoscion virescens*

	Dutch fleet	Korean fleet
Annual landings (all species, kg)	2 330 827	819 502
Number of days at sea (1998)	1 120	180
Number of hauls (1998)	4 144	1 526
Number of boats (1998)	5	2
Average trawling time (hours)	3.8	2.7
Average daily catch (kg)	2 081	4 553
Average catch per haul (kg)	562	537
Average catch per hour (kg)	148	199

The Dutch fleet accounted for approximately 75% of the landings in 1998, but the Korean vessels have a higher fishing power, apparently resulting from undertaking more trawls per day than the Dutch vessels (Table 10.3).

The weight-length conversion parameters were obtained from samples of whole fish taken in 1998 by the quality control laboratory in Paramaribo. The log-linear model parameter **b** was fixed to a value of 3 and parameter **a** was estimated, so:

$$W = 0.0069\ L^{3}$$

The von Bertalanffy growth parameter $\mathbf{L_\infty}$ was first estimated using the FISAT package using the length frequencies of the two trawler fleets, which were available for all months of 1998. This provided an estimate of $\mathbf{L_\infty}$ = 94.6 cm. An estimate of parameter **K** was calculated using the modal progression analysis routine included in FISAT, but the poor quality of data made the results unreliable. A number of alternative modal pathways were identified from the data but, taking into account the previously estimated L_∞ of 94.6 cm, the only fits that appeared feasible were identified:

L_∞	96.6	98.77	91.99
K	0.32	0.23	0.83
t_0	-0.14	-0.13	-0.18

The arithmetic average of these estimates of L_∞ is 95.6 cm and of K is 0.46 year^{-1}.

The M value was estimated to be 0.74 year^{-1} by Pauly’s empirical equation, using the above von Bertalanffy parameters and assuming a mean water temperature of 25^{o}C.

$$\text{Log } M = -0.0152 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log t.$$

A length-converted catch curve analysis (using a spreadsheet designed by Ehrhardt and Legault, 1996) was used to estimate F for the stock. This was done by fitting a length converted catch curve to the length frequencies of the separate months (Table 10.4) based on the growth and mortality parameter estimates given above.

Table 10.4 Fishing mortality by month obtained from a length-converted catch curve

Month	Feb	Mar	May	Jun	Jul	Aug	Sep	Oct	Nov	Average
F	1.78	2.69	2.09	1.17	0.94	2.52	1.85	2.84	0.90	1.86
R^2	0.95	0.92	0.94	0.86	0.97	0.98	0.99	0.98	0.98	

The average of the fishing mortality estimates obtained (F=1.86 $year^{-1}$) was used in the further analysis.

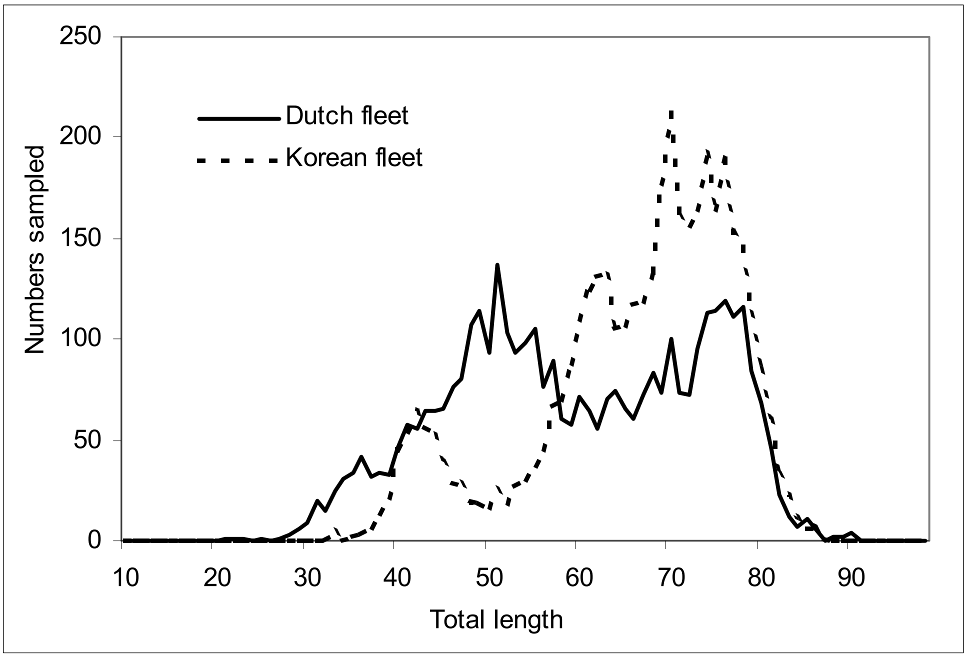

Figure 10.17 Length frequency distribution for *C. virescens* by fleet from samples taken during 1998

Examination of the length frequencies of the Dutch and Korean fleets indicated differences in their selectivity, with the former catching a higher proportion of smaller fish (Fig. 10.17). Average length was 44 cm for the Korean fleet and 35 cm for the Dutch fleet. Fishing mortalities were therefore calculated separately for the data sets of each fleet. The values obtained were considerably higher than the mean annual F resulting from the combined monthly length frequencies.

Table 10.5 Fishing mortality estimates for each fleet from catch curves fitted separately to each fleet's length frequency samples

	Dutch Kotter fleet	Korean Osiri fleet	F mean
F	2.48	2.09	**2.28**
R^2	1.00	0.98	

In addition, a weighted length frequency of the annual catches from the two fleets was calculated, weighted according to the annual catch of each fleet (all species). The total catch for 1998 of the 5 Dutch vessels was 2 330 827 kg and that of the Korean fleet was 819 502 kg. Catch curve analysis on this weighted distribution produced an F estimate of 2.34.

A length of maturity of 33 to 34 cm was chosen, which is equivalent to an age of 0.88 years old. From the landings length frequencies, the size and age of first capture of the Dutch fleet was determined to be 35 cm (0.95 years old) and that of the Korean fleet to be 44 cm (1.29 years old).

These values were used as inputs in a multi-fleet per recruit model (Booth 1999). Biological reference points were generated, which, when compared to the estimated current F, give indications on the status of the stock (Tables 10.6 – 10.8). The weighted F was considered to be the best estimate of the current F. In addition to the per recruit analyses for the combined fleet, separate analyses were undertaken for the Dutch and Korean fleets (as if they operated alone).

Table 10.6 Yield per recruit analyses for the combined fleet

	Current status (combined fleets)	Biological Reference Points				
		Unexploited	SBR 50%	SBR 40%	SBR 30%	$F_{0.1}$
F	**2.34**	0	0.4	0.57	0.83	0.55
Spawning Biomass per Recruit (g)	**117**	1042	521	417	313	425
Yield per recruit (g)	**213**	0	194	216	230	215
Slope YPR	**-0.17**	9.73	1.84	0.91	0.24	0.97

Table 10.7 Yield per recruit analyses for the Korean fleet. The same parameters as for the combined fleet were used

	Current status (Korean fleet)	Biological Reference Points				
		Unexploited	SBR 50%	SBR 40%	SBR 30%	$F_{0.1}$
F	**2.09**	0	0.47	0.68	1.02	0.61
SBR (gr)	**196**	1042	512	417	313	447
YPR (gr)	**253**	0	205	228	241	222
Slope YPR	**-0.07**	9.2	1.55	0.71	0.14	0.92

Table 10.8 Yield per recruit analyses for the Dutch fleet. The same parameters as for the combined fleet were used

	Current status (Dutch fleet)	Biological Reference Points				
		Unexploited	SBR 50%	SBR 40%	SBR 30%	$F_{0.1}$
F	**2.48**	0	0.38	0.53	0.76	0.53
SBR (g)	**96**	1 042	521	417	313	420
YPR (g)	**201**	0	189	211	224	210
Slope YPR	**-0.17**	9.87	1.92	0.96	0.26	0.98

Examination of the behaviour of the catch curve analysis suggested that it was particularly sensitive to the values of K, which is known only approximately for *C. virescens* in Suriname. Therefore, as a sensitivity test, the lowest reasonable K estimate consistent with the length frequency data was used (K=0.23 L_{∞}=95.6 cm). These new values were used to estimate, with Pauly's empirical equation, a natural mortality M= 0.47.

With these parameters, a catch curve analysis produced an F 1.07. The selectivity of the two fleets also needed to be recalculated with the modified growth parameters. The results were 1.89 years for the Dutch fleet (35 cm) and 2.57 years for the Korean fleet (44 cm), while a length at maturity of 34 cm would correspond to an age of 1.82 years. These new parameters were used in a new per recruit analysis (Table 10.9).

Table 10.9 Yield per recruit analyses for the Dutch and Korean fleets combined, using the lower bound K parameter, with other parameters modified accordingly

	Current status (2 fleets)	Biological Reference Points				
		Unexploited	SBR 50%	SBR 40 %	SBR 30%	$F_{0.1}$
F	**1.07**	0	0.36	0.50	0.72	0.45
SBR (g)	**181**	856	428	343	256	365
YPR (g)	**158**	0	138	152	159	149
Slope YPR	**-0.12**	7.93	1.37	0.61	0.1	0.79

The different analyses undertaken all indicate a high fishing mortality for *Cynoscion virescens*. According to the calculations, maintaining the current F level will lead to the spawning biomass per recruit (SBR) being reduced to 11.3% of the initial level. With the new set of parameters (lower K value), the sustained application of the estimated F would lead to a reduction of the SBR to 21.3% of its original level, which is still very low. The fishing pressure therefore appears to be excessive.

A number of measures could be considered in order to improve the situation of the stock:

- Increase the mesh size of the Dutch fleet to at least that of the Korean fleet.

- Reduce the effort exerted by one or both fleets by reducing the number of boats.
- As an alternative to excluding some vessels, closed seasons for fishing could be considered as a means of reducing total effort to the desired level.
- A further means of reducing the catch and providing a refuge for the spawning stock, would be to introduce restricted areas for fishing with trawlers. Further studies are required to investigate the necessary size of the closed area or areas.

Without adequate action to reduce fishing mortality to sustainable limits, it is very unlikely that the catch rates will improve over time and they may deteriorate. A possible scenario would be to decrease the fishing effort of the Dutch fleet by 40% and that of the Korean fleet by 50%. At the same time, the mesh selectivity of both fleets could be brought to 130% of the present value of the Korean fleet. These measures would lead to a reduction of the spawners biomass to 39% of its original level, which is better than the current calculated situation (20%). Fishing mortality would however still be at an excessive level of 1.4.