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Variations in the Fish Catch Composition in the Bay of St Vincent, New Caledonia, as Determined by Experimental Trawling

M. Kulbicki and L. Wantiez

ORSTOM, Nouméa, New Caledonia.

Abstract

An experimental trawl survey was conducted in the Bay of St Vincent between December 1984 and April 1986. In all, 85 hauls were performed during four cruises. The trawled fish represented 233 species and 59 families. Biomass and density estimates declined 13-fold between the first and last cruises. This decline is not due to the survey catch (less than 2% of the biomass of the bay), nor is it likely to be due to trawling-induced changes in habitat. Natural causes are the most likely reason for the decline. The *r*-type species (Leiognathidae, *Lethrinus nematacanthus*) had the largest population fluctuations, whilst longer living and later reproducing species (*Saurida undosquamis*, large *Upeneus* spp.) had the smallest. Trophic structure is studied using three expressions: number of species, biomass and density per trophic group. Number of species per trophic group was the most insensitive to changes in time and place, with density being the most sensitive. Study of the variations in trophic structure could help with the monitoring of major changes in fish populations caused by fishing or environmental changes.

Introduction

The aim of this survey was to estimate the potential for a shrimp trawl fishery in the Bay of St Vincent, north of Nouméa (Fig. 1). A side result was the provision of information on small benthic fish fauna and some appreciation of the impact that a shrimp trawl fishery might have on commercial fish species. Although it was not possible to maintain a homogeneous sampling procedure throughout the survey, certain major trends were discovered.

Shrimp trawlers act on fish populations in at least two ways. First, they catch commercially important species as adults and juveniles (Aoyama 1973; Pong *et al.* 1976; Sinoda *et al.* 1978; Grantham 1980; Okera 1982; Villoso and Hermosa 1982; Chong 1984; Poiner and Harris 1986). The catching of juveniles is a controversial subject, but in most tropical Indo-Pacific trawl fisheries such fish are not an important part of the catch (Sinoda *et al.* 1978; Chong 1984; Poiner and Harris 1986). Second, the shrimp trawlers affect benthic organisms (e.g. sponges, algae, corals, alcyonarians) that are part of the habitat of fish (Poiner and Harris 1986; Sainsbury 1987). This disturbance of the biotope is believed to be one of the causes of long-term species changes in tropical trawl fisheries such as have been observed in the Gulf of Thailand and the north-western continental shelf of Australia (Pauly 1979; Sainsbury 1987).

The by-catch of shrimp trawlers is highly multi-specific and the management of such stocks is a complex issue (Sainsbury 1982, 1987). Single-species models are not adapted to this situation, and multi-species models require a large quantity of information that is not available. New approaches to management are therefore needed. In particular, it is necessary

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to examine the hypothesis of food limitation of post-larval fish recruits (Sainsbury 1982). In analysing this hypothesis, the trophic structure of the fish population must be determined. This paper presents such a determination at a general level for the Bay of St Vincent.

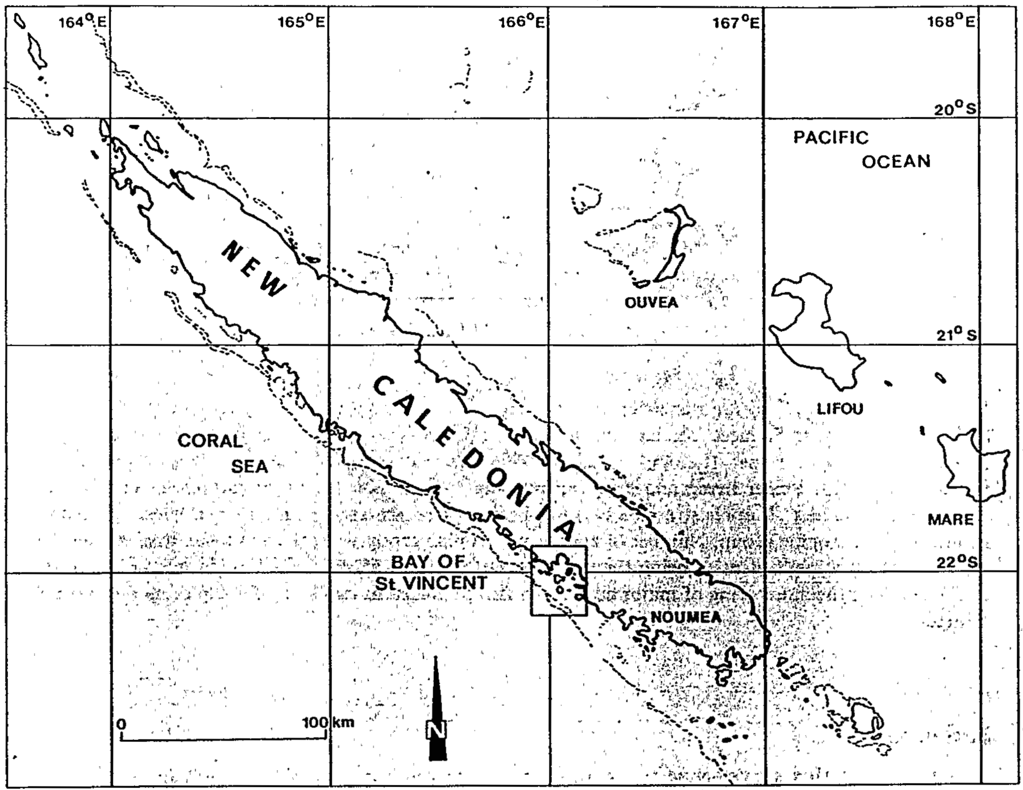

Fig. 1. Location of the study area.

Materials and Methods

Trawling and Sampling

The RV *Vauban* (25 m) towed a shrimp trawl net equipped with a 14-m head-line, a 2-cm-mesh cod end, and a tickler chain. At a speed of 2 knots, the opening of the net was 1·2 m high and 7 m wide.

In all, 85 hauls were performed during four cruises. Each haul lasted 20–40 min (average 30 min). The hauls took place in two different parts of the Bay of St Vincent ('north bay' and 'south bay'; Fig. 2 and see Table 3). Initially, the cruises were intended to be 4 months apart, but the December 1985 cruise had to be cancelled for technical reasons. Depth was 5–13 m in the north bay and 8–20 m in the south bay. During the first cruise, the number of hauls was intended to cover as much area as possible. During subsequent cruises, the number of hauls was reduced to 11 in the north bay and 9 in the south bay, although technical problems prevented the completion of all hauls in the south bay during the second and third cruises. At the end of each haul, the fish were sorted to species level; species names are those given by Rivaton *et al.* (1989). Each species was then weighed and counted. If a species was represented by more than 200 individuals, a subsample was drawn and numbers were estimated by extrapolation. Length frequencies were determined for the most abundant species.

Estimates of fish density (d, expressed as fish ha^{-1}) were calculated by

$$d = \frac{n \times 60}{t \times l_1 \times 1{\cdot}852 \times k},$$

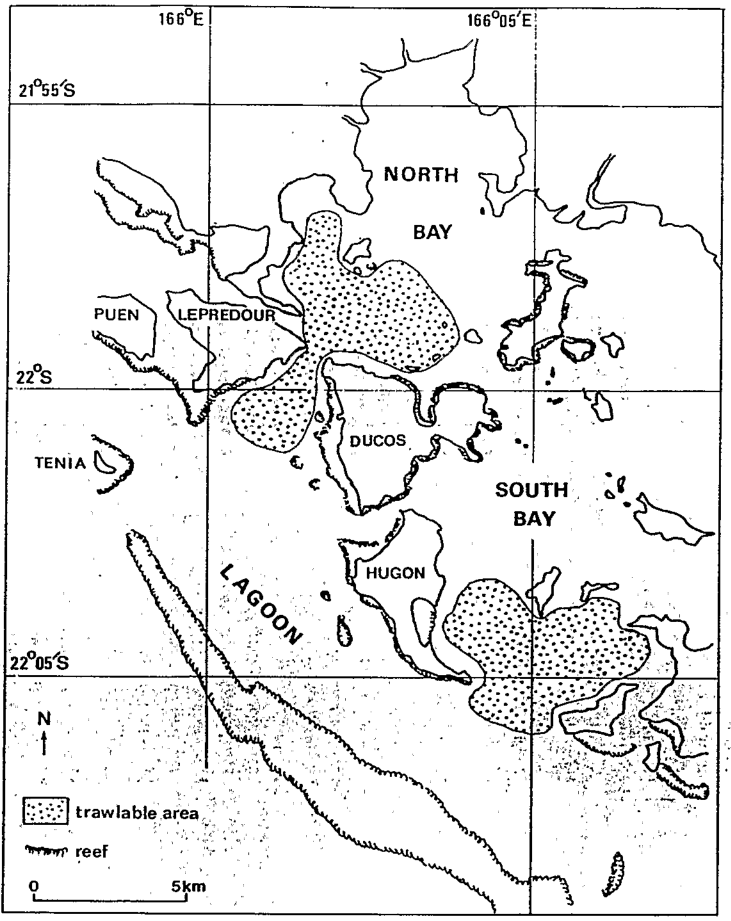

Fig. 2. Trawlable areas in the Bay of St Vincent.

where n is the total number of fish, t is the trawling time in minutes, l_1 is the width of the net (7 m) divided by 10, and k is the speed of the boat in knots.

Estimates of fish biomass (b, expressed as kg km^{-2}) were calculated by

$$b = \frac{w \times 60}{t \times l_2 \times 1{\cdot}852 \times k},$$

where w is the weight of the catch in kilograms and l_2 is the width of the net divided by 1000.

To calculate the mean density, D, or the mean biomass, B, computations were made using

$$T = \sum_{i=1}^{p} t_i, \qquad N = \sum_{i=1}^{p} n_i, \qquad W = \sum_{i=1}^{p} w_i,$$

where p is the number of hauls; t_i is the trawling time, n_i is the number of fish and w_i is the weight for a given haul i. Thus,

$$D = \frac{N \times 60}{T \times l_1 \times 1{\cdot}852 \times k}, \qquad B = \frac{W \times 60}{T \times l_2 \times 1{\cdot}852 \times k}.$$

The variance estimates v_D or v_B for D or B were calculated by

$$v_D = \sum_{i=1}^{p} \frac{(d_i - D)^2}{p - 1}, \qquad v_B = \sum_{i=1}^{p} \frac{(b_i - B)^2}{p - 1}.$$

Table 1. Checklist of fishes caught during exploratory trawling in the Bay of St Vincent

*, Species common with the checklist of Sainsbury *et al.* (1984) for the north-western Australian continental shelf; see also Rivaton *et al.* (1989) for species authors

- Orectolobidae
  - *_Stegostoma fasciatum_
- Sphyrnidae
  - *_Sphyrna lewini_
- Carcharhinidae
  - *_Carcharhinus limbatus_
- Rhynchobathidae
  - *_Rhynchobatus djiddensis_
- Dasyatidae
  - _Dasyatidae_ sp.
  - *_Dasyatis kuhlii_
- Muraenidae
  - _Muraenidae_ sp.
  - _Gymnothorax albimarginatus_
  - _Siderea picta_
- Muraenesocidae
  - *_Muraenesox bagio_
  - _Muraenesox_ sp. St Vincent
- Clupeidae
  - _Amblygaster_ sp.
  - *_Amblygaster sirm_
  - _Dussumieria_ sp. B
  - _Herklotsichthys quadrimaculatus_
  - _Herklotsichthys_ sp. A
- Engraulidae
  - _Engraulidae_ sp.
  - _Stolephorus devisi_
  - *_Stolephorus indicus_
- Chirocentridae
  - *_Chirocentrus dorab_
- Plotosidae
  - *_Plotosus lineatus_
- Synodontidae
  - _Saurida gracilis_
  - *_Saurida undosquamis_
  - _Cociella crocodilla_
  - *_Onigicia spinosa_
  - *_Onigocia macrolepis_
- Serranidae
  - _Pseudanthias_ sp.
  - *_Cephalopholis boenack_
  - *_Epinephelus areolatus_
  - _Epinephelus cyanopodus_
  - *_Epinephelus maculatus_
  - *_Epinephelus malabaricus_
  - _Epinephelus merra_
  - _Epinephelus rivulatus_
  - _Plectropomus leopardus_
- Pseudochromidae
  - _Assessor macneili_
- Priacanthidae
  - *_Priacanthus hamrur_
- Apogonidae
  - _Apogon_ sp.
  - _Apogon catalai_
  - *_Apogon elliotі_
  - *_Apogon aureus_
  - _Apogon fraenatus_
  - _Apogon kiensis_
  - _Apogon lineolatus_
  - *_Apogon septemstriatus_
  - _Apogon_ sp. aff. _compressus_
  - _Apogon trimaculatus_
  - _Archamia fucata_
  - _Archamia_ sp.
  - _Cheilodipterus quinquelineatus_
  - _Fowleria marmorata_
  - _Rhabdamia cypselurus_
- Sillaginidae
  - _Sillago ciliata_
- Gerreidae
  - *_Gerres filamentosus_
  - _Gerres ovatus_
- Haemulidae
  - *_Diagramma pictum_
  - *_Pomadasys argenteus_
- Lethrinidae
  - _Gymnocranius_ sp.
  - *_Gymnocranius rivulatrus_
  - _Lethrinus_ sp.
  - *_Lethrinus lentjan_
  - *_Lethrinus miniatus_
  - *_Lethrinus nebulosus_
  - *_Lethrinus nematacanthus_
  - *_Lethrinus rubrioperculatus_
  - *_Lethrinus semicinctus_
- Nemipteridae
  - *_Neimpterus peroni_
  - _Scolopsis temporalis_
- Mullidae
  - _Mulloides flavolineatus_
  - _Parupeneus barberinoides_
  - *_Parupeneus indicus_
  - *_Parupeneus pleurospilos_
  - *_Parupeneus signatus_
  - _Parupeneus_ sp.
  - _Upeneus_ sp.
  - *_Upeneus moluccensis_
  - *_Upeneus sulphureus_
  - *_Upeneus tragula_
  - _Upeneus vittatus_
  - _Upeneus_ sp. aff. _asymetricus_
- Chaetodontidae
  - *_Chaetodon auriga_
  - _Chaetodon bennetti_
- Scaridae
  - _Scarus_ sp. juvenile
  - *_Scarus ghobban_
- Mugiloididae
  - _Parapercis_ sp.
  - _Parapercis cylindrica_
  - _Parapercis polyophthalma_
  - _Parapercis schauislandi_
- Blennidae
  - _Blenniidae_ sp.
  - _Petroscirtes breviceps_
- Callionymidae
  - _Repomucenus virgis_
  - _Repomucenus huguenini_
  - *_Synchiropus rameus_
- Gobiidae
  - _Gobiidae_ sp.
  - _Exyrias puntang_
  - _Glossogobius biocellatus_
  - _Glossogobius giuris_
  - _Oxyurichthys tentacularis_
  - _Oxyurichthys papuensis_
  - _Yongeichthys nebulosus_
- Trypauchenidae
  - _Ctenotrypauchen microcephalus_
- Acanthuridae
  - _Acanthurus_ sp.
  - _Acanthurus_ sp. juvenile
  - _Acanthurus dussumieri_
  - _Acanthurus blochii_
  - _Acanthurus xanthopterus_
  - _Naso hexacanthus_
  - _Naso_ sp.
- Siganidae
  - _Siganus canaliculatus_

Chaetodon ephippium _Siganus oramin_

*_Saurida undosquamis_
Sillago ciliata
Chaetodon bennetti
Siganus canaliculatus

Synodus binotatus
*_Synodus variegatus_
Synodus dermatogennis
*_Synodus hoshinonis_
Synodus sp.
*_Trachynocephalus myops_
Carapidae
Carapus homei
Antennariidae
Phrynelox tridens
Phrynelox zebrinus
Anthennariidae sp.
Atherinidae
Atherinidae sp.
Holocentridae
*_Sargocentron rubrum_
Sargocentron sp.
Fistulariidae
*_Fistularia petimba_
Centriscidae
Aeoliscus strigatus
Syngnathidae
Zalises draconis
Syngnathe sp.
*_Hippocampus hystrix_
Dactylopteridae
*_Dactyloptena orientalis_
Scorpaenidae
Scorpaenidae sp.
*_Dendrochirus brachypterus_
Pterois zebra
Pterois sp.
*_Erosa erosa_
*_Inimicus didactylus_
Erisphex obbesi
Paraploactis trachyderma
Platycephalidae
Platycephalidae sp.
Echeneidae
*_Echeneis naucrates_
Carangiade
Carangidae sp.
*_Alectis indicus_
*_Atule mate_
*_Carangoides chrysophrys_
Caranx papuensis
*_Decapterus russellii_
*_Gnathanodon speciosus_
*_Megalaspis cordyla_
Pseudocaranx dentex
*_Scomberoides tol_
*_Selar crumenophthalmus_
Leiognathidae
*_Gazza minuta_
Leiognathus sp.
*_Leiognathus bindus_
*_Leiognathus equulus_
*_Leiognathus leuciscus_
Leiognathus rivulatus
*_Leiognathus splendens_
*_Secutor ruconius_
Lutjanidae
Lutjanus adetii
*_Lutjanus argentimaculatus_
*_Lutjanus bohar_
Lutjanus fulviflammus
Lutjanus fulvus
Lutjanus kasmira
*_Lutjanus quinquelineatus_
*_Lutjanus russelli_
*_Lutjanus vittus_
*_Symphorus nematophorus_
Caesionidae
Caesio sp.
*_Caesio cuning_
Pterocaesio tile
Chaetodon ephippium
Chaetodon flavirostris
Chaetodon lineolatus
Chaetodon plebeius
Chaetodon speculum
Chaetodon trifascialis
Chaetodon trifasciatus
*_Coradion altivelis_
Heniochus acuminatus
Pomacentridae
*_Amphiprion clarkii_
Amphiprion tricinctus
*_Chromis fumea_
Dascyllus sp.
Dascyllus aruanus
Neopomacentrus azysron
Pomacentrus amboinensis
Pomacentrus philippinus
Pomacentrus sp.
*_Pristotis jerdoni_
Mugilidae
Valamugil seheli
Sphyraenidae
Sphyraena barracuda
Sphyraena japonica
*_Sphyraena obtusata_
*_Sphryaena putnamiae_
Polynemidae
Polydactylus microstoma
Labridae
Labridae sp.
Anampses sp.
Cheilinus bimaculatus
Cheilinus chlorourus
Cheilinus orientalis
Thalassoma sp.
Thalassoma lunare
*_Xiphocheilus typus_
Siganus oramin
Siganus sp.
Trichiuridae
*_Trichyurus lepturus_
Scombridae
*_Rastrelliger kanagurta_
*_Scomberoides commersoni_
Bothidae
Bothidae sp.
Arnoglossus sp.
*_Asterorhombus intermedius_
*_Engyprosopon grandisquama_
*_Grammatobothus polyophthalmus_
Soleidae
Aesopia sp.
*_Pardachirus pavoninus_
Balistidae
Balistes sp.
*_Abalistes stellaris_
Monacanthidae
*_Paramonacanthus japonicus_
Pseudalutarius nasicornis
Ostraciidae
Lactoria cornuta
*_Lactoria diaphana_
Lactoria fornasini
*_Ostracion cubicus_
*_Tetrosomus gibbosus_
Tetraodontidae
Amblyrhynchotes hypselogeneion
Arothron sp.
Arothron alboreticulatus
Arothron hispidus
*_Arothron manillensis_
*_Arothron stellatus_
Canthigaster compressa
Canthigaster sp.
*_Lagocephalus sceleratus_

No catchability factor was introduced, so that the results could be compared with most of the data in the literature.

Trophic Structure

Each fish species was attributed with a diet having seven possible components: fish, macroinvertebratres, microinvertebratres (benthic), zooplankton, other types of plankton, algae and coral (Wantiez and Kulbicki, in press). A given species may have several components in its diet and so contribute to several trophic categories. This procedure is more precise than the usual attribution of a species to a single trophic category (Parrish *et al.* 1986).

Results and Discussion

Species Diversity

In all, 233 species in 59 families were recorded in the catch (Table 1). Such diversity is common in most tropical trawl fisheries (Table 2). However, species checklists like those referred to in Table 2 are seldom exhaustive, and the number of species in tropical trawl fisheries is actually much greater (as, for example, in northern Australia, where 732 species have been recorded by trawling; Sainsbury *et al.* 1984). The species list from the present survey has many similarities with that from north-western Australia since 53 families and 95 species (90 and 41%, respectively, of those in the Bay of St Vincent) are common to both areas. The families with the most species in common are the Leiognathidae, Lethrinidae and Synodontidae.

Table 2. Number of species and families reported for trawling surveys in tropical waters

Source	Region	Species	Families
Druzhinin and Phone Hlaing 1972	Burma	88	42
Fernando 1972	Ceylon	151	50
Sinoda *et al.* 1978	Singapore	>95	50
Wei *et al.* 1973	North-western Australia	114	—
Seno and Matsuda 1966	North-western Australia	171	—
Rainer and Munro 1982	Gulf of Carpentaria	180	—
McManus 1986	Philippines	83	16
Villloso and Hermosa 1982	Philippines	226	82
Darcy and Gutherz 1984	Florida	234	71

Table 3. Number of hauls per cruise and number of species collected in the Bay of St Vincent

	No. of hauls per cruise					No. of species collected				
	Dec. 1984	Apr. 1985	Aug. 1985	Apr. 1986	Total	Dec. 1984	Apr. 1985	Aug. 1985	Apr. 1986	Total
North bay	16	11	11	11	49	77	76	57	52	134
South bay	14	5	8	9	36	114	87	106	68	191
Total	30	16	19	20	85	143	120	126	97	233

Two major factors contributed to the species distribution in the present study: location and cruise. Table 3 and Fig. 3 show that more species were collected in the south bay than in the north bay, the mean number of species per haul being statistically different (t test, $P < 0{\cdot}05$). This is due to differences in the bottoms and the depths of the two bays. The south bay is open toward the lagoon, has a high percentage of coarse sand (Dugas and Debenay 1980), and shelters a large number of benthic organisms such as large sponges, *Halimeda* algae, *Sargassum* and *Eunice* worm tubes. Conversely, the north bay has a high turbidity, little interchange with the lagoon, heavily silted bottoms (Dugas and Debenay 1980), and low numbers of large benthic invertebrates (except for outbreaks of sand urchins of the *Laganum* type). Table 3 suggests a slight decrease in the number of species over time. However, on the basis of number of species per haul (Fig. 3), no particular trend can be detected. The number of species per haul is comparable to that found in the Gulf of Carpentaria by Rainer (1984), who also found that in shallow waters there was no significant variation in species richness with season.

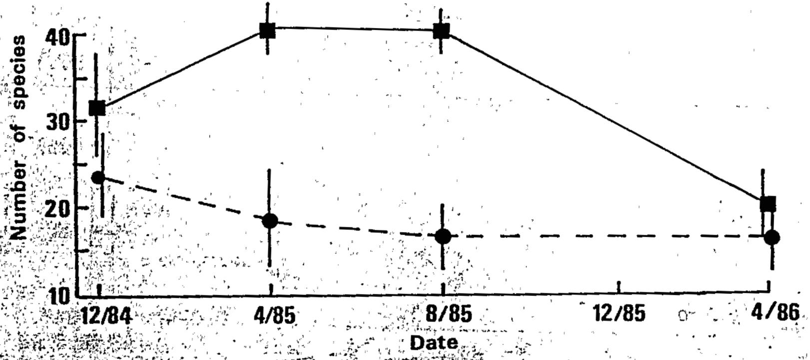

Fig. 3. Change in mean number of species per haul. ●, North bay; ■, south bay; the bars are the 95% confidence intervals of the mean (Sokal and Rholf 1981).

Table 4. Fish biomass estimates (ignoring trawl efficiency) for trawl surveys in tropical waters
F, fish trawl; S, shrimp trawl

Source	Trawl	Region	Biomass (t km^{-2})	Headrope (m)
Anon. 1972	S	India	4·2–10·7	14–18·5
Penn 1983	S	Bangladesh	2·9	40–50
Senta *et al.* 1973	F	Sunda Shelf	1·4–1·5	36
		Malaysia	1·0–1·3	36
		Borneo	1·3–1·5	36
		Thailand	0·8	36
Senta and Tan 1973	F	Andaman Sea	2·5–4·3	36–52
Darcy and Gutherz 1984	S	Florida	0·6–7·6	36
Villoso and Hermosa 1982	F	Philippines	2·4	46
Salzen 1957	F	Ghana	1·6	24
Sainsbury 1987	F	North-western Australia	1·0–6·3	26–48
Present study	S	New Caledonia	1·96	14

Catch Rates

The overall catch rate was 51 kg h^{-1}. In order to compare this result with those of other fisheries, a biomass estimate of 1·96 t km^{-2} was calculated. Because the method used does not take into account the efficiency of the net, the result is a gross underestimate of the real biomass (Uzman *et al.* 1977; Kulbicki and Wantiez, unpublished data). The horizontal opening of a trawl net is 50–70% of the headrope length (Okonski 1972; Shindo 1973). Since trawling speed is usually 2 to 2·5 knots for shrimp trawls and 3 to 3·5 knots for fish trawls, it is possible to calculate biomass estimates from data in the literature when such estimates are not given explicitly. Table 4 shows that the biomass estimate for the Bay of St Vincent is slightly larger than those for south-eastern Asia but smaller than that for north-western Australia. However, as in most trawl fisheries, catch rates show large fluctuations. Fig. 4*a* indicates the variation in biomass estimates for the present study. The south bay initially had a higher biomass than the north bay, but both bays showed decreases over time.

Density followed the same trend (Fig. 4*b*). Comparison with data from the Gulf of Carpentaria (Rainer 1984; Poiner and Harris 1986) shows that initial densities were higher in the Bay of St Vincent than in the Gulf. This is probably due to differences in the mesh size of the cod end of the net (3·8 cm in the Gulf, 2 cm in the present survey). The rapid decrease observed in the Bay of St Vincent brought the density after less than 2 years to a lower level than that in the Gulf after 20 years of fishing.

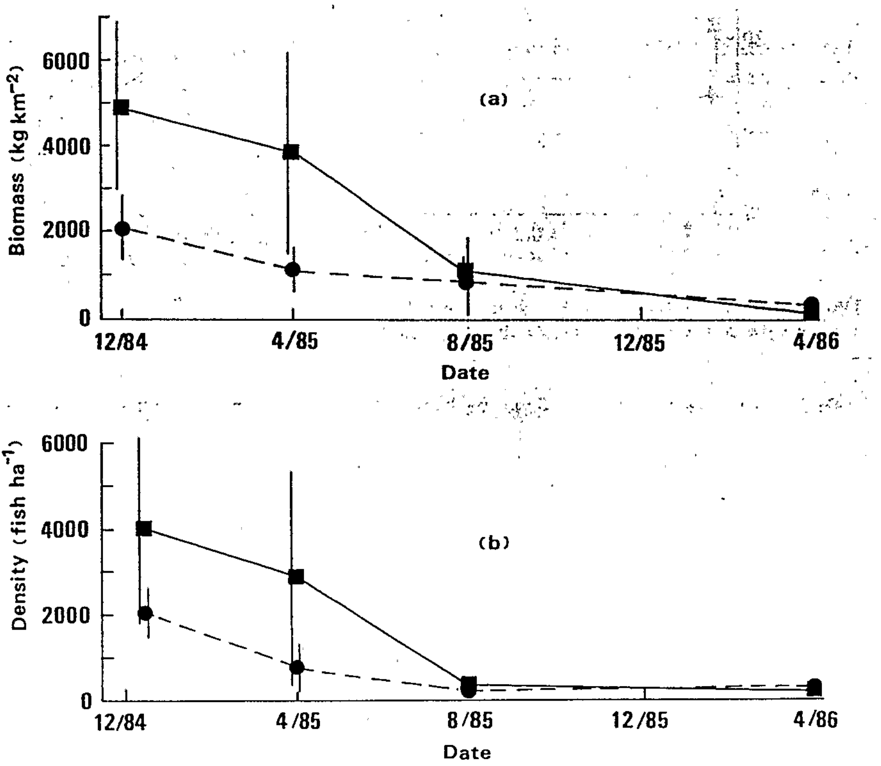

Fig. 4. Change in (*a*) mean biomass and (*b*) mean density. ●, North bay; ■, south bay; the bars are the 95% confidence intervals of the mean (Sokal and Rholf 1981).

Main Species

Species were ranked according to their catch rate in weight and numbers and to their frequency in the catch (percentage of hauls in which the species was present). Table 5 shows that only a limited number of species was important to the catch. Such a situation is common in most tropical trawl fisheries, where the importance of species shows large variations over space and time.

Leiognathidae

The Leiognathidae family made the greatest contribution to the catch in the Bay of St Vincent (42% of the weight, 82% of the numbers). These fish are a frequent and often important component of the catch in tropical trawl fisheries (see, for example, Bapat *et al.*

Table 5. Main species collected in the Bay of St Vincent
Numbers in parentheses are percentages of total catch

Species	Abundance	Weight (kg)	Frequency (%)
Synodontidae			
Saurida undosquamis	1 150 (0·6)	90 (3·7)	73
Leiognathidae			
Leiognathus bindus	61 400 (35)	288 (12)	66
Leiognathus leuciscus	43 310 (24)	277 (11)	66
Leiognathus splendens	20 120 (11)	276 (11)	44
Secutor ruconius	2 450 (1·4)	9 (0·4)	19
Other Leiognathidae	18 050 (10)	165 (6·8)	
Total (8 species)	145 330 (82)	1 018 (42)	
Gerreidae			
Gerres ovatus	1 370 (0·8)	56 (2·2)	55
Lethrinidae			
Lethrinus nematacanthus	6 040 (3·4)	240 (9·8)	60
Nemipteridae			
Scolopsis temporalis	580 (0·3)	32 (1·3)	54
Mullidae			
Upeneus molluccensis	6 870 (3·9)	199 (8·1)	69
Upeneus tragula	3 090 (1·7)	68 (2·8)	41
Upeneus vittatus	470 (0·3)	28 (1·1)	47
Upeneus sp. aff. *asymetricus*	620 (0·3)	13 (0·5)	21
Other Mullidae	950 (0·5)	36 (1·5)	
Total (12 species)	12 000 (6·7)	344 (14)	
Bothidae			
Asterorhombus intermedius	1 075 (0·6)	9 (0·4)	85
Engyprosopon grandisquama	660 (0·4)	5 (0·2)	39
Other Bothidae	75 (–)	3 (0·1)	
Total (5 species)	1 810 (1·0)	17 (0·7)	
Tetraodontidae			
Canthigaster compressa	2 000 (1·1)	27 (1·1)	62
Total (all species)	177 800	2 438	100

1972; Druzhinin and Phone Hlaing 1972; Sinoda *et al.* 1978; Rainer and Munro 1982; Villoso and Hermosa 1982; Lamboeuf 1987; Pauly 1987). Thus, in the present study this family had a biomass of 1900 kg km^{-2} during the first cruise and averaged 770 kg km^{-2} for all cruises, whilst in the literature its highest biomass is 870 kg km^{-2} in the Philippines (Villoso and Hermosa 1982). In the Gulf of Thailand, Leiognathidae had a large biomass (approximately 600 kg km^{-2}) at the start of the fishery, contributing 18–29% of the total catch (Pauly 1987).

Leiognathidae are often represented by a large number of species in the catch (13 species in the Philippines; Villoso and Hermosa 1982). In the Bay of St Vincent, eight species were present, accounting for 72% of the Leiognathidae species known in New Caledonia (Rivaton *et al.* 1989). These fish can be divided into three trophic categories (Tiews *et al.* 1973): planktivores (*Secutor ruconius*); mixed planktivores and bottom-invertebrate feeders (*Leiognathus* spp.); and small-fish and bottom-invertebrate feeders (*Gazza minuta*). In line with these categories, these species tend to have separate spatial and depth distributions. In the present study, two species were restricted to the north bay (*S. ruconius* and *G. minuta*). The biomasses and densities of the other species (*Leiognathus* spp.) were larger in the south bay than in the north bay because of the higher biomass of benthic organisms in the south bay.

Leiognathidae undergo seasonal and long-term variations in the catch of tropical trawl fisheries. In the present study, the contribution of Leiognathidae dropped from 55 to 2% of the catch. The seasonal component of this trend could not be discerned clearly, but two of the major species (*L. splendens* and *S. ruconius*) were absent from the south bay in April 1985 and April 1986 (Fig. 5). Seasonal variations in Leiognathidae are known to exist in New Caledonia. Thus, the tuna live-bait fishery in the Bay of St Vincent has maximum catches of these fish (mainly *L. bindus*) during the dry season between August and November (Hallier and Kulbicki 1985). In Bangladesh, these species show strong seasonal fluctuations with two peaks of abundance (April–May and November–December) that correspond to the beginning and end of the dry season (Lamboeuf 1987).

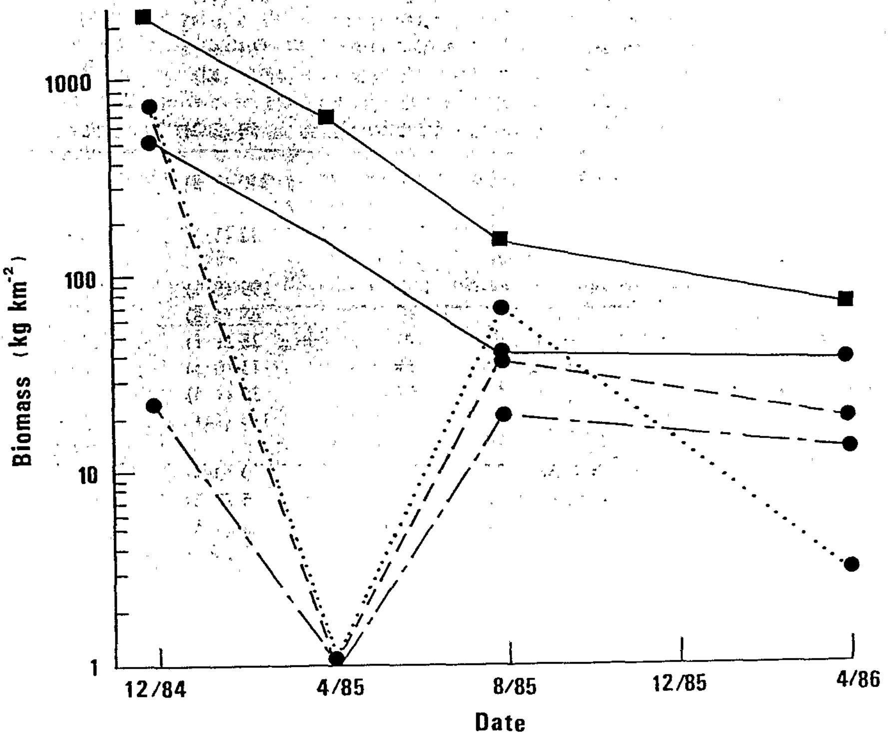

Fig. 5. Change in mean biomass of *Leiognathus bindus* (—●—), *Leiognathus leuciscus* (--●--), *Leiognathus splendens* (··●··), *Secutor ruconius* (—-●—-), and all Leiognathidae (8 spp.) (—■—).

The decrease of Leiognathidae in the present survey may also be due to long-term variations. Conand (1988) indicates that the life-history strategy of these annual fish is the source of wide interannual fluctuations in the lagoon, that each bay is sufficiently independent to support its own population, and that interchanges with other bays enable these populations to recover after periodic crashes. Indeed, Leiognathidae have a rapid growth rate and a high mortality rate (Silvestre *et al.* 1987; Conand 1988) since, like most live-bait fish, they seldom live longer than a year. In New Caledonia, these fish have a maximum weight in September–October just before their breeding season and a minimum weight in December when they recruit (Conand 1988). The massive decrease in the biomass and density of Leiognathidae between December 1984 and August 1985 could be due to a large recruitment in December followed by high mortality or migration of the adults to other parts of the bay. A failure in the recruitment of the 1985–86 year class could explain the low biomass of these fish in April 1986. Though it is unlikely, the decrease could also have come from the sensitivity of these fish to the trawling gear. In the Gulf of Thailand, catch records indicate that Leiognathidae have contributed a decreasing proportion of the catch, making up 18–29% at the start of the fishery and now contributing 4–8%.

Mullidae

Table 5 shows that the Mullidae family was the second most important component of the catch in the Bay of St Vincent, accounting for 14% of the weight and 6·7% of the numbers. Mullidae are bottom feeders and are widely distributed in tropical trawl fisheries (see, for example, Druzhinin and Phone Hlaing 1972; Senta *et al.* 1973; Lamp and Latiff 1976; Latiff and Leong 1976; Sinoda *et al.* 1978; Villoso and Hermosa 1982; Rainer 1984; Lamboeuf 1987). However, the contribution of this family seldom exceeds 10% of the catch (Latiff and Leong 1976; Pong *et al.* 1976; Sinoda *et al.* 1978; Young and Sainsbury 1985).

Table 6. Biomass and density of Mullidae in the Bay of St Vincent
Biomass, kg km^{-2}; density, fish ha^{-1}

	Dec. 1984		Apr. 1985		Aug. 1985		Apr. 1986		Total	
	Biomass	Density	**Biomass**	Density	**Biomass**	Density	**Biomass**	Density	**Biomass**	Density
North bay	**478**	146	**413**	116	**148**	52	**111**	53	**307**	97
South bay	**272**	127	**378**	121	**136**	54	**9**	5	**185**	77
Total	**382**	137	**402**	118	**143**	52	**65**	31	**250**	87
Percentage of total biomass	**11**		**19**		**14**		**25**		**13**	

In all, 12 species of Mullidae were caught during the present study, representing 50% of the Mullidae species known in New Caledonia (Rivaton *et al.* 1989). The north and south bays have different species compositions; the north bay supports *Upeneus moluccensis* and *U. vittatus*, whereas the south bay supports mainly *U. tragula* and *U.* sp. aff. *asymetricus* as well as four species of *Parupeneus*. Visual census information (Kulbicki, unpublished data) indicates that large *U. tragula* and *Parupeneus* spp. are often present near reefs and on coarse sand. Table 6 shows that, in both bays, the biomasses and densities of Mullidae declined over time but that the contribution of this family to total biomass had no particular tendency. In the Gulf of Thailand, Mullidae have decreased from 6–8% of the catch (1963–69) to 1–2% (1977–82) (Pauly 1987), whereas on the north-western shelf of Australia, Mullidae were almost absent from the catch in 1966 but made up more than 10% in 1982 (Young and Sainsbury 1985). However, in the South China Sea, Senta *et al.* (1973) observed that, depending on the area, Mullidae either increased or decreased by up to four times in a 10-year period.

In the Bay of St Vincent, two species showed variations that might be seasonal; *U. vittatus* was most abundant in April 1985 and April 1986 (the wet season), and *U.* sp. aff. *asymetricus* was most abundant in August 1985 and August 1986 (the dry season) (Kulbicki and Wantiez, unpublished data). Rainer (1984) found that *U. sundaicus* has its maximum catch rate in the wet season and that *U. sulphureus* tended to migrate to deeper waters during the dry season. Similarly, Lamboeuf (1987) found that in Bangladesh *U. sulphureus* tended to live in shallower water during the dry season. In most reports (Senta *et al.* 1973; Villoso and Hermosa 1982; Lamboeuf 1987) Mullidae are presented as a medium-depth species (20–80 m), whereas in the present survey they were found in shallow water. Thus, *U. moluccensis* in New Caledonia seemed restricted to shallow (5–15 m) muddy bottoms, whereas it is caught mainly below 40 m in the Philippines (McManus 1986).

Saurida undosquamis

The lizard fish, *Saurida undosquamis*, was the most abundant piscivorous species caught in the Bay of St Vincent. This species is recorded in a number of tropical trawl fisheries

(Ben-Yami and Glaser 1974; Grantham 1980; Villoso and Hermosa 1982; Rainer 1984; McManus 1986; Lamboeuf 1987; Pauly 1987; Sainsbury 1987). In the present survey, this species had an average biomass of 73 kg km^{-2}, which is less than those in the Philippines (165 kg km^{-2} for all Synodontidae; Villoso and Hermosa 1982) and Bangladesh (150 kg km^{-2}; Lamboeuf 1987) but is within the range of 70–250 kg km^{-2} that can be estimated for the north-western Australian shelf (Sainsbury 1979, 1984, 1987). There was no difference between the north and south bays for this species (Table 7) and there was no particular trend in biomass or density. However, the contribution of *S. undosquamis* to the total catch increased from 2·2 to 21·9%. An even stronger increase was observed in Israel at the beginning of the trawl fishery (Ben-Yami and Glaser 1974). In the Gulf of Thailand (Pauly 1987) and on the north-eastern Australian shelf (Sainsbury 1984; Young and Sainsbury 1985), no such trend has been observed over a 20-year period. In the present study, this species increased in density, biomass and average weight as depth increased from 5 to 20 m (Fig. 6). Rainer (1984) indicated that *S. undosquamis* was found mainly at 10–20 m in the Gulf of Carpentaria and that there was a slight seasonal change in mean depth, the species being deepest in autumn. Lamboeuf (1987) found that Synodontidae tended to migrate to shallower water during the dry season in Bangladesh and that they were mainly found at 20–80 m, which is similar to the depth observed in the Philippines (Villoso and Hermosa 1982). Similar migrations have also been observed in Israel (Ben-Yami and Glaser 1974).

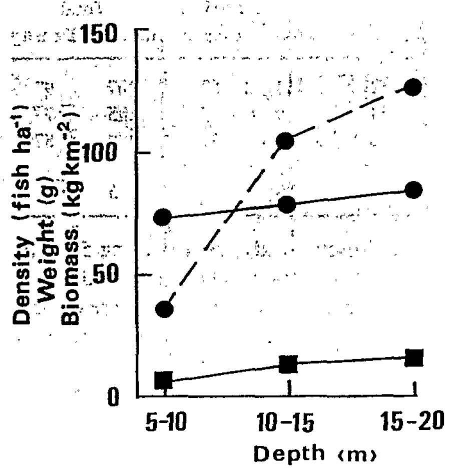

Fig. 6. Change in mean density (—■—), mean average weight (—●—), and mean biomass (--●--) of *Saurida undosquamis.*

S. undosquamis had a maximum length of 30 cm in the Bay of St Vincent and never exceeds 33 cm in New Caledonia. This size is similar to those cited by Ben-Yami and Glaser (1974) in Israel and Sinoda *et al.* (1978) in Singapore but is much lower than that on the north-western Australian shelf, where *S. undosquamis* is always more than 25 cm and may reach 50 cm (Sainsbury 1987). The latter author has identified a second species of *Saurida* that is gradually replacing *S. undosquamis* as fishing continues on the north-western Australian shelf. This second species has a size smaller to those of *S. undosquamis* in New Caledonia, Israel and Singapore. Sainsbury *et al.* (1984) mention that the two species can be distinguished by electrophoretic analysis but that they are otherwise extremely similar. It is therefore likely that the species known in New Caledonia as *S. undosquamis* could in fact be the *Saurida* sp. 2 of Sainsbury *et al.* (1984). According to Ben-Yami and Glaser (1974) and Budnichenko and Nor (1978), this species would have a rapid growth rate (2 cm a month between 16 and 24 cm) and would be 2 years old in that size range. The scant data available from length frequencies in the Bay of St Vincent (Fig. 7) confirm this hypothesis

Table 7. Biomass and density of *Saurida undosquamis* in the Bay of St Vincent
b, Biomass, kg km^{-2}; d, density, fish ha^{-1}; *a*, average weight, g

	Dec. 1984			Apr. 1985			Aug. 1985			Apr. 1986			Total		
	b	d	*a*	b	d	*a*	b	d	*a*	b	d	*a*	b	d	*a*
North bay	92	9·3	*100*	56	9·6	*58*	61	5·8	*104*	82	18	*47*	74	11	*68*
South bay	76	8·4	*90*	61	6·5	*94*	58	4·8	*120*	5·5	1·1	*50*	52	5·5	*94*
Total	85	8·9	*96*	57	8·7	*66*	59	5·4	*110*	50	10·8	*47*	66	8·5	*78*
Percentage of total biomass	2·2			2·4			5·2			17·3			3·6		

Table 8. Variation in the biomass, density and average weight of *Lethrinus nematacanthus* in the Bay of St Vincent
b, Biomass, kg km^{-2}; d, density, fish ha^{-1}; *a*, average weight, g

	Dec. 1984			Apr. 1985			Aug. 1985			Apr. 1986			Total		
	b	d	*a*	b	d	*a*	b	d	*a*	b	d	*a*	b	d	*a*
North bay	5·6	0·96	*59*	2·4	0·59	*44*	3·6	0·53	*69*	1·8	0·16	*117*	3·4	0·57	*62*
South bay	722	182	*40*	1458	365	*40*	76	17	*44*	10	3·5	*30*	478	120	*40*
Total	322	81	*40*	431	108	*40*	34	7·5	*45*	5·3	1·6	*45*	196	49	*40*
Percentage of total biomass	8·4			18·4			3			1·8			10·6		

(6 cm of growth in 4 months between 16 and 22 cm). Such a rapid growth rate would partly explain the success of this species in competing with larger species (*Merluccius merluccius* in Israel, *S. undosquamis* in Australia).

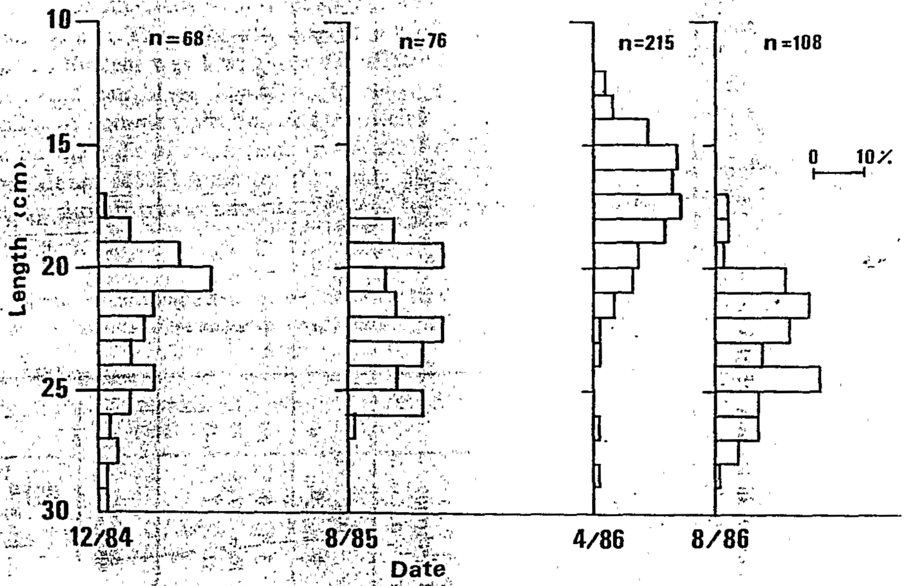

Fig. 7. Length-frequency distribution of *Saurida undosquamis*. The distribution for August 1986 is from Wantiez and Kulbicki (in press).

Lethrinus nematacanthus

The Lethrinidae are a family of large commercial species, of which *Lethrinus nematacanthus* is the smallest. In New Caledonia, *L. nematacanthus* is a non-commercial but economically important species; it is not sold but is caught in large numbers by amateur fishermen. The species has been caught on the north-western Australian shelf (Sainsbury 1987) and is present as a trash fish in the catch of Singapore trawlers (Sinoda *et al.* 1978). In the Bay of St Vincent, *L. nematacanthus* was caught in appreciable quantities making up 10·5% of the biomass. In tropical trawl fisheries, Lethrinidae usually represent less than 1% of the catch (Villoso and Hermosa 1982 for the Philippines; Lamp and Latiff 1976, Latiff and Leong 1976, and Pong *et al.* 1976 for Malaysia; Lamboeuf 1987 for Bangladesh; Fernando 1972 for Ceylon; Pauly 1987 for Thailand). There are two major exceptions: the north-western Australian shelf, where this family represented 5–6% of the catch in 1983 despite a drastic decline (Sainsbury 1984), and the Persian Gulf, where these species constitute more than 10% of the shrimp trawl by-catch (Grantham 1980).

In the Bay of St Vincent, *L. nematacanthus* was unevenly distributed, being found mainly in the south bay (455 kg km^{-2}), where it made up 18% of the total biomass (as opposed to 3·4 kg km^{-2} and 0·3% in the north bay). This species also fluctuated over time, reaching (in the south bay) a high of 1460 kg km^{-2} in April 1985 and a low of 10 kg km^{-2} in April 1986 (Table 8). *L. nematacanthus* had a consistent size (13–16 cm FL) during the survey. This fish has a rapid growth and a high mortality (Loubens 1980*a*, in Munro and Williams 1985). It matures at a small size (11 cm) and at 1 year of age (Loubens 1980*b*). Females are predominant at sizes of $\leqslant 15$ cm, but males make up 80% of the population at sizes of >17 cm. These traits, along with a high gonadosomatic ratio (Loubens 1980*b*), indicate that this species has a life history that allows for sudden population size increases (*r*-type strategy). This might explain the large catch of this species in April 1985.

Commercial species

The catching of juveniles of commercially important species by shrimp trawls is a concern in tropical trawl fisheries (Chong 1984; Poiner and Harris 1986). In the present survey, 52 commercially important species were caught (Table 9). Of these, 43 species were present as juveniles and 21 as adults. These fish accounted for 16·4% of the total catch weight, but 60% of the weight of the commercially important species was made up of *L. nematacanthus*, which seldom exceeds 20 cm. Thus, the catching of juveniles of commercially important species in the Bay of St Vincent was low, the most affected group being the Carangidae, 11 species of which were caught as juveniles. In Singapore (Sinoda *et al.* 1978), the proportion of juveniles of commercially important species was 31·7%, but Nemipteridae and Scienidae made up the bulk of trash fish. In the Gulf of Carpentaria, the species list given by Rainer and Munro (1982) indicates that only about 15 commercially important species were caught by shrimp trawls and that, except for *Scomberoides queenslandicus*, all were small species.

Table 9. Economically important species collected by the Bay of St Vincent
J, junveiles; A, adults; numbers in parentheses are percentages of the total catch

Family	Number of species Total	J	A	Abundance	Weight (kg)
Serranidae	8	5	6	83	35
Priacanthidae	1	1	0	22	0·5
Sillaginidae	1	1	0	30	1·1
Carangidae	11	11	0	834	29
Lutjanidae	3	3	3	195	30
Haemulidae	2	2	1	123	21
Lethrinidae	10	6	7	6166	260
Nemipteridae	1	1	1	45	3·3
Mugilidae	1	1	0	3	0·3
Polynemidae	1	1	0	87	5·4
Labridae	1	1	1	3	0·5
Scaridae	2	2	0	24	4·4
Acanthuridae	7	5	2	19	6·3
Siganidae	3	3	0	54	1·6
Total	52	43	21	7688 (4·3)	398 (16·4)

Population Structure

In most tropical trawl fisheries, catch rates decrease over time. Fishing effort alone partly explains such decreases (Sainsbury 1984, 1987; Pauly 1987; Silvestre *et al.* 1987). In the present study, fishing effort was limited in relation to the size of the trawlable area. The south bay has a trawlable area of 15 km^2, the north bay 13 km^2 (Fig. 2). During each cruise, only a small proportion of the bays was trawled (0·06–0·21 km^2, or 0·4–1·6%). It is therefore unlikely that the fishing effort had a direct effect on the stock size.

Disturbance of the benthic community is seen as a major factor in stock declines in tropical trawl fisheries (Rainer 1984; Poiner and Harris 1986; Sainsbury 1987). In the present survey, trawls were always performed along the same track. In most of the hauls, large benthic organisms (sponges, soft coral, echinoderms, algae, etc.) amounted to more than 100 kg (and in some cases to more than 1000 kg) per 30-min trawl. Unfortunately, these organisms were not recorded except for one bivalve, *Chlamys gloriosa* (Reeve), which remained constant during the first three cruises (4·8, 5·1 and 5·1 kg per 30-min trawl) but dropped drastically on the fourth cruise (1·2 kg per 30-min trawl). This bivalve attaches to sponges and other large sessile organisms and can therefore be considered as an indicator of benthic fauna. It is not possible to assess the detrimental effects on catch rates of such benthic changes. The benthic feeding species should be the most sensitive to variations in the benthic community. As is indicated below, benthic feeding fishes were not the most affected trophic group. Therefore, other causes must be found to explain the decline of catch rates over time.

The magnitude of the decrease in the catch rate in the Bay of St Vincent (13-fold in less than 2 years) may be explained in part by the following hypothesis in population structure.

The Bay of St Vincent has little interchange with the lagoon and can be considered as a closed system. Most of the species caught during the present survey can be divided into four groups. The first group consists of annual or biannual fish (Leiognathidae, Engraulidae, *Asterorhombus intermedius*, *Engyprosopon grandisquama*, *Paramonacanthus japonicus*) that have a rapid growth rate, a high mortality rate, and a high fecundity. In New Caledonia, most of these species undergo peak reproduction between July and November. During this period in 1984, there was above-average rainfall on the catchment that drains into the Bay of St Vincent. This may have created favourable conditions for good larval survival (plankton bloom), leading to a large post-larval recruitment of these short-lived species, which appeared in maximum abundance in December 1984. Strong correlations between rainfall and recruitment are known for many tropical Clupeidae and Engraulidae (Ben-Tuvia 1960; Raja 1972; Dalzell 1984) and for Leiognathidae (Pauly 1977; Quinn and Kojis 1986). The second group of fish consists of species that live 3–5 years, reproduce at a small size, and in some species undergo sex reversal to males with age (*Lethrinus nematacanthus*, *Upeneus* sp. aff. *asymetricus*, *U. moluccensis*, *U. tragula*, *Scolopsis temporalis*). The life-history characteristics of these species could be the cause of population fluctuations such as those observed for *L. nematacanthus*, *U. moluccensis* and *U. tragula* in the present study. These species have a slower growth rate, so if 1984 was a good recruitment year they would have reached a peak abundance between April and August 1985. Such increases were observed for *Gerres ovatus*, *L. nematacanthus*, *U. tragula* and *Canthigaster compressa* in April 1985. The third group of fish consists of species that are also short-lived (3–6 years) but reproduce later with less reproductive effort (*Saurida undosquamis* and *U. vittatus*). These species had a rather constant biomass throughout the survey. The last group of fish consists of large (more than 30 cm average length), long-living (more than 5 years of life expectancy), and late-reproducing species such as large Serranidae, Lethrinidae or Lutjanidae. These species were scarce in our samples but may be more abundant than our results indicate because of their ability to evade the net.

We are evaluating the above hypothesis in another survey that was started in January 1989 and consists of monthly cruises in both bays.

Trophic Structure

The species contributing the most to the various trophic categories are given in Table 10. Some species may be important in a given trophic category despite the fact that their diet is only partly appropriate to that category. An example is *Lethrinus nematacanthus*, which appears as an important piscivore even though fish make up only 10% of its diet. The contribution of *L. nematacanthus* to piscivory is due to the abundance of this species. Similarly, Leiognathidae contribute to four trophic categories. The Bay of St Vincent was characterized by macro- and microcarnivores (Table 11). These two trophic categories consisted of many species and made major contributions to the abundance and total weight in the present study. Piscivores were diverse (19% of the species) but made up only 2·1% of the abundance. Conversely, planktivores consisted of only a few species but made up an important part of the abundance and total weight. The nearby reefs (Kulbicki 1988) differed from the soft-bottomed bays in the importance of the herbivore and 'miscellaneous' categories and their low abundance of macrocarnivores (Table 11). However, piscivores and

Table 10. Main species in each trophic group, Bay of St Vincent

Some species appear in more than one group because of mixed diets; species in bold characters are predominant in a given bay; numbers in parentheses indicate sources for diets: 1, Hiatt and Strasburg 1960; 2, Bograd-Zismann 1965; 3, Tiews *et al.* 1973; 4, Ben-Yami and Glaser 1974; 5, Allen 1975; 6, Amesbury and Myers 1982; 7, Sorden 1982; 8, Fischer and Bianchi 1984; 9, Sano *et al.* 1984; 10, Thong and Sasekumar 1984; 11, Norris 1985; 12, Parrish *et al.* 1986; 13, Shorei and Shirai 1986

Trophic group	South bay	North bay
Piscivores	*Saurida undosquamis* (2, 4)	***Saurida gracilis*** (1, 11, 12)
	Synodus hoshinonis (6)	*Saurida undosquamis* (2, 4)
	Lethrinus nematacanthus (9)	***Scomberoides tol*** (8)
		Gazza minuta (8)
		Sphyraena putnamie (8, 13)
Macrocarnivores	*Leiognathus bindus* (3)	***Atule mate*** (10)
	Leiognathus equulus (3)	***Gazza minuta*** (8)
	Leiognathus leuciscus (3)	*Leiognathus bindus* (3)
	Leiognathus splendens (3)	*Leiognathus leuciscus* (3)
	Gerres ovatus (6)	*Leiognathus splendens* (3)
	Lethrinus nematacanthus (9)	*Gerres ovatus* (6)
	Scolopsis temporalis	*Scolopsis temporalis*
	Parupeneus pleurospilos (7, 9)	***Mulloides flavolineatus*** (7)
	Upeneus moluccensis	*Upeneus moluccensis*
	Upeneus tragula (9)	***Upeneus sulphureus*** (10)
	Upeneus **sp. aff.** ***asymetricus***	***Upeneus vittatus***
	Asterorhombus intermedius	*Asterorhombus intermedius*
Microcarnivores	*Leiognathus bindus* (3)	***Plotosus lineatus***
	Leiognathus equulus (3)	*Leiognathus bindus* (3)
	Leiognathus leuciscus (3)	*Leiognathus leuciscus* (3)
	Leiognathus splendens (3)	*Leiognathus splendens* (3)
	Gerres ovatus (6)	*Gerres ovatus* (6)
	Upeneus molluccensis	***Mulloides flavolineatus*** (7)
	Upeneus tragula (9)	*Upeneus molluccensis*
	Upeneus **sp. aff.** ***asymetricus***	***Oxyurichthys papuensis***
	Asterorhombus intermedius	*Asterorhombus intermedius*
	Engyprosopon grandisquama	
	Paramonacanthus japonicus	
	Pseudalutarius nasicornis	
	Canthigaster compressa (6)	
Zooplanktivores	*Apogon* sp. (4)	*Apogon* sp. (4)
	Leiognathus bindus (3)	***Apogon*** **sp. aff.** ***compressus***
	Leiognathus equulus (3)	***Apogon septemstriatus***
	Leiognathus leuciscus (3)	*Leiognathus bindus* (3)
	Leiognathus splendens (3)	*Leiognathus leuciscus* (3)
	Pristotis jerdoni (5)	*Leiognathus splendens* (3)
		Secutor ruconius (3)
Other planktivores	*Leiognathus bindus* (3)	***Stoleophorus indicus***
	Leiognathus equulus (3)	*Leiognathus bindus* (3)
	Leiognathus leuciscus (3)	*Leiognathus leuciscus* (3)
	Leiognathus splendens (3)	*Leiognathus splendens* (3)
		Secutor ruconius (3)

planktivores had similar importance in both habitats. The biomasses of piscivores and their potential prey (defined as fish <20 g and not belonging to the scorpaeniforms) are well correlated in the Bay of St Vincent (Fig. 8; $r = 0{\cdot}88$), whilst such correlation did not occur on the nearby reefs ($r = -0{\cdot}33$) (Kulbicki 1988); this is probably due to differences in the composition of the piscivore category in each of these habitats. In the Bay of St Vincent, most piscivores are small (91 g average weight) and have similar life histories (3–7 years life expectancy, fast growth, early reproduction), whereas on the reefs piscivores have a wide range of sizes but a large average weight (870 g) and different life histories (ranging from Apogonidae of the *Cheilidopterus* genus to large Serranidae).

Table 11. Comparison of trophic structure between soft bottoms and coral reefs in the south-western lagoon of New Caledonia

Data for reefs are from Kulbicki (1988); numbers represent maximum and minimum percentages

Trophic group	Number of species (%)		Biomass (%)		Abundance (%)	
	Coral reefs	Soft bottoms	Coral reefs	Soft bottoms	Coral reefs	Soft bottoms
Piscivores	9–14	18–22	5–20	10–20	0·4–2	1·5–3
Macrocarnivores	15–21	33–39	10–18	38–50	1·4–4	26–29
Microcarnivores	23–28	17–19	4–27	15–18	4–39	22–22
Herbivores	19–29	5–7	31–59	0·1–2	8–15	0·2–1·0
Planktivores	9–13	17–20	9–28	24	43–62	47–49
Miscellaneous	8–11	1–3	1–17	0·0–0·1	1–33	0·0–0·02

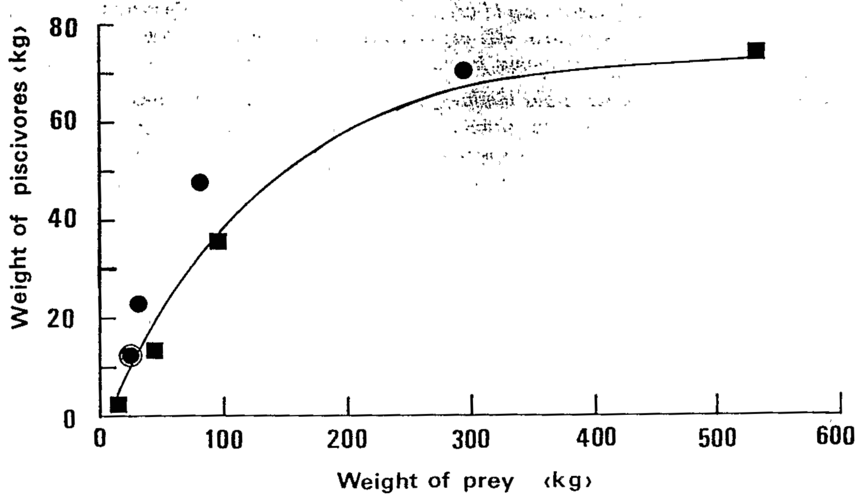

Fig. 8. Relationship between the weight of piscivores and that of their prey. ●, North bay; ■, south bay. The circle around the first north-bay point indicates that a 80 kg *Rhynchobatus djiddensis* was not taken into account.

The trophic structure demonstrates the differences between the north and south bays, but the variables used to express this structure (number of species, abundance and total weight) are not equally sensitive. The trophic structures of the two bays were not significantly different ($P < 0{\cdot}05$) when the number of species (multinomial χ^2 test; Siegel and Castellan 1988) or weight (Friedman two-way analysis of variance; Siegel and Castellan 1988) for each trophic group is considered (Table 12). When abundance is considered, however, the north bay had a significantly higher abundance of piscivores (χ^2 test, $P < 0{\cdot}05$; Siegel and Castellan 1988) than the south bay. The abundances of the other trophic groups were not significantly different between bays (χ^2 test). Changes in trophic structure over time also depend on the variable chosen. Thus, Table 12 shows that the number of species per trophic group did not change significantly in either bay (multinomial χ^2 test), whereas the weight (Friedman two-way analysis of variance) or abundance (multinomial χ^2 test) per trophic group did vary significantly ($P < 0{\cdot}05$) in both bays.

Table 12. Significance of changes in trophic structure, Bay of St Vincent
Number of species and abundance tested with a multimonial χ^2, weighted with a Friedman two-way analysis of variance (Siegel and Castellan 1988). n.s., not significant at $P = 0{\cdot}05$; *significant at $0{\cdot}01 < P < 0{\cdot}05$; *significant at $P \ll 0{\cdot}01$; X, calculated value of χ^2.

Treatment	Number of species	Abundance per haul	Weight per haul
North bay, changes with time	n.s.	**, $X=570$	*, $X=12{\cdot}4$
South bay, changes with time	n.s.	**, $X=210$	*, $X=13{\cdot}2$
Comparison between bays	n.s.	*, $X=11{\cdot}9$	n.s.

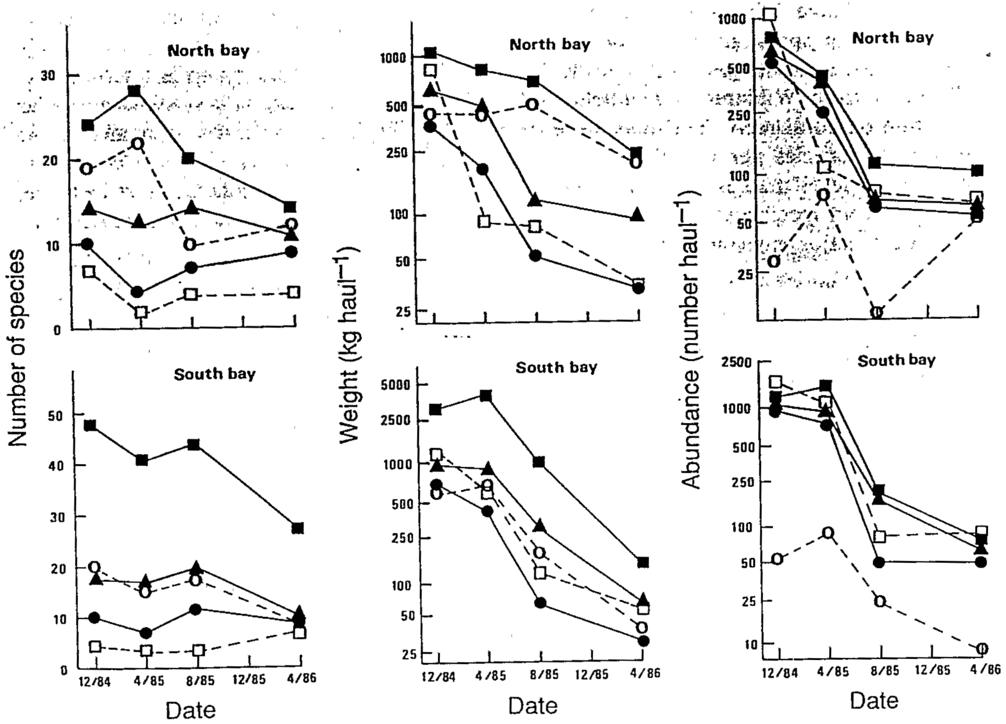

Fig. 9. Variations in the main trophic groups. ○, Piscivores; ■, macrocarnivores; ▲, microcarnivores; ●, zooplanktivores; □, other planktivores.

In both bays at all times, macrocarnivores were the most important group in all three expressions of trophic structure (Fig. 9). The group 'other planktivores' showed the largest change in its ranking over time for both abundance and weight. This variability is probably related to the species composition of this group (essentially Leiognathidae). Piscivores showed some change in their ranking over time for number of species and weight. This variability is due mainly to the occasional occurrence of pelagic piscivores (*Scomberoides tol*, *Sphyraena putnamie*, Carangidae), especially in the north bay. Piscivores also were the least abundant of all trophic groups at all times in both bays. This result is a common one in most studies on trophic structure in tropical waters (Williams and Hatcher 1983; Galzin 1985; Parrish *et al.* 1986; Kulbicki 1988). Microcarnivores were less diverse than piscivores but were second only to macrocarnivores for abundance and weight in both bays.

Young and Sainsbury (1985) have highlighted major changes in species composition after 16 years of trawling on the north-western Australian shelf, and Senta *et al.* (1973) have described drastic changes after 10 years of trawling in the south China Sea. However, the families involved in each case have acted quite differently. For instance, Lutjanidae have decreased dramatically on the north-western Australian shelf while increasing in the south China Sea. Conversely, Mullidae have increased on the north-western Australian shelf while either decreasing (by up to four times) or only slightly increasing in the South China Sea. Similar comparisons have been made between the Gulf of Carpentaria and the Gulf of Thailand (Rainer and Munro 1982). These results show that in fisheries with comparable species compositions, the effects of trawling may be drastically different for a given species or family.

However, what is more important is the overall change due to trawling. One way to measure such variation is to watch for alterations in the trophic structure of the catch. The data (Table 12) suggest that the number of species per trophic group is insensitive to changes in space and time, that the abundance of fish per trophic group is highly sensitive to such changes, and that the biomass of fish per trophic group is intermediate. The data from Williams and Hatcher (1983) and from Kulbicki (1988) show a similar situation on coral reefs. This may have management implications, in that a change in the number of species per trophic group is more likely to signal a significant event at the population level than is a similar change in either biomass or abundance. For instance, the shift from specialized to opportunistic feeders in the Gulf of Thailand (Pauly 1979) may indicate a major environmental change induced by trawling.

Conclusions

The present study shows that the biomass and density of bottom fish decreased by 13-fold in the Bay of St Vincent within less than 2 years. This decrease is due mainly to natural fluctuations in a population that has little interchanges with the nearby lagoon. The size of the catch made during the survey is negligible in comparison with the estimated stock of the bay (<2%), and disturbance of the habitat is unlikely to be the main cause of such variations. Not all species were affected in the same way. In particular, *r*-type species showed more important variations than did species with a longer life span, later reproduction, and slower growth.

The management of such a multi-species fishery lacks suitable models. One of the first steps is to follow the structure of the fish populations involved. This structure can be defined in several ways. On way is to group species according to the characteristics of their life histories. In the present study, this led to four classes ranging from fast-growing, early-reproducing, short-lived species to large-sized, late-reproducing, long-lived species. Another way is to look at the trophic structure of the fish populations. In the present study, three variables were used to define trophic structure: number of species, biomass, and density per trophic group. Number of species per trophic group was found to be the most insensitive to changes, with density being the most sensitive. Monitoring alterations in trophic structure is one method of detecting major population fluctuations due to fishing or environmental changes. Combined study of both types of structure (life-history and trophic) may provide a management approach intermediate between the single-species and multi-species approaches.

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