Abstract.—Density and biomass estimates from a shrimp trawl and a visual survey are compared. Results indicate that the visual survey gives estimates eight to nine times larger than the trawl survey. However, there are important variations by species. Estimates of fish size from the visual censuses are larger than fish sizes observed in the trawl catch. These results suggest that the catchability of fish by shrimp trawls may be lower than usually thought for multispecies tropical stocks. In shrimp trawl fisheries, this may have important consequences for stock assessment and for evaluation of parameters such as fishing mortality. Trawling should be adequate for qualitative and semiquantitative stock assessment, but will need to be compared with other methods for quantitative studies on multispecific stocks.

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Comparison Between Fish Bycatch from Shrimp Trawlnet and Visual Censuses in St. Vincent Bay, New Caledonia

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Shrimp trawl fisheries are the source of a large fish bycatch in the tropical Indo-Pacific (Aoyama 1973, Grantham 1980, Villoso and Hermosa 1982, Chong 1984). One question concerning these fisheries is how much damage they cause to fish stocks. To answer this question, it is useful to assess the catchability of fish by shrimp trawls. Many methods exist to assess this parameter. Most use the same gear under different conditions, such as double codends, split codends, and replicate hauls with different mesh sizes (Macket 1973, Gulland 1975). The bias of such methods may be acceptable for single-species populations but has seldom been studied in relation to tropical multispecies stocks. Another approach is the cross-evaluation of trawling and echosurveys (Doubleday 1976, Dines 1982, Dickie et al. 1983), but this method is not well adapted to tropical multispecies stocks. Another way is to correlate the results of two methods, such as with a TV camera and otter trawl (Uzmann et al. 1977), submersible and longlines (Ralston et al. 1986, Richards and Schnute 1986, Grimes et al. 1982), visual census and longlines (Kulbicki 1988) or poisoning and beamtrawl (Gray and Bell 1986).

The use of several methods has the advantage of allowing some evaluation of the biases of each method. In the present study it was possible to compare the results of visual censuses and shrimp trawl bycatches. This work was originally designed to estimate the catchability of the net (q = number of fish caught/number of fish present), but it also provided information on the biology of the fish.

Material and methods

Location

The study was performed during August 1986 on the trawling grounds of the South Bay in St. Vincent Bay, in the southwest lagoon of New Caledonia. The trawling grounds cover 15 km^2, or approximatively one-tenth of the Bay area. A total of eight stations were sampled (Fig. 1), one of which was sampled at night (Station n°6).

Visual census

A 200-m transect line was laid on the bottom with a buoy set at each end of the line. The transect was divided into 10-m sections. For each section, two divers—one on each side of the line—counted all fish, estimated their length, and estimated the perpendicular distance of the fish to the transect. Length was given in 2-cm size classes for fish less than 20 cm, 5-cm size classes for fish between 20 and 50 cm, and 10-cm size classes for fish larger than 50 cm. Only fish less than 1.5 m above the bottom were counted. The distance from the fish to the transect was recorded in 1-m

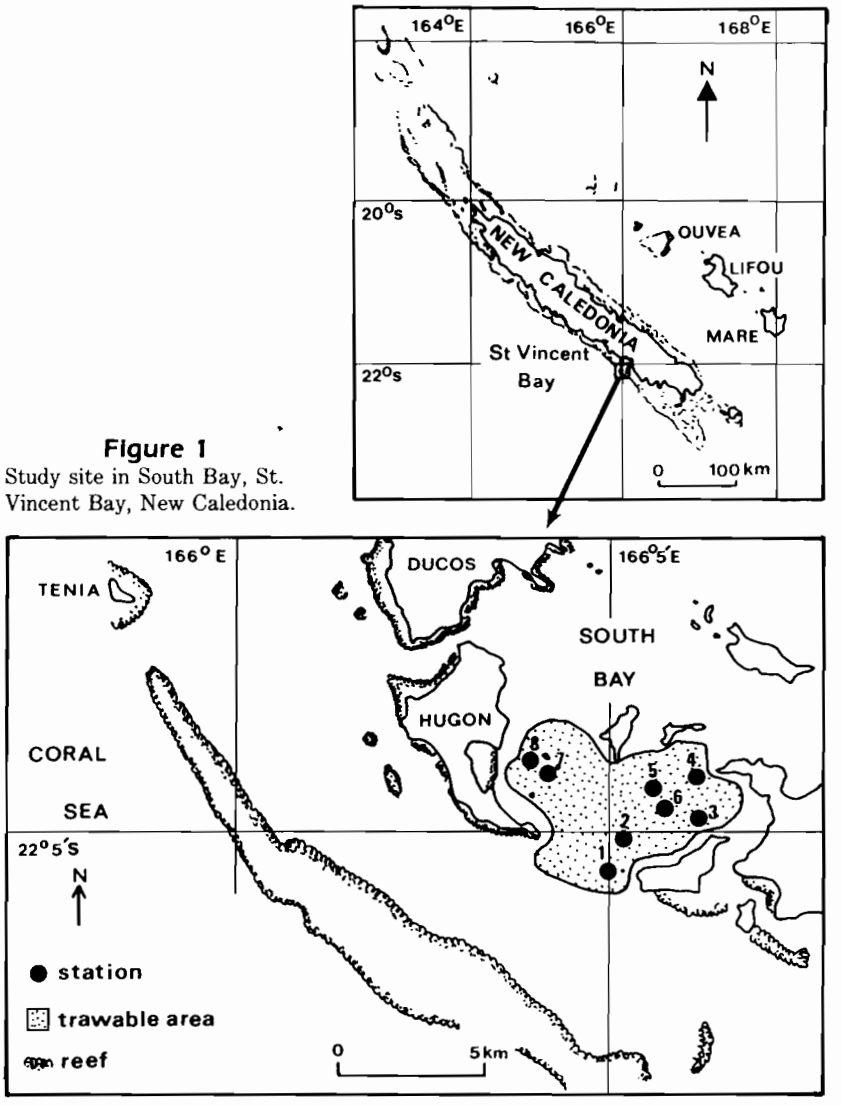

Figure 1
Study site in South Bay, St. Vincent Bay, New Caledonia.

classes up to 5 m, and in 2-m classes beyond 5 m. Fish were not recorded beyond 10 m from the transect. Both divers had a good knowledge of the fish fauna and also had a good training in visual censuses. The transects were finished between 30 and 45 minutes before the start of the trawling.

For this type of data, many density estimators may be chosen (Burnham et al. 1980). Among these estimators, Kulbicki and Duflo (unpubl. data) show that the most robust one for fish density (D) in similar conditions is given by:

$$D = (10^4/2L) \sum_{i=1}^{p} (n_i/d_i)$$

where D = fish density (fish/ha),
p = number of species,
n_i = number of fish of species i,
d_i = average distance (m) of species i to the transect, and
L = length of the transect (200 m).

Biomass B (kg/ha) was calculated in a similar fashion:

$$B = (10/2L) \sum_{i=1}^{p} (w_i/d_i)$$

where w_i = weight of species i (g).

The weights of fish were estimated from length-weight relationships (Wantiez and Kulbicki In press).

Trawling

The RV *Vauban* (24 m long) towed a shrimp trawlnet of the semiballoon, floridian type with a 14-m headrope and a 2-cm mesh codend. The vertical opening was 1.2 m and the distance between the otterboards was 7 m at a speed of 2 knots. Towing speed varied from 2 to 2.5 knots.

The hauls were each 800 m in length (±80 m). The net was submerged immediately after completion of the visual census at a distance of 400 m from the first buoy of the transect. The track of the haul was along the transect line and the net was retrieved 200 m after the second buoy of the transect line. All fish caught were sorted to species (Rivaton et al. 1990). All fish were counted and weighed.

For the calculation of density D (fish/ha), no catchability coefficient was used. Therefore,

$$D = \sum_{i=1}^{p} (n_i/S)$$

where p = number of species caught,
n_i = number of fish of species i, and
S = surface area of the haul (7 m × 800 m = 5600 m^2 = 0.56 ha).

Biomass (kg/ha) B was estimated in a similar fashion,

$$B = \sum_{i=1}^{p} w_i/S)$$

where w_i = weight of species i (kg).

Results

Species

A total of 82 species were either caught by trawls or recorded by divers (Table 1). All the common species known to occur in trawls in St. Vincent Bay (Kulbicki and Wantiez 1990) were found in the present study except for the Leiognathidae (ponyfishes). This family, represented by eight species in the bay, is characterized by large fluctuations in trawl catches depending on season and locality. In the present survey, *Leiognathus rivulatus* which is normally an uncommon species in the catch, was the major Leiognathidae.

Table 1 indicates that the trawls caught more species (64) than were seen on the transects (51). This could be due to the larger area covered by the trawls (~5600 m^2/trawl versus 700–1000 m^2 per transect). Most cryptic species, such as Scorpaeniforms, Platycephalidae (flatheads), flatfishes, and small Balistidae (triggerfishes) (including the filfishes *Paramonacanthus japonicus* and *Pseudalutarius nasicornis*) were poorly represented in the visual transects but caught by the trawls. Conversely, small species such as Apogonidae (cardinalfishes) and Pomacentridae (damselfishes) could be detected on the transects but were too small to be retained by the net. Large, fast-swimming species such as Carangidae, Serranidae, or Scombridae were seen on the transects but evaded the trawls. Gobiidae, which are burrowing species, were also seen during the dives but absent from the trawl catch.

A total of 32 species were detected by both methods (Table 1). Among these, only eight species were seen or caught in more than 50% of the samples for both methods (*Saurida undosquamis*, *Synodus hoshinonis*, *Leiognathus rivulatus*, *Lethrinus nematacanthus*, *Upeneus tragula*, *Upeneus* sp. aff. *asymetricus*, *Pristotis jerdoni*, and *Canthigaster compressa*). These eight species will subsequently be referred to as "main species." Except for *Synodus hoshinonis* and *Leiognathus rivulatus*, all these fish are among the 15 most frequent species in the trawl catch of St. Vincent Bay (Kulbicki and Wantiez 1990).

The number of species per station was statistically larger (t test at $\alpha = 0.05$) for the trawls than for the transects (Table 2). However, a chi-square test for independent samples (Siegel and Castellan 1988) indicates that the ranking of the stations is not significantly different (at $\alpha = 0.05$) between methods.

Fish size

Only fish lengths were used to compare fish size between the two methods. Table 3 indicates that visual censuses always yielded larger lengths than trawls, except in the case of *Pristotis jerdoni*. However, the lengths are significantly different (t test at $\alpha = 0.05$) for only four species (Table 3), and the two methods give mean lengths which are less than 2.8 cm apart. Due to the fact that fish length was estimated in 2-cm size classes for transects and 0.5-cm size classes for trawls, one should be cautious about the significance of the differences observed.

In a review on the problems of visual transects, Harmelin-Vivien et al. (1985) indicate that fish size is usually underestimated by this method. In the present study, if this were the case, it would mean that the larger fish (within a given species) are able to evade the trawl. In our opinion this is not the only reason, and the discrepancy of fish length between transects and trawls is probably also due to an overestimate of length by the divers.

Table 1

Species composition of transects and trawls in St. Vincent Bay, New Caledonia. For dives and trawls, numbers indicate at how many stations the species were recorded.

Species	Dives	Trawls
Muraenidae		
Muraenidae spp.	1	4
Synodontidae		
Saurida gracilis	0	2
Saurida nebulosa	0	2
Saurida undosquamis	4	4
Synodus dermatogenis	1	0
Synodus hoshinonis	4	7
Trachynocephalus myops	0	1
Carapidae		
Carapus homei	0	1
Fistularidae		
Fistularia petimba	0	1
Syngnathidae		
Hippocampus histrix	0	1
Dactylopteridae		
Dactyloptena orientalis	0	2
Scorpenidae		
Scorpaenidae sp.	0	1
Dendrochirus brachypterus	0	1
Pterois volitans	1	0
Synanceiidae		
Inimicus didactylus	0	3
Aploactinidae		
Aploactis aspera	0	2
Platycephalidae		
Platycephalidae spp.	1	7
Onigocia spinosa	0	3
Serranidae		
Cephalopholis boenack	2	0
Epinephelus cyanopodus	2	0
Epinephelus maculatus	3	0
Epinephelus malabaricus	0	1
Priacanthidae		
Priacanthus hamrur	0	2
Apogonidae		
Apogon spp.	2	1
Apogon catalai	0	1
Apogon ellioti	0	4
Apogon aureus	1	0
Apogon frenatus	1	1
Apogon sp. cf *compressus*	0	1
Cheilodipterus quinquelineatus	0	1
Rhabdamia spp.	1	0
Carangidae		
Decapterus russeli	1	2
Gnathanodon speciosus	1	0
Siganidae		
Siganus canaliculatus	0	3
Scombridae		
Scomberomorus commersoni	1	0
Bothidae		
Arnoglossus sp.	0	1
Asterorhombus intermedius	1	8
Engyprosopon grandisquama	1	7
Grammatobothus polyophthalmus	0	3
Balistidae		
Abalistes stellatus	0	3
Paramonacanthus japonicus	1	7
Pseudalutarius nasicornis	2	4
Leiognathidae		
Leiognathus rivulatus	5	6
Secutor ruconius	1	0
Lutjanidae		
Lutjanus quinquelineatus	2	2
Lutjanus vittus	2	3
Gerreidae		
Gerres ovatus	1	3
Haemulidae		
Diagramma pictum	2	1
Lethrinidae		
Lethrinus nematacanthus	6	8
Lethrinus semicinctus	1	2
Nemipteridae		
Nemipterus peroni	0	2
Scolopsis temporalis	3	6
Mullidae		
Parupeneus pleurospilos	1	4
Upeneus sp.	0	1
Upeneus moluccensis	1	2
Upeneus tragula	7	7
Upeneus sp. aff. *asymetricus*	6	8
Chaetodontidae		
Heniochus acuminatus	1	1
Pomacentridae		
Chromis fumea	1	0
Dascillus aruanus	0	1
Neopomacentrus sp. Allen	1	0
Pristotis jerdoni	4	5
Labridae		
Anampses spp.	1	0
Cheilinus bimaculatus	2	6
Xiphocheilus typus	0	2
Scaridae		
Scarus ghobban	0	1
Mugiloididae		
Parapercis sp.	2	0
Parapercis cylindrica	4	2
Blenniidae		
Petroscirtes breviceps	2	4
Callionymidae		
Synchiropus rameus	0	2
Gobiidae		
Gobiidae sp.	2	0
Amblyeleotris sp.	2	0
Amblygobius sp.	1	0
Ptereleotris hanae	1	0
Ostraciidae		
Tetrasoma gibbosus	0	5
Lactoria cornuta	0	3
Tetraodontidae		
Amblyrhynchotes hypselogeneion	0	3
Arothron immaculatus	3	6
Arothron stellatus	1	3
Canthigaster compressa	8	8
Canthigaster valentini	2	0
Lagocephalus sceleratus	1	1
Total number of species	51	64
Species common to both methods	32	
All species	82	

Table 2

Number of species per station according to transects and trawls, St. Vincent Bay, New Caledonia. CI = confidence interval at $\alpha = 0.05$.

	Station number									
	1	2	3	4	5	6	7	8	Average	CI
Transects	13	11	18	4	16	16	14	15	13.4	9.5–17.2
Trawl	22	31	25	18	20	38	21	27	25.3	19.3–31.2

Chi-square value for two independent samples = 7.63. Limit value = 14.07 (7 df) at $\alpha = 0.05$ (Siegel and Castellan 1988).
Station 6 was performed at night.

Table 3

Comparison of fish lengths given by transects and trawling for main species, St. Vincent Bay, New Caledonia.

	Trawl			Transect				
Species	L	n	$s/\sqrt{n}$	L	n	$s/\sqrt{n}$	F	t
Saurida undosquamis	22.7	108	0.07	23.3	8	1.10	**	0.50 NS
Platycephalus sp.	14.6	12	0.29	15.0	1		—	—
Leiognathus rivulatus	8.2	130	0.07	9.2	499	0.41	—	1.30 NS
Lethrinus nematacanthus	12.2	186	0.12	14.3	244	0.08	—	14.9 **
Scolopsis temporalis	14.0	22	0.58	14.8	4	0.25	**	1.16 NS
Upeneus tragula	12.0	26	0.60	14.8	30	0.55	NS	3.46 **
Upeneus sp. aff. *asymetricus*	10.9	329	0.07	12.0	46	0.20	—	5.52 **
Pristotis jerdoni	9.1	46	0.08	8.7	490	0.04	—	4.92 **
Paramonacanthus japonicus	9.0	30	0.13	10.0	1		—	—
Pseudalutarius nasicornis	11.3	3	0.83	12.6	5	1.12	—	0.78 NS
Canthigaster compressa	8.3	217	0.06	8.6	38	0.20	—	1.62 NS

L = length in cm,
n = sample size,
$s/\sqrt{n}$ = standard error,
F = Fmax test for homogeneity of variance (Sokal and Rohlf 1981) performed if $n<30$,
t = Student test if F not significant, otherwise t' test for samples of unequal variance (Sokal and Rohlf 1981),
** = significant at $\alpha = 0.01$,
NS = not significant at $\alpha = 0.05$, dashes indicate not calculated.

Abundance and biomass

Density estimates from transects were on average 9.7 times larger than from trawls, this difference being highly significant (F test for paired comparison (Sokal and Rohlf 1981) at $\alpha = 0.01$) (Table 4). Depending on the species, the ratio between the two methods varied from 0.9 to 80 (Table 5). If one considers only the eight most common species mentioned in the previous section, then the ratio is 7.93. This would indicate a catchability of the trawl net of 0.103 for all species and 0.127 for the main species. Species for which the ratio is close to 1 (Synodontidae, *Canthigaster compressa*, *Upeneus* spp.) are difficult to detect underwater. This can be due to either their behavior (e.g., Synodontidae are usually motionless on the bottom, and at times, half buried in the sand) or to their coloration (*Canthigaster compressa* being well camouflaged among algae, and *Upeneus* spp. being able to drastically change their coloration to mimic the bottom). In addition, Table 6 indicates that these criptic species are usually found singly or in pairs.

Species with a high ratio (Apogonidae, *Leiognathus rivulatus*, *Pristotis jerdoni*) are not caught by the net for two main reasons. Either they are too small (Apogonidae, most *Pristotis jerdoni*) or they swim too high above the bottom (*Leiognathus rivulatus* were usually 0.5–3 m above the bottom) for the net to catch them. These fish are also found in small schools (21–36 fish/sighting) (Table 6). The correlation between the two methods (Table 5) is some indication of the patchiness of the distribution of these species. Thus a high correlation such as for the Synodontidae ($r = 0.75$) or *Leiognathus rivulatus* ($r = 0.92$), indicates that these

Table 4

Density estimates (fish/ha) for all species for visual transects and trawls, St. Vincent Bay, New Caledonia. CI = confidence interval ($\alpha = 0.05$).

	Station number									
	1	2	3	4	5	6	7	8	Average	CI
Transect	6020	7190	1930	8650	2610	1160	1750	4340	4200	1690–6700
Trawl	245	620	183	312	590	920	197	380	431	200–662

F test value for paired comparison = 15.1. Limit value = 5.59 (1, 7 df) at $\alpha = 0.05$.

Table 5

Comparison of density and biomass estimates from transects and trawls for main families and species, St. Vincent Bay, New Caledonia.

Family or species	Density		Biomass	
	ratio	r	ratio	r
Synodontidae	0.88	0.75*	0.80	0.93**
Apogonidae	80	0.66	13	0.78*
Leiognathus rivulatus	33	0.92**	49	0.97**
Lethrinus nematacanthus	7.4	−0.03	10	−0.02
Upeneus spp.	2.3	0.63	4	0.57
Pristotis jerdoni	29	0.04	39	0.03
Canthigaster compressa	1.2	0.49	1.3	0.40
All species	9.7	−0.17	9.1	0.72′
Main species (see text)	7.9	0.23	6.4	0.34′

Ratio = density from transects/density from trawls,
r = correlation coefficient,
* significant at $\alpha < 0.05$, ** significant at $\alpha < 0.01$.
′ night station (n°6) not included.

Table 6

Average distance between sightings and number of fish per sighting for main families and species, St. Vincent Bay, New Caledonia.

Family or species	Average distance between sightings (m)	Number of fish per sighting
Synodontidae	110	1
Apogonidae	260	35
Leiognathus rivulatus	120	36
Lethrinus nematacanthus	28	4
Upeneus spp.	35	1.8
Pristotis jerdoni	80	21
Canthigaster compressa	55	1.3

species are rather uniformaly distributed on the bottom. Conversely, species such as *Lethrinus nematacanthus* ($r = 0.03$) or *Pristotis jerdoni* ($r = 0.04$) have a very patchy distribution. A pratical consequence is that a larger number of stations will be needed to get a good stock assessment for the latter species than for the former.

Biomass estimates from transects are 9.1 times larger than those from the trawls (Table 7), this difference being significant (F test for paired comparison (Sokal and Rohlf 1981) at $\alpha = 0.05$). Although density estimates for all species were not correlated between trawls and transects ($r = -0.17$), biomass estimates show some correlation between the two methods, if the night station n°6 is excluded ($r = 0.72$, significant at $\alpha = 0.07$). The absence of correlation between the two methods in the density estimates may be explained by the large contribution of small fish such as Pomacentridae to transect density estimates, whereas these species escape the net. Conversely, biomass estimates are almost unaffected by these species because of their small weight. At the species level the correlations between the two methods for biomass estimates are of the same magnitude as those observed for density estimates.

Discussion

The comparison of two methods with such different concepts requires some adjustments. Trawls swept approximately 5600 m^2 and transects covered between 700 and 1000 m^2 (depending on species) for each station. The trawls did fish over the transect lines, but a perfect match would mean a trawl track with a precision of ± 1 m which is untractable even in shallow water. This is, in our opinion, the main source of difference in the number of species given by each method.

Table 7

Biomass estimates (kg/ha) for transects and trawls, St. Vincent Bay, New Caledonia. CI = confidence interval at $\alpha = 0.05$.

	Station number									
	1	2	3	4	5	6	7	8	Average	CI
Transect	225	242	49	65	160	43	123	74	123	53–193
Trawl	10	19	8.3	4.9	11	34	15	6	13.5	5.0–22.0

F test value for paired comparison = 15.0. Limit value is 5.59 (1, 7 df) at $\alpha = 0.05$ (Sokal and Rohlf 1981).

Because of the low number of stations, this difference in sampled area may also be important to explain the low correlation between the two methods for density or biomass estimates of fish with a patchy distribution. Conversely, comparisons of the density or biomass for fishes with a regular distribution should not be affected.

An important result from the present survey is the magnitude of the difference between trawl and transect estimates of density. This difference, which is a factor of 9.7 for all species and a factor of 7.9 for the main species, certainly indicates that shrimp trawls poorly sample the bottom fish fauna in St. Vincent Bay. Visual transects are usually performed as strip transects, where distance of the fish to the transect line is not taken into account (Harmelin-Vivien et al. 1985). This underestimates density, especially if the width chosen is large (Burnham et al. 1980). The method chosen in the present survey is more accurate; however, it is not possible to know by how much one underestimates or overestimates the "real" density. Fish numbers (Harmelin-Vivien et al. 1985) and distances are both underestimated but play opposite roles in the density estimation. Even in the unlikely case of a large overestimate of fish density (let's suppose by 100%) by transects, the catchability of the trawl would still be 0.25 for the main species and 0.21 for all species.

Several surveys indicate that trawls may not be as efficient as usually thought. Thus Uzmann et al. (1977) found that estimates of fish density from submersibles were 8.0 times greater than density estimates from otter trawls, this ratio varying between 0.8 and 18 depending on the species. Similarly, Gray and Bell (1986) found that poisoning indicated densities 2.5 to 6.5 times greater than a beam trawl over seagrass beds. However, in some conditions trawling may be more efficient, as shown by Harden Jones et al. (1977) who used accoustical tags to estimate that 44% of the tagged flatfishes *Pleuronectes platessa* were caught by a Granton otter trawl. Uzmann et al. (1977) had found that only 7% of the flatfishes seen from a submersible were caught by the otter trawl. Serebrov (1986) used submersibles to show that the catchability of an otter trawl varied with the size of the fish, mesh size, and overall catch composition.

In the case of one or a few species, catchability of trawls may vary between 0.5 and 1.0. Such values of catchability are widely used, even in multispecies tropical fisheries, for which Pauly (1982) states that a value of 0.5 is "realistic" and Gulland (1979) even suggests that a catchability of 1.0 should apply to the eastern Indian Ocean trawl fisheries. In many of these fisheries, shrimp trawls of design similar to the one used in the present experiment are used to get a mixed catch of shrimp and fish (Grantham 1980, Poiner and Harris 1986, Lamboeuf 1987, Sainsbury 1987). Our results indicate a catchability near 0.1 (0.103 for all species and 0.127 for the main species). Such a value may need further testing; but if it proved correct, it would have important implications in the management of these tropical multispecies trawl fisheries. In particular, depending on whether one uses a catchability of 1.0 or 0.1, stock size will increase by a factor of 10. This would also affect the estimated fishing mortality (Pauly 1982) and, as a result, most of the equations used in stock management. What is more important, in our opinion, is that if one applied a catchability of 0.1 in most of these tropical trawl fisheries of the Indo-Pacific, the current models would be unable to explain the long-term decline of the catch seen in these fisheries. This could mean that trawling induces detrimental changes in fish populations which are beyond the simple removal of fish. In particular, habitat changes may be important, as noted by Poiner and Harris (1986) and Sainsbury (1987).

Another question arising from the present work is the value of the catch per unit effort (CPUE) of trawls as an indicator of population abundance. Our results show a poor correlation between abundance estimates from trawls and visual transects at the population level, but good correlations for a few selected species. Numerous studies have examined the correlation of CPUE by trawling and acoustic surveys. Most of these indicate good correlations (see Tesler (1977), Olsen et al. (1977), or Thorne (1977a) among others) but important varia-

tions may result from fish behavior (Thorne 1977b). However, most of these surveys are performed on a single pelagic or semipelagic species, and the correlation between acoustic surveys and CPUE by trawling for multispecies tropical stocks is currently poorly documented. Soetre and Paula e Silva (1979) found from comparison between demersal trawl catch and echointegration on a multispecific stock off Mozambique that the catchability of the otter trawl was 0.3. These authors state that this value is "suspiciously low for demersal species." Guillory et al. (1982) concluded from replicate sampling with otter trawls that this type of gear should be used strictly for qualitative purposes in a multispecies situation. This is in part supported by the present work, which indicates a need for alternate methods of stock assessment. Longlines show similar problems to trawling. Thus, correlation between longline CPUE and observed densities from a submersible was weak at the multispecies level (Richards and Schnute 1986, Ralston et al. 1986) but satisfactory for some selected species. Similar work involving longline CPUE and observed densities by visual transects indicated a good correlation for all species ($r = 0.88$) but considerable variations depending on species (Kulbicki 1988). Visual census either by diving or from submersible might be an alternative, but these methods also have numerous limitations. In particular, they do not allow a quick coverage of large areas and are not usable in turbid waters. If reasonably accurate density estimates are required in a multispecies tropical trawl fishery, it is likely that this can be achieved only by a combination of several independent methods.

Citations

Aoyama, T.
1973 The demersal fish stocks and fisheries of the South China Sea. South China Sea Development and Coordinating Programme. IPFC, FAO, Rome, 80 p.

Burnham K.P., D.R. Anderson, and J.L. Laake
1980 Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72, 202 p.

Chong, V.C.
1984 Prawn resource management in the west coast of peninsular Malaysia. Wallaceana (Kuala Lampur) 37:3-6.

Dickie, L.M., R.G. Dowd, and P.R. Boudreau
1983 An echo counting and logging system (ECOLOG) for demersal fish size distributions and densities. Can. J. Fish. Aquat. Sci. 40:487-498.

Dines, N.
1982 Essai d'application de l'échointégration à la mesure de l'efficacité des chaluts. Proc. Council Meeting, ICES-CM-1982/B:12, 11 p. [in French, Engl. abstr.].

Doubleday, W.G.
1976 A pilot study of a survey design for a combined acoustic and otter-trawl groundfish survey. ICES CM 1976/B, 30 p.

Grantham, G.J.
1980 The prospect for bycatch utilization in the Gulf area. Regional fishery survey and development project. Barhain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates. FAO, Rome, 43 p.

Gray, C.A., and J.D. Bell
1986 Consequences of two common techniques for sampling vagile macrofauna associated with the seagrass *Zostera capricorni*. Mar. Ecol. Prog. Ser. 28:43-48.

Grimes, C.B., K.W. Able, and S.C. Turner
1982 Direct observation from a submersible vessel of commercial longlines for tilefish. Trans. Am. Fish. Soc. 111:94-98.

Guillory, V., J.E. Roussel, and C. Miller
1982 Appraisal of otter trawl tow lengths and replicate sampling. Proc. Annu. Conf. Southeast. Assoc. Fish. Wildl. Agencies 34:158-166.

Gulland, J.A.
1975 Manual of methods for fisheries resource survey and appraisal. Part 5. Objectives and basic methods. FAO Fish. Tech. Pap. 145, 29 p.
1979 Report of the FAO/IOP workshop on the fishery resources of the western Indian Ocean south of Equator. IOFC/DEV/79/45, FAO, Rome, 99 p.

Harden Jones, F.R., A.R. Margetts, M. Greer Walker, and G.P. Arnold
1977 The efficiency of the granton otter trawl determined by sector-scanning sonar and acoustic transponding tags. Rapp. P.-V. Réun. Cons. Int. Explor. Mer 170:45-51.

Harmelin-Vivien, M.L., J.G. Harmelin, C. Chauvet, C. Duval, R. Galzin, P. Lejeune, G. Barnabe, F. Blanc, R. Chevalier, J. Duclerc, and G. Lasserre
1985 Evaluation visuelle des peuplements de poissons: Méthodes et problèmes. Rev. Ecol. Terre Vie 40:467-539 [in French].

Kulbicki, M.
1988 Correlation between catch data from bottom longlines and fish censures in the SW lagoon of New Caledonia. *In* Choat, J.H. et al. (eds.), Proceedings, 6th International Coral Reef Symp., Townsville, Australia, 8-12 August 1988. Vol. 2, p. 305-312.

Kulbicki, M., and L. Wantiez
1990 Variations in the fish catch composition in the Bay of St Vincent, New Caledonia, as determined by experimental trawling. Aust. J. Mar. Freshwater Res. 41 (1):121-144.

Lamboeuf, M.
1987 Bangladesh demersal fish resources of the continental shelf. R/V *Anasandhani* trawling survey results. September 1984-June 1986. FI:DP/BGD/80/025. FAO, Rome, 79 p.

Mackett, D.J.
1973 Manual of methods for fisheries resource survey and appraisal. Part 3. Standard methods and techniques for demersal fisheries resource surveys. FAO Fish. Tech. Pap. 124, 39 p.

Olsen, S., S. Tveite, and D. Chakraborty
1977 Acoustic surveying in tropical waters. Rapp. P.-V. Réun. Cons. Int. Explor. Mer 170:248-252.

Pauly, D.
1982 Une sélection de méthodes simples pour l'estimation des stocks de poissons tropicaux. FAO circulaire sur les pêches 729, 63 p. FAO, Rome [in French].

Poiner, I.R., and A. Harris
1986 The effect of commercial prawn trawling on the demersal fish communities of the south eastern Gulf of Carpentaria. *In* Haines, A.K., G.C. Williams, and D. Coates (eds.), Torres Strait Fisheries Seminar, p. 239-259. Aust. Gov. Publ. Serv., Canberra.

Ralston, S., R.M. Gooding, and G.M. Ludwig
1986 An ecological survey and comparison of bottom fish resource assessments (submersible versus handline fishing) at Johnston Atoll. Fish. Bull., U.S. 84:141–155.

Richards, L.J., and J.T. Schnute
1986 An experimental and statistical approach to the question: Is CPUE an index of abundance? Can. J. Fish. Aquat. Sci. 43:1214–1227.

Rivaton, J., P. Fourmanoir, P. Bourret, and M. Kulbicki
1990 Checkliste préliminaire des poissons de Nouvelle-Calédonie. Rap. Sci. Tech. 54, ORSTOM Océanogr., Nouméa, New Caledonia, 170 p. [in French, Engl. abstr.].

Sainsbury, K.J.
1987 Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. *In* Polovina, J.J., and S. Ralston (eds.), Tropical snappers and groupers: Biology and fisheries management, p. 465–503. Westview Press, London.

Serebrov, L.I.
1986 Differential catchability of bottom trawls as revealed by underwater exploration. *In* Underwater exploration for fishery purposes, p. 21–38. Pinro, Murmansk, USSR [in Russ.].

Siegel, S., and N.J. Castellan Jr.
1988 Nonparametric statistics, 2d ed. McGraw-Hill Int. Ed., Stat. Ser., NY, 399 p.

Soetre, R., and R. de Paula e Silva
1979 The marine fish resources of Mozambique. Reports on surveys with the R/V *Dr Fridtjof Mansen*. Servio de Investigaoes Pesqueira, Maputo. Inst. Mar. Res., Bergen, Norway, 179 p.

Sokal, R.R., and F.J. Rohlf
1981 Biometry, 2d ed. W.H. Freeman, San Francisco, 859 p.

Tesler, V.D.
1977 Measuring of average amplitude of echoes for fish density estimation. Rapp. P.-V. Réun. Cons. Int. Explor. Mer 170:152–158.

Thorne, R.E.
1977a Acoustic assessment of Pacific hake and herring stocks in Puget Sound, Washington and southeastern Alaska. Rapp. P.-V. Réun. Cons. Int. Explor. Mer 170:265–278.
1977b A new digital hydroacoustic data processor and some observations on herring in Alaska. J. Fish. Res. Board Can. 34:2288–2294.

Uzmann, J.R., R.A. Cooper, R.B. Theroux, and R.L. Wigley
1977 Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: Submersible VS camera sled VS otter trawl. Mar. Fish. Rev. 39(12):11–19.

Villoso, E.P., and G.V. Hermosa Jr.
1982 Demersal trawl fish resources of Samar Sea and Carigara Bay, Philippines. Fish. Res. J. Philipp. 7:59–78.

Wantiez, L., and M. Kulbicki
In press Les pêches exploratoires au chalut en baie de Saint-Vincent. Rapp. Sci. Tech. 55, ORSTOM Océanogr., Nouméa, New Caledonia [in French, Engl. abstr.].

Kulbicki Michel, Wantiez Laurent. (1990).

Comparison between fish bycatch from shrimp trawlnet and visual censuses in St. Vincent Bay, New Caledonia.

Fishery Bulletin, 88 (4), 667-675.