Managing South Africa's trawl bycatch

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Over the past few decades, it has become widely recognized that the management strategies of world fisheries must ensure sustainability of bycatch as well as of target species. South Africa implemented a pilot observer programme from 1995 to 2000 to collect data on the levels and patterns of bycatch and discards in the demersal trawl fishery. Here, the results of that programme are used in conjunction with information on bycatch value and compliance to assess the issues and problems regarding bycatch and discarding in the fishery. In general, bycatch components can be placed into one of three categories (discarded bycatch, retained bycatch, and processing waste), each of which present different management problems and require different management approaches. The results were used to formulate a bycatch management plan for the demersal trawl fishery in South Africa. Given the need to continue monitoring bycatch, the performance of the pilot observer programme is reviewed, and the levels of sampling effort required for a national programme are discussed.

Keywords: bycatch, observer programme, South Africa.

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Introduction

Many concerns exist regarding the effect that non-target catches (bycatch) and discarding have on marine systems (Dayton *et al.*, 1995; ICES, 1995; Alverson, 1998; Pauly *et al.*, 2002). These include underestimation of fishing mortality, overexploitation of bycatch species (Alverson *et al.*, 1994), and impacts on other fisheries (Alverson, 1998). However, detailed historical information on bycatch is lacking for many fisheries (Saila, 1983; Alverson *et al.*, 1994; Hall, 1996). Such information is essential when proposing measures to manage bycatch or discard practices.

Debate on bycatch issues has been clouded by terminology, and the term has been applied variously to the portion of the catch discarded at sea, the retained and sold non-target portion of the catch, and recently as a general term for fisheries "waste" (Alverson *et al.*, 1994; Hall, 1996). The definition of bycatch used in this study is "That part of the gross catch which is captured incidentally to the species toward which there is directed effort. Some, all, or none of the by-catch may become the discard catch." (Saila, 1983, p. 1). In addition, undersized fish of target species are also included as bycatch in this study.

In South Africa there has been increasing awareness of bycatch issues that has coincided with a period of transformation in the fishing industry, following the election of a fully democratic government in 1994. In 1998, after a period of consultation with all stakeholders, South Africa adopted a new policy for managing its marine resources, enshrined in the Marine Living Resources Act (Anon, 1998; Cochrane and Payne, 1998; Hersoug and Holm, 2000). That Act recognizes the need to utilize South Africa's resources fully while managing them in a sustainable manner, and suggests that an ecosystem approach to management is needed. One of the primary areas highlighted for attention was an understanding of the implications of bycatch in South African fisheries.

In order to understand bycatch issues, basic data on the levels and patterns of bycatch are required. The first comprehensive estimates of bycatch and discards for the demersal trawl fishery (see Figure 1) were those of Japp (1996), based on bycatch ratios determined from research survey data. However, the gear used for research surveys is often different from that used by commercial trawlers, and South Africa's research surveys take place over a limited part of the year and cover non-commercial and commercial trawling grounds. As Japp (1996) acknowledged, such factors may bias the estimates. A second (pilot) study was initiated in 1995, using observers aboard commercial vessels to collect bycatch data. This study provided data on trawl catch composition, estimates of bycatch and discarding, and bycatch dynamics and also highlighted areas of concern with regard to bycatch (Walmsley *et al.*, in press).

The purpose of this paper is to describe the translation of pilot scheme results into a management plan to quantify bycatch. The results of the pilot programme are used in conjunction with information on bycatch value and compliance to understand the implications of possible management measures. In addition, we assess here the successes/failures of the pilot observer scheme and propose a structure for a national observer programme (NOP), capable of delivering data that can be used to monitor the efficacy of any new management measures.

Methods

The process of formulating a bycatch management plan in the South African trawl fishery followed the approach suggested by

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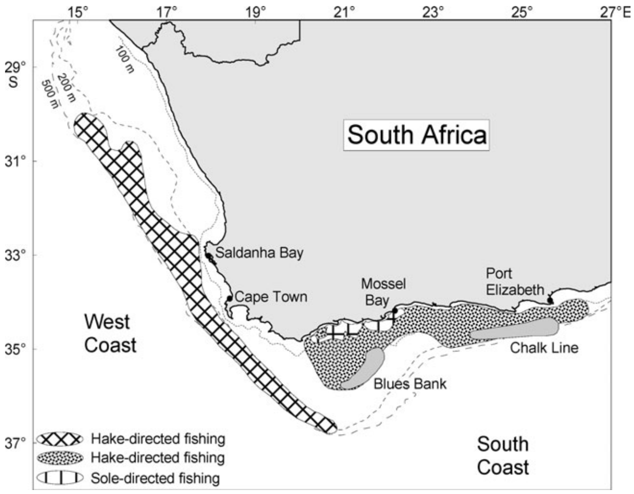

Figure 1. Map of South Africa, showing the main demersal fishing grounds and places mentioned in the text.

Kennelly (1997). The first step in Kennelly's model is data collection, closely followed by analysis and assessment of the scale of the problem. The second step is to identify solutions to the highlighted issues.

To fulfil the first step, we used three data sources. These were (i) the pilot observer programme described by Walmsley *et al.* (in press), (ii) two studies into bycatch value that investigated the reliance of operators on bycatch revenue and assessed the attitude of operators and processors towards bycatch, and (iii) an assessment of compliance. The results of the programme were used to determine categories of bycatch and to identify the management issues that exist with regard to category. In this way, areas of bycatch that require immediate management solutions were identified. The information on bycatch value and compliance was used to assess the social impacts of proposed management measures. For example, there would be no point in introducing measures to reduce bycatch if, as a result, it was no longer viable economically to fish, or if new regulations would be ignored.

Kennelly's (1997) second step, the identification of solutions to the issues raised, was fulfilled through a series of debates between fisheries managers, biologists, and industry representatives, based on all of the studies listed earlier and resulting in a series of solutions to each issue identified. Next, a workshop was organized for members of the fishing industry where the areas of concern were presented and possible solutions proposed. Participants were given the opportunity to discuss these proposed solutions. The comments from the debates and workshop were used to formulate a draft management plan, concentrating on immediate management measures and medium-term targets to address the key issues raised.

The process of designing an NOP used the lessons learned from the pilot observer scheme. The major limitations to the scheme were identified, and solutions to eliminate these problems in future sampling were considered. A structure for future work, including sampling levels, distribution of observer coverage, and sampling methods was formulated.

Results

Pilot observer programme

The pilot observer programme yielded South Africa's first comprehensive data on actual trawl, as opposed to landed, catches. A full analysis of the results of the pilot observer programme can be found in Walmsley *et al.* (in press), but in order to put bycatch issues into context, a summary of the results is given in Table 1.

Although the west and south coast fisheries are diverse, each with more than 70 species identified in the catches, notable differences were observed between the two areas (Table 1). Cape hake (*Merluccius capensis* and *M. paradoxus*) totally dominate the west coast catch, and a large proportion of the bycatch was of species that cannot easily be utilized, such as macrourids. In contrast, Cape hake contribute 53–70% by mass and up to 53% of the landed value of catches on the south coast. Much of the bycatch there, such as panga (*Pterogymnus laniarius*) and horse mackerel (*Trachurus trachurus capensis*), can be utilized. However, on both coasts, ~90% of the total catch is processed and retained (Table 1).

The west coast fishery is mainly prosecuted by large companies that have shore-based factories geared towards processing hake. In contrast, the south coast fishery is more diverse and consists of smaller companies that utilize many species (Walmsley *et al.*, in press). These differences not only affect the patterns of catch and discarding, but will also have implications for the introduction of management measures.

The results of the pilot observer programme indicated that bycatch and discards generally fall into one of three categories: discarded bycatch, retained bycatch, and processing waste or offal (Walmsley *et al.*, in press). Each category presents different management problems that require different management approaches.

Discarded bycatch

Discarded bycatch is of two types, undersized fish of target (e.g. Cape hake) and non-target species (e.g. ribbonfish *Lepidopus caudatus*), and species that cannot be utilized (e.g. macrourids). Using a landings-based extrapolation method, it is estimated that 7000 t and 2000 t of hake were discarded annually on the west and south coasts, respectively (Table 1). Possible reasons for such discarding include the fish being too small for traditional markets, or highgrading (the discarding of small fish in favour of larger, more valuable fish). In order to minimize the potential loss of revenue that discarding represents, solutions must be found to reduce the catches of undersized fish and to prohibit highgrading.

Retained bycatch

Although the demersal hake fishery is managed as a single-species fishery, many of the bycatch species are processed and retained (Walmsley *et al.*, in press), and species are sometimes targeted. Utilization of non-target species is affected by factors such as market demand and quota allocations, and the catch may not always be maximally utilized. During its development, the capital-intensive nature of the deep-sea demersal trawl sector favoured large conglomerates (Payne and Bannister, 2003), but recently the number of participants has increased (Kleinschmidt *et al.*, 2003). However, the new participants have small hake allocations, and there are concerns that they may be encouraged to target bycatch, especially monkfish (mainly *Lophius vomerinus*) and kingklip (*Genypterus capensis*), and to highgrading hake in order to maximize the economic return on their allocation.

A recent study on the value of bycatch has suggested that the need to utilize decreasing allocations maximally would encourage the landing and marketing of bycatch species in future (Erstadt, 2002). Some bycatch species, such as commercially sought linefish (fish caught by the commercial and recreational linefisheries) and

Table 1. Summary of catch composition data collected by observers aboard commercial fishing vessels on the west and south coasts of South Africa between June 1995 and September 2000.

Parameter	West coast		South coast	
	Hake-directed	Monkfish-directed	Hake-directed	Sole-directed
Number of trawls observed	430	49	320	294
Total observed catch (t)	2 073	137	537	138
Percentage of total catch retained	86–92	96	94–96	81
Percentage of total catch discarded	9–15	4	4–7	20
Percentage contribution of selected species to the total observed catch				
Cape hake	65–92	62	53–70	62
Monkfish	2–4	33	1–2	0.2
Agulhas sole	<0.1	<0.1	0.0–0.5	18
Percentage contribution of selected species to the landed catch				
Cape hake	59–89	59	51–69	49
Monkfish	1–4	33	<0.1	<0.1
Agulhas sole	<0.1	<0.1	<0.1–1	17
Percentage of the landed value from bycatch	2–24	73	15–37	47
Estimated annual discards (t)	29 619		5722	
Cape hake	6915		2003	
Ribbonfish	14198		649	
Monkfish	254		214	
Horse mackerel	159		179	
Jacopever (*Helicolenus dactylopterus*)	426		649	
Other	7667		2028	
Offal discarded (t)	29 859		13 423	
General characteristics	• Large proportion of the bycatch cannot be utilized, e.g. macrourids		• Large proportion of the bycatch can be utilized, e.g. panga and horse mackerel	
	• 71 spp. caught, 19 retained		• 74 spp. caught, 32 retained	
	• Decrease in the percentage of bycatch in the catch with increasing depth		• The sole-directed fishery discards ~20% of the hake that it catches	

The results represent the total catch (or percentage of the total catch) from all trawls sampled in each area for all years combined. Data for west coast hake-directed trawls represent the range of results obtained for four depth ranges (0–300 m, 301–400 m, 401–500 m, and >500 m), and data for the south coast hake-directed trawls represent the range of results obtained from three areas (Blues Bank, Chalk Line, and inshore). (Note that if monkfish or Agulhas sole is the target species, Cape hake becomes a bycatch.) Data are summarized from the results presented in Walmsley *et al.* (in press).

snoek (*Thyrsites atun*), are the target of other fisheries sectors. Catches of such species by the trawl fishery should ideally be minimized. Although linefish are generally retained and processed when they are captured, many South African linefish stocks are collapsed or overexploited (Griffiths, 1997a, b, 2000). The current management proposal for the commercial linefishery in South Africa is to cut the catch by some 70%. Therefore, the incidental capture of juvenile linefish such as silver kob (*Argyrosomus inodorus*) by the inshore trawl fishery for Agulhas sole (*Austroglossus pectoralis*) on the south coast (Walmsley *et al.*, in press) is of particular concern.

Processing waste

The pilot programme data indicated that almost 30 000 t of offal is discarded annually on the west coast and 13 500 t on the south coast (Table 1). This represents a substantial return of organic material to the marine environment.

Evaluation of the pilot observer programme

One of the main aims of the pilot study was to use the lessons learned to design the first stage of an NOP. In designing an NOP, the limitations of the pilot programme must be understood, in order to improve the data collection of future work.

Several limitations were identified in the pilot observer scheme, including the small sample size. It was estimated that just 0.49% of west coast and 0.62% of south coast trawls were subjected to observation in 1997, the year of greatest observer effort (Walmsley *et al.*, in press). This is clearly not sufficient sampling to provide representative coverage of such a diverse fishery and should be increased in future. Better observer coverage could be obtained by aiming for a particular stratified sampling level (such as 5% or 10% of all trawls) that could provide representative data for the fleet. The results obtained in the pilot scheme indicate that coverage of 15% of all trawls, i.e. 30 times higher than the pilot programme, could provide reliable data on discarding. We estimate that 294 sampling trips are needed to cover 15% of trips undertaken by the fleet annually.

The species composition in different fishing areas and the use of different gears can affect the estimates of discards. Fewer samples are required to provide representative catch data from a fishing area where the variance in catch composition is low, than in an area where the variance is high. If there are large differences in variance, the observer effort can be stratified accordingly. To assess the variation in discarding levels in the pilot programme, the mean discard rate (kg km^{-2} trawled), the standard deviation (s.d.), and the coefficient of variation (CV) of hake-, monkfish-, and sole-directed effort was calculated for each of the fishing areas defined. The discard rate was calculated from:

$$D = \frac{W}{\mathrm{MW} \times V \times T},$$

where D is the discard rate (kg km^{-2}), W the weight of the discard species (kg), MW the mouth width of the trawl (km), V the trawl speed (km h^{-1}), and T is the trawl duration (h). The CVs were high for all areas (Table 2), especially for the inshore hake-directed area on the south coast, and the 0–300 m and 401–500 m depth ranges on the west coast, i.e. the areas with greatest species diversity.

Also of concern was the sampling methods used. The sampling protocol was aimed at collecting data on the discarded portion of the catch only. However, more information is required on the length distribution of the retained catch, and on the benthic component of the catch. Also, the percentage of the discards subsampled was often small (10–100% for west coast, 50–100% for south coast catches), increasing the sampling error. These concerns must be taken into account when planning an NOP.

Bycatch value

Two investigations were made into the value of bycatch. The first examined the importance of bycatch revenue to trawling companies, and the second involved interviewing industry representatives and small-scale processors to determine their attitudes to bycatch. Two important points were made. First, Erstadt (2002) estimated that the west coast fishery, which is dominated by hake, derived 7% of its revenue from bycatch, whereas the more diverse south coast fishery derived between 15% and 36% of its revenue from bycatch. Second, although small-scale processors would be able to sell bycatch to local residents and entrepreneurs if it was available, the cost to operators of sorting and packing bycatch is often greater than the landed value. Therefore, even if a market exists, it is often not worthwhile landing the fish (Karaan *et al.*, 2001).

These factors highlight the importance of considering the economic implications for fishing companies when formulating management strategies. For example, introduction of stringent regulations to reduce bycatch on the south coast could lead to unsustainable loss of profit in the fishing industry, so any measures suggested need to be carefully evaluated. Alternatively, if a no-discards policy were to be introduced to provide processors with more bycatch, it must take place in conjunction with other plans for creative marketing or value-addition, to ensure a commercially viable operation.

Compliance

There is little point in introducing additional measures to manage bycatch if they cannot be enforced. In 1999, a Marine and Coastal Management (MCM; South Africa's department charged with marine resource management, research, and control) task group reported that several areas of concern existed with regard to compliance. These included a lack of monitoring at sea, problems with highgrading, and the limited monitoring at offloading points (Department of Environmental Affairs and Tourism, 2000).

Some changes have been implemented since the release of that report. Trawlers are now required to carry a vessel monitoring system (VMS), which allows the monitoring of closed areas, and a scientific observer programme has been established, although compliance monitoring is not part of the job description of such observers. In addition, the introduction of real-time electronic logbooks has been proposed, and may yet be implemented. Finally, a collaborative bycatch management approach should increase industry responsibility towards sustainable utilization of the resource and encourage better adherence to the rules.

Round-table discussions

The workshop that was held with industry representatives, fisheries managers, and scientists present proved to be very valuable in that it gave an opportunity for those who would be affected by management measures to have their say. Thus, possible industry

Table 2. Mean mass (kg km^{-2} trawled) of Cape hake, monkfish, and Agulhas sole discarded in each of the nine fishing areas defined, calculated from trawls observed between 1995 and 2000 on the south and west coasts of South Africa.

Ground, depth, or fishery	*n*	Cape hake			Monkfish			Agulhas sole		
		Mean	s.d.	CV	Mean	s.d.	CV	Mean	s.d.	CV
South coast										
Blues Bank	139	60.9	113.1	209.9	0.03	0.3	2.1	0.2	1.3	11.2
Chalk Line	41	100.0	242.3	586.6	40.3	93.1	214.8	0.1	0.3	2.2
Inshore hake-directed	140	135.2	253.4	474.9	–	–	–	–	–	–
Inshore sole-directed	294	251.9	294.6	344.6	0.01	0.1	1	7.6	13.5	23.9
West coast										
0–300 m	52	1003.6	1300.2	1684.3	18.1	33.2	60.9	–	–	–
301–400 m	142	1488.1	157.2	16.6	17.0	54.7	176.1	–	–	–
401–500 m	201	1270.4	2279.9	4091.6	56.2	217.4	840.7	–	–	–
>500 m	35	188.6	368.8	721.3	121.2	227.4	427.0	–	–	–
Monkfish-directed	49	288.5	237.4	195.3	–	–	–	–	–	–

n = number of trawls observed, s.d. = 1 standard deviation, CV = coefficient of variation.

buy-in to a variety of suggestions was gauged. Many proposals received a mixed response, with disagreement largely along the lines of the type of operator that was represented. For example, some proposals were perceived to be of more benefit to large-scale operators and, as a result, were unpopular with smaller operators. The comments received at the workshop were taken into account when formulating the bycatch action table.

Discussion

When thinking of designing an NOP, each of the concerns identified in the results mentioned earlier was discussed, and the solutions identified were used to propose a new programme (Table 3). One method of allocating sampling effort would be to use a métier approach, in which vessels or fleets with similar gear and target species are grouped and sampling targets set for each group, based on some predetermined criterion. This could be the proportion of total annual fishing effort expended by each métier, the proportion of the annual catch of the target species taken by each, or a proportion of the total sampling time available. Based on the pilot programme results, we suggest three métiers for the west coast and four for the south coast. Given that 294 trips will provide 15% coverage of the fleet, 42 sampling trips (14.2% of the available sampling effort) should be allocated to each métier.

However, the sampling effort would need to be stratified, based on the size of the fleet in that métier and the variance observed in catches. Table 3 gives the proposed number of trips for each métier. Proportionally more sampling trips are proposed for the west coast offshore (small allocation) métier (which was not sampled during the pilot scheme), south coast inshore hake-directed vessels (which had high CVs), and sole-directed vessels (which had high levels of hake discarding). However, the results need to be assessed at the end of the first year to determine whether the proportion of sampling effort allocated to each métier is appropriate.

The sampling protocols detailed in Table 3 should alleviate the concerns regarding the sampling methods and subsample size. The protocols for catch composition sampling and length frequency sampling are rotated on a trawl-by-trawl basis. For many bycatch species, there is a lack of basic biological data upon which to base stock assessments, and data collected by fishery observers would be valuable for assessment and monitoring.

Table 3. Suggested distribution of effort, levels of coverage and sampling protocols, as an example, for an NOP for the South African demersal trawl fleet, based on the results of the pilot programme.

West coast		**South coast**	
Distribution of effort and levels of coverage			
Métier	Number of trips required	Métier	Number of trips required
Offshore (large allocation)	42 (14)	Sole-directed vessels	46 (16)
Offshore (small allocation)	47 (16)	Inshore hake-directed	47 (16)
Monkfish-directed vessels	35 (12)	Offshore (large allocation)	35 (12)
		Offshore (small allocation)	42 (14)
Catch composition sampling			
1. Collect 3–5 baskets of the catch, before the crew sorts it		1. If the catch is small, collect 50% of the catch, before the crew sorts it. If the catch is large, collect 3 baskets of unsorted catch	
2. Estimate the size of the subsample by recording the sampling time and time of conveyor belt operation		2. Estimate the size of the subsample visually	
3. Sort the sample to species. Sort the benthos as far as possible		3. Sort the sample to species. Sort the benthos as far as possible	
4. Weigh each species, starting with the target species, followed by the retained bycatch, then the discard species		4. Weigh each species, starting with the target species, followed by the retained bycatch, then the discard species	
5. Collect trawl information from the ship's log		5. Collect trawl information from the ship's log	
6. Scale up the subsample to estimate the total catch composition by weight		6. Scale up the subsample to estimate the total catch composition by weight	
7. Obtain information on trawl position, etc.		7. Obtain information on the trawl position, etc.	
Length frequency sampling			
1. Collect 3–4 baskets of discards after the crew has sorted it		1. Collect 3 baskets of discards after the crew has sorted it	
2. Collect 1–2 boxes of retained catch from the crew		2. Collect 1–2 boxes of hake and 1 box of sole (during sole-directed fishing) from the crew	
3. Measure the retained catch		3. Measure the retained catch	
4. Sort the discarded catch and measure the priority discard species		4. Sort the discarded catch and measure the priority discard species	
5. If time allows, measure any other discard species		5. If time allows, measure any other discard species	
6. Obtain information on the trawl position, etc.		6. Obtain information on the trawl position, etc.	
Biological sampling (to be collected only as required by MCM, one sample per trip to either west coast or south coast)			
1. Collect ~20 specimens of the sample species, covering all length classes			
2. Weigh, measure, and collect relevant biological data (e.g. sex, maturity, otoliths)			

Values in parenthesis are the percentage of available sampling effort that should be allocated to each métier.

Possible bycatch management measures

The pilot observer programme data and discussions with the fishing industry highlighted several areas of concern with regard to bycatch, and areas that require management attention. To address these concerns, a bycatch action table similar to those proposed for Australian trawl fisheries (AFMA, 2002a, b), was formulated. The table lists the problems identified, proposes some targets that could alleviate the problems, and suggests solutions that may be used to achieve such targets. One of the most important concerns was the lack of a coordinated approach to bycatch management. Therefore, the establishment of a bycatch working group (BWG), composed of representatives of all stakeholders and charged with developing management measures, is required.

With regard to specific bycatch components, the most important is the capture of juvenile hake, because of the potential loss of yield and the effect of unknown juvenile mortality on stock assessments. Incorrect estimates of fishing mortality have clear implications for stock assessment and in certain cases will lead to underestimated catch per unit effort (cpue) and flawed assessments. However, if discard rate is constant over time, then the cpue trend would not be influenced, and stock assessments would probably not be seriously impacted. Notwithstanding, because the discard rate of small hake is to some extent driven by economic forces (e.g. market demand, highgrading), it is unlikely that it would be constant over time. Therefore, a cpue time-series based on landed catch may not be a reliable index of abundance, and it could ultimately lead to biased advice on total allowable catches (TACs).

Although the operational management procedure (OMP) currently used to provide management advice for Cape hake uses a biomass dynamic model to estimate the TAC, it has been tested against an age-structured operating model. The effect the unreported catches have on the OMP is unclear, although the sensitivity of the OMP to various assumptions of both catch-at-age and cpue was tested during development, and the OMP was found to be relatively robust to assumptions regarding discarding levels (Rademeyer, 2003).

For demersal fisheries, the simplest and most common method of reducing the capture of juveniles of target species is to increase the minimum mesh size (Armstrong *et al.*, 1990). Alternative methods, such as square mesh panels (Broadhurst and Kennelly, 1995a; Petrakis and Stergiou, 1997) and grid sorters (Larsen and Isaksen, 1993; Eayres *et al.*, 1997) can also be investigated locally as a means of reducing the catch of other discarded species.

An alternative solution to minimizing bycatch would be to close sensitive areas such as nursery or spawning grounds, either permanently (marine protected areas) or during particular periods (time/area closures; Gauvin *et al.*, 1995; Stergiou *et al.*, 1997; Witherell and Pautzke, 1997; NOAA/NMFS, 1998; Machias *et al.*, 2001). However, care must be taken when considering the position and timing of closures to ensure that they effectively protect the sensitive portion of the stock. The closure of sensitive areas can be further refined by the temporary closure of areas when the proportion of small fish in the catch reaches a pre-determined limit, as happens in the Bering Sea (Gauvin *et al.*, 1995) or in some Norwegian fisheries (Olsen, 1995).

Highgrading is a particularly sensitive problem. A possible approach may be to scrutinize the landed hake catch randomly. If the size distribution differs substantially from an expected value, perhaps the monthly average of all operators, then the operator concerned could be required to carry a compliance observer to see his fishing strategy. If that operator is unable to repeat his catch, he could face disincentives, such as fines or other measures.

Managing the retained bycatch requires the development of alternative solutions to ensure that catches are sustainable and maximally utilized. Most bycatch species, however, will not sustain separate targeted fisheries, and a realistic management objective would be to exploit them in an optimally sustainable manner within the demersal fishery. Estimating abundance and interpreting cpue trends for bycatch species is difficult, because effort is usually recorded as hake-directed effort in logbooks. Therefore, redirection of effort within the demersal fleet to target bycatch could lead to a substantial increase in landings of these species, with little or no apparent increase in total effort. Consequently, nominal cpue in such cases is unusable as an abundance index, and attempts to derive standardized cpue series have been unsuccessful for both monkfish and kingklip.

Bycatch species of high value, such as monkfish and kingklip, are unlikely to be managed by an increase in mesh size, because this would affect the capture of the target species. The introduction of a bycatch allocation, based upon the New Zealand example, could be considered, with each operator allocated a proportion of the catch limit (Batstone and Sharp, 1999). If the operator exceeds his limit, he should either pay a levy to land it or be able to buy/trade quota from other operators. Thus, operators wishing to target high-value species could do so, providing that they are willing to pay for it. If not, they are forced to fish using methods that will limit the catch of such species. However, in addition to the problems associated with assessing stock status, establishing an equitable sharing arrangement will not be a trivial matter. The simplest approach would be to make individual bycatch allocations *pro rata* to the hake allocation. This option would enjoy the support of operators with larger allocations of hake. However, although it is not possible entirely to avoid bycatch of kingklip and monkfish, operators can adjust the level of bycatch within bounds by changing their fishing strategy, but it must still be remembered that operators with smaller allocations of hake are more reliant on bycatch than are those with larger allocations. Consequently, smaller operators do not support a simple *pro rata* allocation of bycatch, but favour a method that will give them a higher relative share of any bycatch allocation. However, before any innovative sharing arrangement can be considered, the level of inevitable bycatch of kingklip and monkfish in purely hake-directed fishing operations (the unavoidable bycatch) should be estimated and taken into account in setting catch limits (Leslie, 2004).

Reduction of the juvenile linefish bycatch in the trawl fishery may help arrest the decline of linefish stocks and may reduce the current level of friction between trawler operators and linefishers over the bycatch issue. Broadhurst and Kennelly (1994, 1995b) report that square-mesh netting in the anterior section of the codend allows a significant proportion of mulloway (*Argyrosomus hololepidotus*) to escape from prawn trawls in Australia, suggesting that such a device could also be used to reduce catches of silver kob in South Africa.

Processing waste may pose a management problem, but utilization of offal is largely maximized by fishing companies, who retain the tongues, cheeks, and roes of Cape hake because of their high value, as well as some of the heads for bait for the spiny lobster (*Jasus lalandii* and *Palinurus gilchristi*) fisheries. Therefore, although it is suggested here that investigations into better utilization of offal should take place, discarding of offal is not considered to be an immediate concern.

The final issue requiring consideration is that of compliance. There are various ways of ensuring better compliance, including deployment of compliance observers at sea and at discharge points, stiffer penalties for transgressors, and understanding by the industry of the need for more-selective fishing. Annala (1996) reports that implementing penalties, such as the loss of rights, vessels, and equipment, substantially reduced transgressions in the New Zealand demersal fishery. Adoption of new technology, such as electronic logbooks and real-time recording, which would aid compliance officers determine if the recorded catch tallies with the catch in the hold, is under consideration in South Africa and should be encouraged. Finally, a collaborative management approach should increase industry responsibility towards the sustainable utilization of the resource, encouraging adherence to the rules.

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