Trawling Operations and South African (Cape) Fur Seals, *Arctocephalus pusillus pusillus*

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Introduction

The incidental take of marine mammals during trawl operations has received attention in several countries, including South Africa (Shaughnessy and Payne, 1979), Alaska (Perez and Loughlin, 1991), Canada (Pemberton et al., 1994), and New Zealand (Mattlin and Cawthorn, 1991). Less common are analyses of the losses to trawl fisheries through interaction with marine mammals, although in South Africa this has been documented and discussed (Shaughnessy, 1985; David, 1987; Wickens, 1989; Wickens et al., 1992). Such research has also revolved around the extent of consumption of fish discarded by trawlers and the possibility that trawler offal supports the needs of part of the population (David, 1987; Wickens et al., 1992), but not on cost of the losses from different fisheries. All studies of operational interactions between seals and the trawl fishery in South Africa (Rand, 1959; Shaughnessy and Payne, 1979; Shaughnessy, 1985; Ryan and Moloney, 1988; Anonymous, 1987; Wickens, 1989; Wickens et al., 1992) have focussed on the number of seals attending trawling operations and the numbers entrapped in the nets, and almost all have dealt with offshore demersal trawling only. Wickens et al. (1992) reviewed research on all seal-fisheries operational interactions in South Africa, and this was followed by an evaluation of these interactions in South Africa (Wickens, 1993, 1994). Based on that study, this paper evaluates the operational interactions between seals and each of the three trawl fisheries (offshore demersal, inshore demersal, and midwater) separately, in terms of financial cost to the industry (from catch losses, gear damage, and operational disturbance) and mortality or injury to the seals (through incidental and deliberate killing) in South African waters. This is done by evaluating new data and by making comparisons with published studies.

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ABSTRACT—South African (Cape) fur seals, Arctocephalus pusillus pusillus, *interact with the South African trawl fisheries—offshore demersal, inshore demersal, and midwater fisheries. These interactions take the following forms: Seals take or damage netted fish, on particular vessels they become caught in the propeller, seals drown in the nets, live seals come aboard and may be killed. Except in specific cases of seals damaging particular trawler propellers, interactions result in little cost to the offshore and midwater trawl fisheries. For the inshore fishery, seals damage fish in the net at an estimated cost in excess of R69,728 (US$18,827) per year, but this is negligible (0.3%) in terms of the value of the fishery. Seal mortality is mainly caused by drowning in trawl nets and ranges from 2,524 to 3,636 seals of both sexes per year. Between 312 and 567 seals are deliberately killed annually, but this most likely takes place only when caught and they enter the area below deck, where they are difficult to remove, and pose a potential threat to crew safety. Overall, seal mortality during trawling operations is negligible (0.4–0.6%) in terms of the feeding population of seals in South Africa.*

The South African (Cape) fur seal, *Arctocephalus pusillus pusillus,* is the only breeding pinniped found in southern Africa. This species, with a population size of up to 2 million seals (Anonymous, 1991), constitutes one of the largest fur seal populations in the world (Croxall and Gentry, 1987). Over one-third of the total population ranges along the South African coastline (Wickens et al., 1991), the area considered in this study, while the remainder is found off the Namibian coast. Off South Africa, seals are found at 10 breeding colonies and 5 nonbreeding colonies (where pups are found only on an irregular basis). The largest and only mainland colony is Kleinsee, where two-thirds of the pups in South Africa are born (Wickens et al., 1991). Between 1985 and prior to the cessation of sealing in 1990, this was the only colony at which sealing occurred (Wickens et al., 1991).

In South Africa, the trawl fishery is the second largest contributor, after the pelagic purse-seine fishery (28%, an average of 172,000 metric tons (t) annually between 1988 and 1992 inclusive), to the South African fishing industry in terms of the cleaned (mainly headed and gutted) mass of fish landed. However, it is by far the largest (51%, an average of R260 million or US$74 million) in terms of financial value to the industry (data from Sea Fisheries, Cape Town). Within the fishing industry this sector involves the largest number of personnel (almost 9,000), one-third of whom are fishermen operating on trawlers.

The trawl sector is divided into offshore and inshore demersal trawling and, since 1989, midwater trawling (Fig. 1). Prior to 1991 there was also an experimental demersal longline fishery. During that longlining, an estimated 5.3% of the catch was lost to seals (Wickens et al., 1992), and this was considered a significant quantity. Offshore demersal trawling provides by far the greatest landed mass and landed value of fish. The masses of fish landed by the inshore demersal and midwater trawl sectors are similar, but the value of the inshore trawled fish is greater.

Offshore demersal trawling targets the two species of Cape hake, *Merluccius capensis* and *M. paradoxus*, for which there is a single total allowable catch; kingklip, *Genypterus capensis*, is caught as a by-catch (Payne, 1989). In 1992 there were 58 active offshore trawlers which generally fish only by day. Most are stern trawlers and a few are side trawlers.

Inshore demersal trawling targets hake and the Agulhas sole, *Austroglossus pectoralis*, for which there are species-specific total allowable catches (Payne and Badenhorst, 1989). Kingklip is a by-catch, as in the offshore trawl fishery. This form of trawling is done with side trawlers, both day and night. In 1992 there were 37 trawlers actively used for inshore trawling.

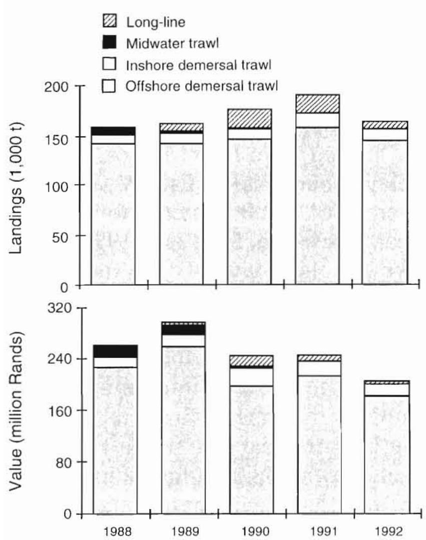

Figure 1.—Contribution of the sectors within the trawl and demersal longline fisheries in South Africa in terms of landings and landed value over a 5-year period (1988–92).

Midwater trawling targets mainly Cape horse mackerel, *Trachurus trachurus capensis* (Crawford, 1989). There is no total allowable catch, but to place some limitation on the exploitation of this species, a maximum annual catch is recommended. In 1992 there were seven vessels, all stern trawlers, licensed for midwater trawling, but most were not exclusively involved in midwater trawling. Midwater trawling is done mainly at night.

Data Collection

Quantitative information through independent surveys was required in which observers record counts of seals and incidences of entrapment during trawling operations aboard commercial vessels. Observers were briefed before leaving, the completed data sheets were examined on their return, and any unusual occurrences were cross-checked. Independent observations were possible on offshore trawlers, but there were logistical difficulties in carrying out independent observations at sea on inshore demersal and midwater trawlers.

Observations of offshore and inshore demersal trawling were made from both commercial and research trawlers, but the data from the two types of vessel are not directly comparable. The research vessel was a stern trawler which trawled for a period of 30 minutes, a shorter trawl time than done by commercial vessels. Research trawls were made using a net with a 27 mm (10.6-inch) mesh liner as opposed to minimum commercial net mesh restrictions of 110 mm (43.3 inches) and 75 mm (29.5 inches) to the west and east of Cape Agulhas, respectively. The two sets of data were analyzed separately, with the research data being used for comparison only.

During 1992 observers made nine demersal offshore trawling trips on commercial vessels, all but one of which were on stern trawlers (Table 1). The observation period totaled some 64 days at sea, during which about 600 t of cleaned (mainly headed and gutted) fish were caught. Observations were made during 222 hauls of the net. A further 75 days of observation took place on

Table 1.—Details of commercial and research trips undertaken to observe seal interactions during trawling operations during 1992–93. Observations on the offshore and inshore trawlers were done by independent observers and those on the midwater trawler by the skipper.

Trip and vessel	Company	Month	Duration (days)	Observed hauls
Offshore demersal				
Commercial		Jan.-July	64	222
1. Anemone	I & J[1]	Jan.	9	26
2. Harvest Galaxy	Sea Harvest	Feb.	6	30
3. Erica	I & J	Feb.	10	36
4. Aloe	I & J	Apr.	4	15
5. Harvest Belinda	Sea Harvest	Apr.	5	21
6. Begonia	I & J	May	7	23
7. Aloe	I & J	June	6	18
8. Aloe	I & J	July	7	21
9. Begonia	I & J	July	10	32
Research		Feb.-April	75	132
1. Africana		Feb.	25	17
2. Africana		April	25	30
3. Africana		Feb.	25	84
Total (12 trips)			139	354
Inshore demersal				
Commercial		Jan.-July	27	65
1. Atlantic Privateer	Mariette Fishing	Jan.	2	3
2. F.V. Immanuel	Mariette Fishing	March	6	17
3. Atlantic Privateer	Mariette Fishing	May	6	22
4. Dunevegan	Mariette Fishing	Jan.	3	5
5. Barcelona	P. Cronje	Feb.	6	13
6. Mary Ann	P. Cronje	July	4	5
Research		April-Sept.	75	72
1. Africana		April	25	43
2. Africana		Sept.	25	29
Total (8 trips)			102	137
Midwater				
Commercial		June-July	21	16
1. Roxana Bank	I & J	June-July	21	16

[1] Irvin & Johnson

the research vessel *F.R.S. Africana* in 1992 and 1993, during which 131 offshore demersal hauls were observed.

Six inshore demersal trawling trips were undertaken in 1992 and 1994 (Table 1). During the 27 days spent at sea, a catch of approximately 44 t of cleaned fish were caught on 65 hauls, all of which were observed. Conditions aboard inshore trawlers did not readily allow for accommodation of additional personnel as observers. Hence, the number of observed commercial hauls was limited. During 50 days at sea on two research cruises on *F.R.S. Africana* during 1992, records of seal activity were made during 72 inshore demersal hauls.

As a result of the difficulties involved in obtaining observations from commercial inshore trawlers and the fact that damaged fish are not sorted at sea, a monitoring program was established to record seal-damaged fish in the catches at landing sites. This took place at the Irvin and Johnson (I & J) and Sea Harvest[1] factories in Mossel Bay, the major landing site for inshore trawlers. Estimates of damaged fish and total landings were recorded by the same two factory production supervisors at each factory from May 1992 to April 1994. These persons are not affiliated with the vessels from which the fish are landed and are therefore considered to be independent recorders. The mass of seal-damaged sole and seal-bitten kingklip was recorded from a total of 991 landings, during which time over 1,068 t of sole and over 133 t of kingklip were landed.

On the smaller midwater trawlers it was not possible to obtain a berth for an observer, and the larger vessels only make a few trips during which midwater trawling may take place. For this reason no independent observation data of seal interactions with the midwater trawl fishery were obtained. However, one of the larger trawling companies chose one of their skippers as an appropriate and reliable person for collecting data. Observations were made by this skipper as some indication of entrapment and deliberate killing during 16 hauls in 1993 (Table 1). A discussion and quantification of the interactions are also provided, based on the data collection from the offshore demersal trawl observations.

For all of the trawl fisheries, catches are expressed in terms of landed mass, and economic calculations are made using landed values from 1992, the latest available data from Sea Fisheries, South Africa. The South African currency of Rands is converted to U.S. dollars using an exchange rate of US$0.27:R1 as of July 1994. For later calculations, the total number of trawls during 1992 is used, and consisted of 42,374 offshore demersal trawls, 21,575 inshore demersal trawls, and 1,100 midwater trawls.

For discussion purposes, the South African coastline is divided into the "west" coast, defined as the region west of Cape Agulhas, and the "south" coast, the region east of Cape Agulhas (Fig. 2). Most offshore trawling takes place and most seal pups are born on the west coast, and likewise most observation effort is concentrated in this region, with less on the south coast. By contrast almost all fishing effort by inshore trawlers is concentrated on the south coast, and all of the observer effort was done in this area, mostly within 50 miles of Mossel Bay. Midwater trawling also takes place mostly on the south coast, with a small quantity being done on the west coast. In this region there are only two breeding colonies of seals but trawling activity is close inshore.

Offshore and inshore demersal trawling is carried out consistently throughout the year, and observations from commercial trawlers occurred during

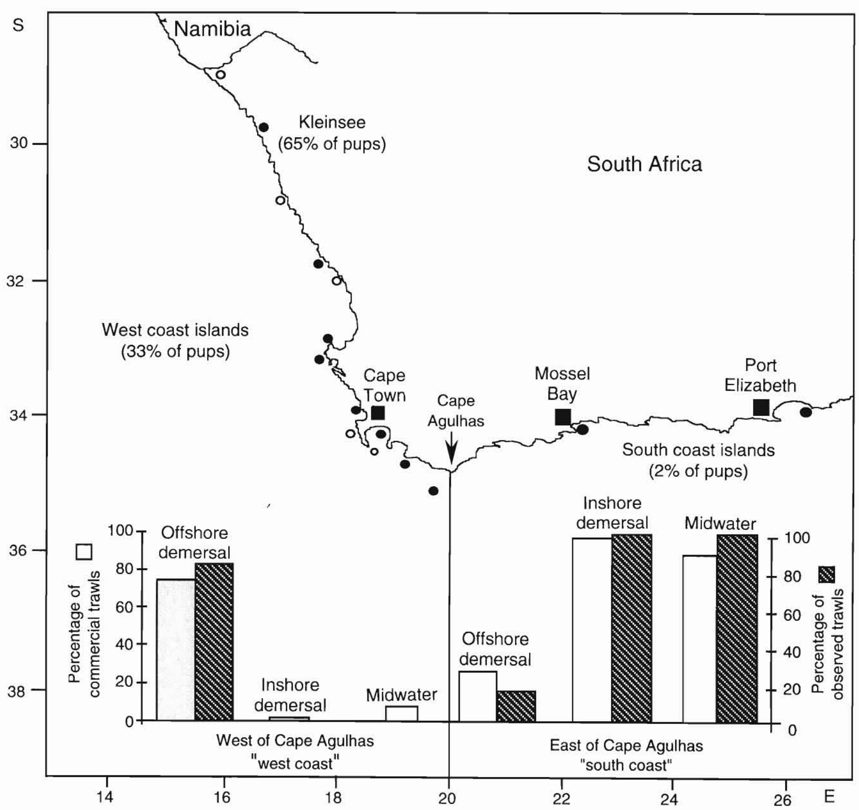

Figure 2.—Distribution of commercial (1992) and observed (1992–94) trawls for the offshore and inshore demersal and midwater trawl fisheries. The location of the breeding (dot) and non-breeding colonies (circle) of the South African (Cape) fur seal in South Africa are shown with the percentage of all pups born in South Africa for Kleinsee and the islands to the west and east of Cape Agulhas.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

the first half of the year when berths and observers were available. Midwater trawling also occurs through the year, but concentrated effort depends on the availability of fish and the allocated quotas. Observations of midwater trawling were made by the selected vessel at midyear.

Seal Attendance

Seal counts were made by observers at commercial offshore and inshore demersal hauls; they include seals around the trawler, i.e., not only at the stern or side where the net was hauled. No counts of seals were made during midwater trawling. Fish processing and discard release take place throughout the trawling process, so seal attendance includes seals that are feeding on such discards. For offshore trawlers it is assumed that the number of seals attending side trawls is the same as at stern trawls, so these data are combined.

The numbers of seals counted during different stages of the trawl are shown in Table 2. Seals are most likely to take fish from the time the net nears the surface until it is hauled aboard. The number of seals counted when the codend of the net surfaces is taken as the average number feeding. However, these counts of the actual number that may be pulling fish from the net are a minimum, because seals will also be feeding below the surface and will not be counted. Seals counted are likely to move between different trawlers working in an area, and therefore this number cannot be multiplied up by the number of trawlers to establish total numbers of seals feeding in an area.

Offshore Demersal Trawling

Seals were seen on the majority (>84%) of observed offshore demersal hauls and more frequently on the west coast. On both the west and south coasts, it was most common for observers to see ≤5 seals/haul, but on the west coast many more were also seen on occasion (Fig. 3). If the maximum number seen during a haul is considered, most observations were of 11–20 seals at a trawl on the west coast and fewer on the south coast. On 40% of the observed commercial trawls, other trawlers were visible and the seals seen by the observers were likely to move between these trawlers. The size of seals is difficult to estimate but only medium (40–100 kg; 88–220 pounds) and large (≥100 kg; ≥220 pounds) seals were reported. This was expected because young, small seals are less likely to feed far from the coast.

The following two points regarding offshore demersal trawling are noted, and both are postulated, based on our knowledge of seal distribution and behavior:

First, more seals attend offshore trawling operations on the west coast than on the south coast. On the south coast, offshore trawlers are restricted from trawling in water <110 m (<360 feet), and this includes the Agulhas Bank which extends 180 n. mi. offshore in places. On the west coast trawling takes place closer inshore and it is therefore more accessible to the seals. The observations show a mean of 18 seals (with a maximum of 260) on the west coast and a mean of 3 (with a maximum of 10) on the south coast; this difference is significant (Kruskal-Wallis test statistic = 35.7, $P<0.001$). Shaughnessy

Table 2.—Observed number of seals around offshore and inshore demersal trawlers during different stages of a trawl. No counts were made from midwater trawlers. The minimum count in each case was zero.

	Number of seals observed	
Stage of trawling operation	Mean ± 1 S.E.	Max.
Offshore demersal		
West coast		
Commercial (*n* = 185)		
Trawling (Shooting to net at depth)	4 ± 0.74	90
Start hauling net	15 ± 2.28	240
Otterboards on vessel	16 ± 2.13	260
Codend surfaces	18 ± 2.06	260
Net aboard	18 ± 1.84	200
Mean: Hauling to net aboard	16 ± 1.99	260
Research (*n* = 102)		
Codend surfaces	2 ± 0.40	30
South coast		
Commercial (*n* = 37)		
Trawling (Shooting to net at depth)	0 ± 0	1
Start hauling net	1 ± 0.16	5
Otterboards on vessel	2 ± 0.33	10
Codend surfaces	3 ± 0.33	8
Net aboard	3 ± 0.33	9
Mean: Hauling to aboard	2 ± 0.33	10
Research (*n* = 30)		
Codend surfaces	1 ± 0.37	6
Inshore demersal		
Commercial (*n* = 65)		
Trawling (Shooting to net at depth)	2 ± 0.52	22
Start hauling net	2 ± 0.39	15
Otterboards on vessel	4 ± 0.52	22
Codend surfaces	7 ± 0.77	27
Net aboard	10 ± 1.16	30
Mean: Hauling to aboard	6 ± 0.90	30
Research (*n* = 72)		
Codend surfaces	2 ± 0.24	10

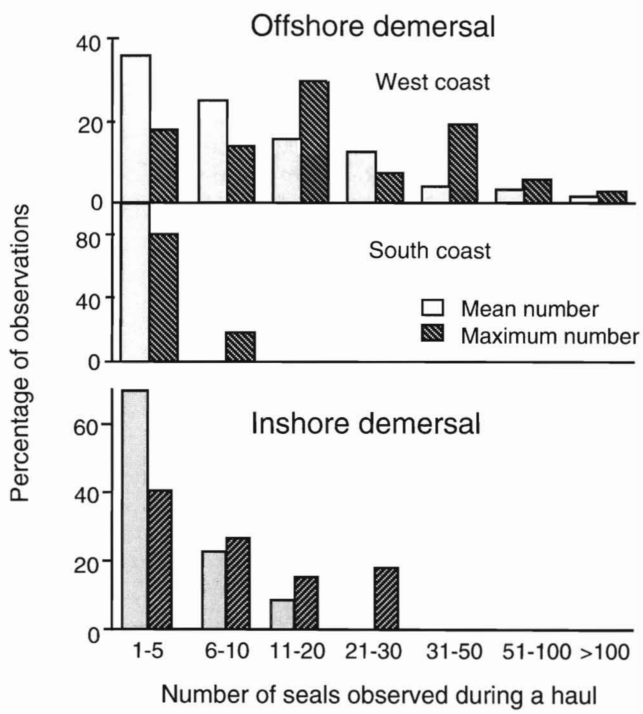

Figure 3.—Numbers of South African fur seals observed at offshore and inshore demersal trawling operations in South Africa.

and Payne (1979) recorded differences of a mean of 6 seals on the west coast and 4 on the south coast during commercial trawling. Data from research trawls indicate double the number of seals on the west coast (2 with a maximum of 30) compared to the south coast (1 with a maximum of 6). Other counts of seals from research trawls that have been documented are: on the west coast, 8 (Ryan and Moloney, 1988) and 10 (Shaughnessy and Payne, 1979); and, on the south coast, 3 seals (Shaughnessy and Payne, 1979). Fewer seals are seen at research trawls than commercial trawls. This is likely to be related to differences in trawl time, mesh size, and the fact that research trawls are made in random areas, often out of the commercial trawling grounds, with no regard for fish density, whereas commercial trawls seek to operate in areas with fish concentrations.

Second, many seals arrive only when the hauling starts. Indeed, seals may be attracted to the trawlers by the sound of the winch starting to haul the net. Current data confirm this, in that there is a significantly greater number of seals present from the time the net starts being hauled until it is aboard compared to when the vessel is trawling (Wilcoxon test statistic using ranks = 0.14 for the west coast and 4.92 for the south coast, P<0.001). On the west coast, there was a fourfold difference between these stages of the operation (from 4 to 16 seals), and on the south coast, numbers changed from no seals to an average of 2 seals.

Inshore Demersal Trawling

Seals were seen on the majority (95%) of inshore demersal hauls observed, and in two-thirds of the observed hauls the mean number seen was no more than five (Fig. 3). In terms of the maximum number of seals recorded during any haul, on over one-third of the hauls there were 1-5 seals, and on just more than one-fifth of the hauls there were 21–30 seals per haul. As during offshore trawling, seals are likely to move between trawlers working in an area, and an average of six trawlers were visible at every haul. Estimates of the size of seals indicated that mostly medium (40–100 kg; 88–220 pounds) and large (≥100 kg; ≥ 220 pounds) seals were reported, although a few small (<40 kg; 88 pounds) seals were also seen. It is probable that the presence of small seals results from the proximity of trawlers to the coast, where younger seals are found.

As with offshore trawling, significantly more seals accompany the inshore trawlers from the time the net starts being hauled than when the vessel is trawling (Wilcoxon test statistic = 5.29, P<0.001). The mean number seen before the net is hauled is 2 seals (with a maximum recorded of 22), whereas the mean number seen when the codend surfaces is 9 (with a maximum of 27 seals). By comparison, on research trawls the mean was 2 seals with a maximum of 10 when the codend surfaced.

Feeding

Seals were seen taking fish sticking through the net and scavenging moribund fish that floated free of the net (Fig. 4). Damaged fish are separated on board, but it is not possible to determine how much of the damage was attributable solely to seals. Damage to fish, and in particular to offshore trawled fish, also results from constriction of the net and the pressure of the fish mass, particularly during hauling.

The duration of each stage of a trawl was recorded during all commercial trawls (Table 3). The time from the net surfacing to its being hauled aboard is the minimum period during which seals may feed from the net. Seals may feed from the net while it is being brought to the surface, and they also feed on floating fish or discarded fish once the net has been hauled.

Offshore Demersal Trawling

In offshore side trawling, the net, or part of it, lies on the surface longer at the end of a haul than in offshore stern trawling. In offshore trawling this period averages 18 minutes for side trawls and 5 minutes for stern trawls. Commercial trawling effort is measured in hours (from the net reaching depth to start of hauling), and in 1992 a total of 92,602 hours was spent offshore trawling during 42,374 hauls. This results in an average trawl time of 2.2 hours. The time of 2.1 hours observed from the net depth to the start of hauling, as recorded from observations (Table 3), therefore indicates that the observed trawls were probably typical of offshore trawling. While seals may eat large quantities of fish near the net (one seal was observed eating 24 free-floating fish), fish damage attributable to seals in offshore-trawled catches is considered negligible.

Inshore Demersal Trawling

During inshore trawling, the average time period that seals have to feed on fish in the net when the codend lies on the sea surface is 8 minutes, although a maximum of 25 minutes was also recorded. This commercial trawling effort is also measured in hours (from the net reaching depth to start of hauling) and a total of 77,425 hours was spent inshore trawling in 1992 during 21,575 hauls. This produced an average trawl time of 3.6 hours. The time of 3.5 hours from the net at depth to the start of hauling as recorded from observations therefore indicates that the observed trawls were probably typical of inshore trawls.

Records of damaged fish made at the factories show that a greater proportion of kingklip is damaged than sole (Fig. 5). This is most likely to be at least partially attributable to the fact that sole can be pulled through the net easily and in this way can be removed whole (and therefore are not recorded in the catch), whereas seals can only bite those parts of kingklip that protrude through the net.

Spoilage of sole and kingklip by seals is not significantly correlated to monthly sole and kingklip landings, respectively (r[sole] = 0.359, r[kingklip] = 0.445, n=12, P > 0.05) so the extent of spoilage is likely to be related to both the time that the codend stays on the surface and the number of seals attending each haul. In both cases the fish are trimmed to remove the damaged portion, and this results in some financial loss.

Damage to sole averaged 0.7%, varying between 0.3 and 1.3% of the landings per month with the lowest losses recorded during June, but the reason for the fluctuations are not clear. Sole are

Figure 4.— South African fur seals feeding at an offshore demersal trawl net. Many seals may feed from the net, particularly on the west coast of South Africa (top; photo by P. Bibb), however fewer are frequently seen (bottom; photo by J. Enticott).

Table 3.—Observed duration in minutes of different stages of offshore and inshore demersal trawls. The difference in the time taken between the codend reaching the surface and the net being aboard is given separately for stern and side offshore trawlers.

Stage of trawling operation	Duration (minutes) Mean ± 1 S.E.	Min.	Max.
Offshore demersal (*n* = 222)			
Shooting net –> net at depth	21 ± 0.47	3	60
Net at depth –> start hauling net	123 ± 2.62	37	305
Start hauling net –> doors on vessel	14 ± 0.47	5	70
Otterboards on vessel –> codend surfaces	5 ± 0.20	1	34
Cod end on surface –> net aboard (stern, *n* = 192)	5 ± 0.22	1	15
Cod end on surface –> net aboard (side, *n* = 30)	18 ± 1.28	10	43
Total : Start hauling to net aboard	25 ± 0.74	2	85
Total · Duration of trawl	171 ± 2.89	74	372
Inshore demersal (*n* = 65)			
Shooting net –> net at depth	9 ± 0.39	1	15
Net at depth –> start hauling net	210 ± 7.62	110	335
Start hauling net –> doors on vessel	10 ± 0.39	5	15
Otterboards on vessel –> codend surfaces	6 ± 0.26	3	15
Cod end on surface –> net aboard	8 ± 0.65	4	25
Total : Start hauling to net aboard	23 ± 0.90	15	45
Total : Duration of trawl	242 ± 7.36	140	359

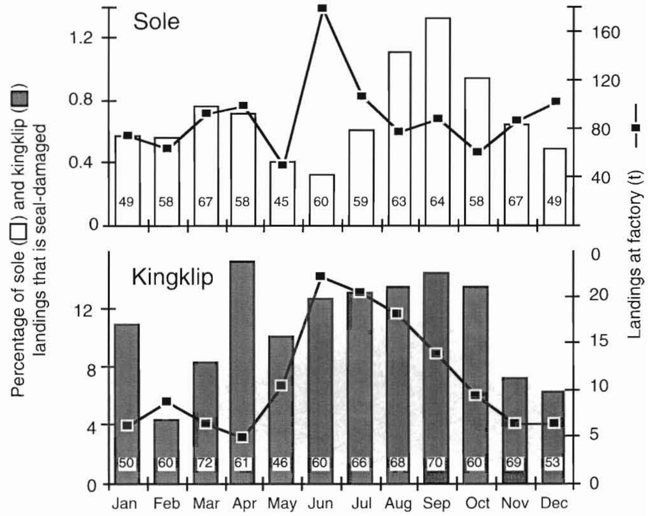

Figure 5.—Monthly inshore demersal trawl landings and the quantities of sole and kingklip that are seal–damaged, as recorded from two factories in Mossel Bay during this study. The numbers indicate the number of landings examined.

most commonly marketed with the head on, so seal-damaged fish which may be missing a portion of the body and head (Fig. 6a) are sold for a lower price per unit mass. The reduction in price of a damaged fish depends on the initial size of the fish, because prices per fish are size-dependent. On average, sole were considered to be reduced in price by 50%, although the vessels sometimes kept the seal-damaged sole to sell elsewhere at a higher price. At least 5.6 t (0.7%) from the 1992 landings (797 t) were estimated to be seal-damaged, although this is an underestimate because whole sole may be pulled from the net by seals and not recorded at the factory amongst the damaged fish. The landed price of sole in 1992 was R8.24 (US$2.22)/kg. If this damaged mass were sold at half price then the loss would be R23,072 (US$6,229).

Kingklip damage varied between 4.4 and 15.3% of the landings and was noticeably lower in February and November/December, but the reasons for this are not known. Kingklip is marketed in various forms so seal-damaged fish (Fig. 6b) is only regarded as a loss of mass, not a loss in the price per unit mass. For kingklip it is assumed that a third of the mass of each damaged fish is lost as a result of the seal bite and trimming. On average, 11.7% of the catch was damaged by seals which is a loss of 3.9% of the mass prior to landing. Although the 1992 landings were 200 t, the potential landing, if no seal damage had occurred, could have been 208.1 t, providing an estimate of damaged kingklip at 8.1 t. At the 1992 landed price of R5.76(US$1.56)/kg, some R46,656 (US$12,597) would be lost because of seals.

Overall the loss through seal depredation of sole and kingklip is calculated as R69,728 (US$18,827). This does not include fish that are pulled through the net mesh by seals and lost (particularly in the case of sole which can be pulled from the net whole), damage to other species, or damaged fish that are not landed. It can therefore be regarded as a minimum.

Midwater Trawling

Midwater trawls may last from about 10 minutes to a few hours, depending on depth and visibility of the fish; they averaged 2.6 hours during the observations in this study. The smaller mesh of the midwater trawl net means that less of the entrapped fish protrude, and they are therefore not easily accessible to seals. The larger catches made by midwater trawlers mean that proportionally less of the catch is available to the seals. Spoilage of fish is therefore considered to be negligible.

Equipment Damage

Net damage by seals is not generally considered to be a problem during any form of trawling. Observers did note, as a matter of course, the damage to fishing gear resulting from various causes, but only on an offshore trawler was minor net damage caused by a seal when it attempted to free itself from the net (0.5% of offshore trawls). Both offshore and inshore demersal nets were occasionally torn during observations, either from dragging on the bottom or from rocks that were brought up. The size of the tears varied, as did the time taken to repair them.

The propellers of some offshore demersal trawlers are mounted in Kort nozzles which increases suction. Seals feeding beside such vessels can be sucked into the nozzle and damage the propeller by bending or breaking off a part, and this may be costly. A trawler with a damaged propeller increases fuel consumption of the vessel, requires inspection by a diver, and may require repair or replacement. At least one-third of the vessels owned by the two major trawling companies are fitted with Kort

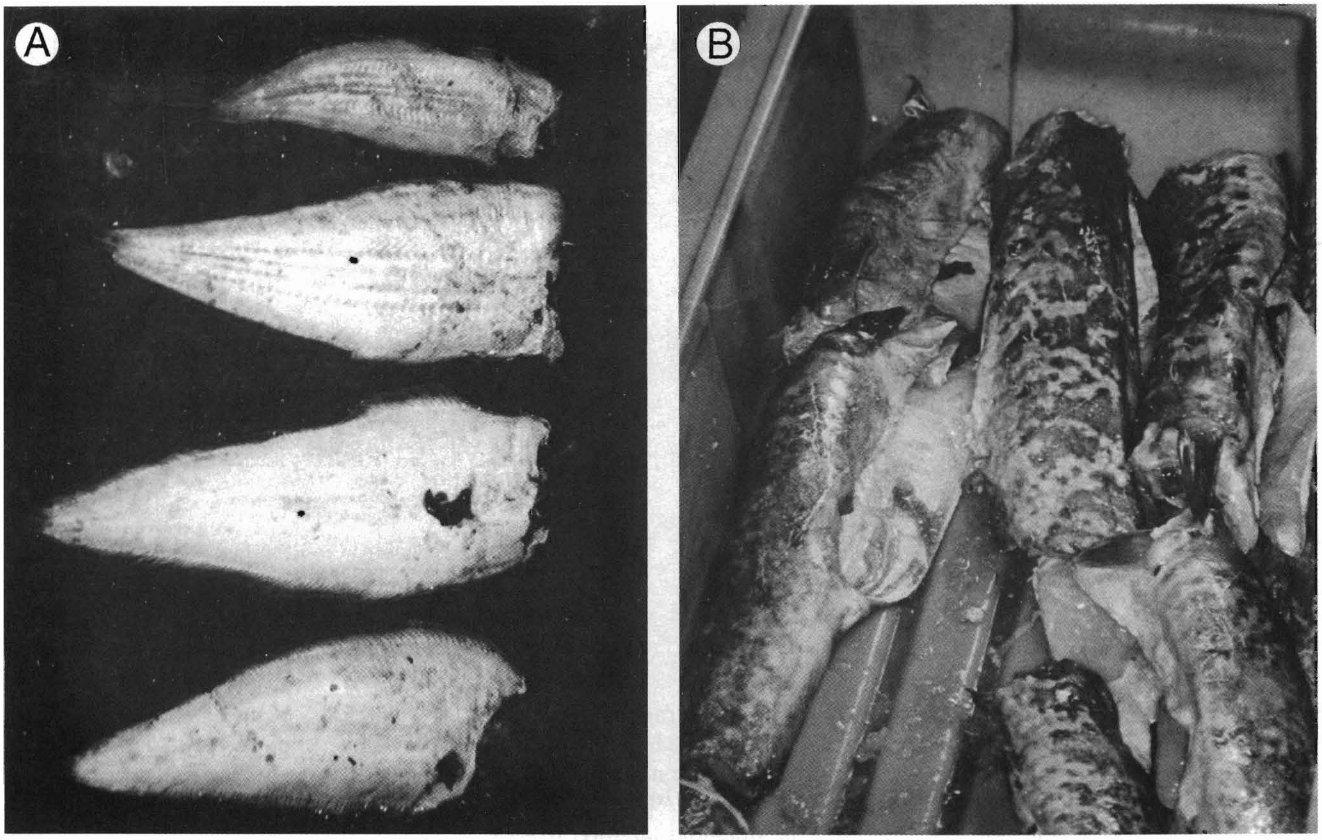

Figure 6.—Seal-damaged sole (a) and kingklip (b) from the inshore demersal fishery. Photo a by P. Sims and Photo b by L. Taylor.

nozzles, but few complaints of seals have been made by skippers. We suggest that problems may be related to the specific design of the vessel or to the position of the offal outlet at which seals may feed.

Two I & J trawlers, in particular, have reported such problems, and in 1991 both had the factory deck layout redesigned to move the outlet for discarded fish away from the propeller. In each case, the cost was about one million Rand (about US$250,000). However, the problem was not resolved and observers present during three trips on these vessels heard a thud and the engine straining as a seal passed through or became stuck in the nozzle. On some occasions there was blood in the water and injured seals surfaced. On one trip, the auxiliary power had to be brought in to complete the trawl and the main engine was then reversed to release a dead seal.

In late 1992, one of the I & J vessels which had problems with seals was fitted with a "crusher" to experiment with finely mincing the discarded fish so that it is less attractive for seals. In this way it is hoped that seals will not feed near the offal outlet and therefore will be less likely to be sucked into the nozzle. From the trials carried out to date, the experiment has proven successful.

Live Seals Aboard

Fishing operations may be disrupted if live seals are brought aboard in the net. Generally, returning live seals to the sea is not a problem and, from observations, in most instances the seals left the vessel of their own accord or were chased out by the crew. Most seals brought aboard do not go below deck, but when this happens it can be a problem. Nevertheless, injuries resulting from seals aboard trawlers are not common.

Offshore Demersal Trawling

During the 185 offshore demersal trawls observed on the west coast, there were 11 incidents (5.9% of hauls) in which live seals were brought aboard. In eight of these, one seal was involved, and in the remaining three there were two seals. These incidents involved a total of 14 seals, averaging 7.6 seals per 100 hauls. In two of the incidents a seal managed to get below deck (1.1% of hauls). In one case, fish boxes were placed strategically to provide the seal with an escape route and it climbed out and left the vessel after about 90 minutes (Fig. 7). In the other case, the seal became trapped in the factory area, and it was clubbed to death after removal attempts failed.

On the 37 observed south coast hauls there was one incident (2.7% of hauls average) of a single seal coming up in the net. The time taken for the seals on deck to leave the vessel generally varied from almost immediately to 45 minutes. An exceptional case was of a seal which was thought to be injured taking over 5 hours to leave, having been brought aboard during the last haul of the

Figure 7.—A seal caught in the hold of an offshore demersal trawler. In this case the crew placed fish boxes in the hold and the seal climbed out and left the vessel via the stern. Photo by J. Enticott.

day. No live seals were brought aboard during the 131 research trawls observed.

Based on the number of commercial trawls on the west coast (31,178) and the south coast (11,196) during 1992 and the observed percentage of times live seals were brought aboard in each area, a total of 2,672 seals are estimated to come aboard in a year (6.3 seals per 100 hauls). This is about 46/vessel annually. In comparison, Shaughnessy and Payne (1979) reported a seal brought aboard in 3.3% of trawls, i.e. 1,398 live seals brought aboard during the number of trawls made in 1992.

Inshore Demersal Trawling

Although no live seals were taken aboard during any of the inshore demersal trawls observed (commercial and research), they are known to get aboard but never to the areas below deck. Therefore they are hardly ever a problem to return to the sea.

Midwater Trawling

The mouth of a midwater trawl is wider than that of a demersal trawl, and consequently more seals are likely to be caught in the net than in other trawl nets. During the 16 midwater hauls observed by a skipper, there were a total of 20 live seals aboard in 10 of the hauls. This amounts to an occurrence of live seals on 63% of hauls or 693 incidences per year. This averaged 1.25 seals per midwater haul or 1,034 seals per year with a maximum of 4 seals in any one haul. Of these seals, 2 (10%) were killed because they entered the area below deck, making it difficult to remove them.

Incidental Seal Mortality or Injury

Incidental killing includes seals becoming caught in Kort nozzles and killed by the propeller as well as seals drowning in nets.

Offshore Demersal Trawling

On one observation trip on offshore trawlers, at least eight seals may have been killed by the propeller, as identified by blood in the water and the straining of the engines as the seals were entrapped.

During offshore demersal trawling, seals drowned in the nets on the west coast only. In total, 3 drowned in 185 hauls, or 1.6 seals per 100 hauls. In each case it was a single seal per haul, two of the seals being female and one male, ranging in size from 1.4 to 1.7 m. The three drownings took place on clear days and were in different areas; the carcasses were dumped overboard. In New Zealand, seals drown predominantly during night trawling (Anonymous, 1990).

Based on the annual number of offshore demersal hauls in each area, the total number of drownings would be 498 per year, possibly in the ratio of 332 females to 166 males, an overall average of 1.2 seals per 100 hauls. By comparison, one seal of unknown sex was drowned during research trawls on the west coast, i.e., 0.8 seals per 100 hauls. Shaughnessy and Payne (1979) indicate a greater drowning frequency than observed during this study, namely 3.8 seals per 100 hauls (no sex differentiation is given), which totals 1,610 seals drowning per year based on the number of trawls during 1992.

Inshore Demersal Trawling

The only form of seal mortality observed on inshore demersal trawlers was through incidental drowning. While live seals brought aboard may be killed deliberately if considered a risk to the crew, there are no data on this. During observations, there were three incidents in which seals were drowned in nets, an average of 4.6 seals per 100 hauls. All were male and ranged in size between 1.2 and 1.4 m, and all three were caught during the day. The annual incidence of drownings, estimated from the total number of commercial hauls, was 992 seals, possibly all male.

Midwater Trawling

The wider opening of the midwater trawl net, as opposed to a bottom trawl net, allows more seals to be caught. The slower retrieval, lower buoyancy, and tendency to trawl until the net reaches the vessel mean that more seals drown than during bottom trawls. It is possible that, as a result of midwater trawls being done at night, more seals may be caught, as occurs in New Zealand (Anonymous, 1990).

During the trip on which the skipper recorded seal occurrences in 16 midwater hauls, there were a total of 15 drowned seals on 10 (63%) of the hauls, an average of 94 seals per 100 hauls. One or two seals were drowned during each of these 10 hauls.

During a limited set of previous observations, in all, 16 dead seals were observed in 4 commercial midwater trawls, averaging 4 per trawl (Wickens et al., 1992). On the *F.R.S. Africana*, large numbers of seals have been caught in pelagic research trawls at night, and on at least two occasions there have been incidents west of Cape Agulhas in which many seals were caught. On one day, in an 11-minute drag, 28 seals were drowned in the net. On another day, during a 20-minute drag, between 25 and 30 seals were caught, most of which were still alive. Those numbers of seals seen caught are, however, uncommon in pelagic research trawls.

Based on the number of drownings observed (0.94/trawl, for the skipper data, or from a select number of commercial hauls, 4/trawl), a probable number of 1,034 drowned seals, or a maximum estimate of 4,400 drownings per year, is likely. Midwater trawling is a relatively new fishing method, but mortality could increase if the midwater trawl fishery increased and if it expanded up the west coast where seals are more abundant.

Deliberate Seal Mortality or Injury

Deliberate killing may take place if live seals are brought on deck, cannot be removed, and are potentially harmful to the crew.

Offshore Demersal Trawling

On one occasion a male seal (which was trapped below deck) was deliberately killed by the crew because it may have injured a crew member. This occurred on the west coast and amounts to a seal being killed in 0.5% of west coast hauls, an average of one seal killed in 0.4% of all hauls. Based on the total number of offshore hauls in 1992 this is equivalent to 169 seals per year. Shaughnessy and Payne (1979) report a single deliberate killing per 100 offshore trawls (no sex given) or 424 per year based on the current number of hauls in 1992.

Inshore Demersal Trawling

No live seals were brought aboard during the 65 observed trawls. However, it may occur and the seals may then be killed.

Midwater Trawling

Based on the observations made by the skipper during 16 hauls, 2 seals went below deck and were killed by the crew. The sex of the seals was not recorded. This amounts to an occurrence of 10% of live seals aboard being killed, or 13 seals per 100 midwater hauls. Based on the 1992 number of midwater trawls, this would amount to 143 seals/year.

Summary of Interactions

The extent of the interactions between seals and the three trawl fisheries in South Africa differ (Table 4). In the offshore demersal trawl fishery, seals appear to cause few problems technically or financially. Some two-thirds of the offshore demersal catch is made on the west coast of South Africa where most of the seals are found. The average number of seals attending offshore trawling operations in this area is 18, but the average is even lower on the south coast. Propeller damage, which has in the past been costly, occurs on only a few vessels, and ways to allevi-

Table 4.—Summary of interactions that occur between seals and offshore and inshore bottom trawling and midwater trawling activities with estimates of cost to the fishery and seal mortality.

Item	Demersal trawling		Midwater trawling
	Offshore	Inshore	
Seal attendance around vessel			
Frequency	>84% of hauls	95% of hauls	
Mean	<18	<10	
Maximum	260	30	
Effect on fishery			
Fish spoilage	Negligible	>R69,728	Negligible [1]
Net damage (tears)			
Frequency	0.5% of hauls	0	0[1]
Type	Small tears		
Annual cost	Negligible	Negligible[2]	Negligible[1,2]
Propeller damage	?[3]	0	0
Live seals aboard			
Frequency	6.3 (3.3[4]) seals/100 hauls	0[5]	1.25 seals/100 hauls
Annual total	2,672 (1,398[4]) seals/yr	0[5]	1,034 seals/yr
Annual cost attributable to seals	Negligible[3]	>R69,728 (US$18,827)	Negligible[1,2]
Landed value of fishery (1992)	R182,799,000 (US$49,356,000)	R20,930,000 (US$5,651,000)	R6,461,000 (US$1,744,000)
Percentage of landed value lost to seals (1992)	Negligible[3]	>0.3%	Negligible[1,2]
Effect on seals			
Incidental mortality			
Drowning			
Frequency	1.2 (3.8[4]) seals/100 hauls	4.6 seals/100 hauls	94 seals /100 hauls
Annual total	498 (1,610[4]) seals/yr	992 seals/yr	1,034 seals/yr
In propeller	?[3]	0	0
Deliberate mortality			
Potential risk to crew			
Frequency	0.5 (1.0[4]) % of hauls	0[5]	13 seals/100 hauls
Annual total	169 (424[4]) seals/yr	?[5]	143 seals/yr
Annual seal mortality	667 (2,034[4]) + ? [3]	992 + ?[5]	1,177
Percentage mortality from feeding population of 650,000 seals[6]	0.1 (0.3[4]) + ?[3]	0.2 + ?[5]	0.2

[1] By inference from a comparison of the information regarding offshore demersal trawling and differences between demersal and midwater trawling.

[2] No net damage was observed, but the cost is likely to be negligible, if it does occur.

[3] The incidence of seals going through the Kort nozzle, damaging the propeller, and being killed occurs only on some offshore demersal vessels and this may have been resolved. The problem is therefore excluded from the calculation of cost to this fishery.

[4] Figure calculated from Shaughnessy and Payne (1979).

[5] No live seals aboard were observed during the limited number of observations, but live seals are likely to come aboard and may be killed if considered a potential risk to the crew.

[6] There are insufficient data on the age and sex of seals that attend trawling operations or die as a result of their encounter. Pups are unlikely to be on the trawling grounds so the maximum number of seals that may be encountered is the South African proportion (Wickens et al., 1991) of the feeding population (Anonymous, 1991). From all three types of trawling, the total mortality is calculated as 2,836–4,203 seals per year. Overall this amounts to 0.4–0.6% of the feeding population annually.

ate or eliminate the problem are being investigated by the company concerned. Incidental and, on occasion, deliberate mortality of seals, is probably in the order of at most a few thousand seals per year. Of the three seals that drowned during observations, two were female but during inshore trawling the drowned animals were all male. The observations therefore do not show that there is necessarily any bias by sex. It is unlikely that the number of seals dying as a result of offshore trawling operations will have a noticeable negative impact on the total population.

In the inshore trawl fishery, damage to fish is generally considered to be the only problem attributable to seals, and it probably occurs during most hauls to at least some degree. Inshore trawling takes place only on the south coast and seals are generally present during operations in numbers <10. The cost of the damage is believed as small in comparison to the landed value of the fishery. Because the Agulhas sole market requires the fish in gutted (but head-on) form, seal damage can reduce the price per unit mass. With kingklip, there is a loss of landed mass as a result of the trimming of fish to remove seal damage. Incidental seal mortality by drowning is not uncommon during inshore trawling and, though not witnessed, live seals aboard may be killed if the crew is believed to be at risk. The total annual mortality of seals during inshore trawling is probably in the region of a thousand seals per year; again, this is not considered important in terms of the size of the seal population.

During midwater trawling, seals can probably be considered little problem and, if anything, less of a problem than during offshore demersal trawling. Fish in the net are less accessible than on demersal trawls, so seal predation on fish in the net is negligible. Based on the limited number of observations, the number of seals, both alive and drowned, that come aboard in the net can be considered notable per trawl, and live seals aboard that are a potential risk to the crew are deliberately killed. However, given the small number of midwater trawls that take place during a year, the overall number dying as a result of inshore trawling is approximately a thousand per year, considered a negligible loss in terms of the feeding population size.

No particular form of deterrent is considered necessary at this stage to prevent interaction of seals with offshore demersal and midwater trawlers. In order to minimize damage to the catch on inshore trawlers, crews usually try to retrieve the net as quickly as possible. Brightly colored strips of plastic or canvas are sometimes also used to deter the seals, but these have not been very effective. Trials with a device to eliminate the problem with seals and Kort nozzles on offshore trawlers, discussed earlier, are underway.

Facilitation of removal of live seals from trawlers is possibly the only action currently required. Various methods, such as those suggested for the New Zealand trawl fishery, could be tried. These include use of choker poles, deck and fire hoses, and the use of nets (Anonymous, 1990).

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