THE EFFECT OF OIL POLLUTION FROM THE TANKER "WAFRA" ON THE MARINE FAUNA OF THE CAPE AGULHAS AREA

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Much was learnt of the effect of oil pollution and the dangers of surfactants from the *Torrey Canyon* disaster off the Cornish coast in 1967 and a useful introduction to the problem of oil pollution will be found in Carthy and Arthur (1968). Since that date, the chemical composition of surfactants has been improved and there are now better methods of applying them. It is well known that hydrological conditions around South African coasts are different from those in the English Channel and that the marine fauna and flora is quite distinct. No scientific account of the biological effects of oil pollution in South Africa has been published and it is hoped that the following observations of the effects of oil spillage on the Cape Agulhas coast will indicate what may be expected when future oil spillages occur. Considering the volume of oil traffic around the Cape of Storms such an event seems inevitable.

THE WRECK OF THE "WAFRA"

The 68 000 ton tanker *Wafra* was owned by Getty Tankers and registered in Liberia. In February, 1971, she was carrying a cargo of about 63 174 tons of crude oil from the Persian Gulf for delivery to Messrs. Caltex Limited in Cape Town. On 27th February she was rounding Cape Agulhas and at 5.40 a.m. the expansion joint on the main sea water cooling system fractured and the engine room started flooding. An S.O.S. was sent out at 6.30 a.m. and the tug *F.T. Bates* at Cape Town was ordered to her assistance. Unfortunately, the tug was held up for more than four hours by formalities. Meanwhile, the *Wafra* was taken in tow first by the S.S. *Gydnia* and later by S.S. *Pongola* but the tow lines parted at 5 p.m. The *Wafra* was anchored in 21m eight km east of Cape Agulhas in a force 7 W.S.W. wind with rain and heavy seas. At 7.30 p.m. she came aground on a reef at 34°.50.5S/20°.07.7E. Three of her oil tanks were punctured and the oil spillage started. Oil reached the beaches between Cape Agulhas and Struisbaai on February 28th. In spite of many efforts to free the tanker, she remained fast on the reef spilling oil until 3 p.m. on 8th March, when she was pulled off by the German salvage tug *Oceanic*. She was then towed 164 miles south to 37°.30′S/20°.10′E. On 10th March, she was struck by seven missiles from Buccaneer aircraft which set her on fire and after nine depth charges had been dropped around her she finally sank on 11th March at 36°.57′S/20°.42′E in 1 830 m of water.

THE QUANTITY OF OIL SPILT AND THE AREA AFFECTED

During the ten days the *Wafra* was fast on the reef, her agents estimate that she lost 15 000 tons of crude oil. More was lost while she was being towed to the south and Stander (1971)

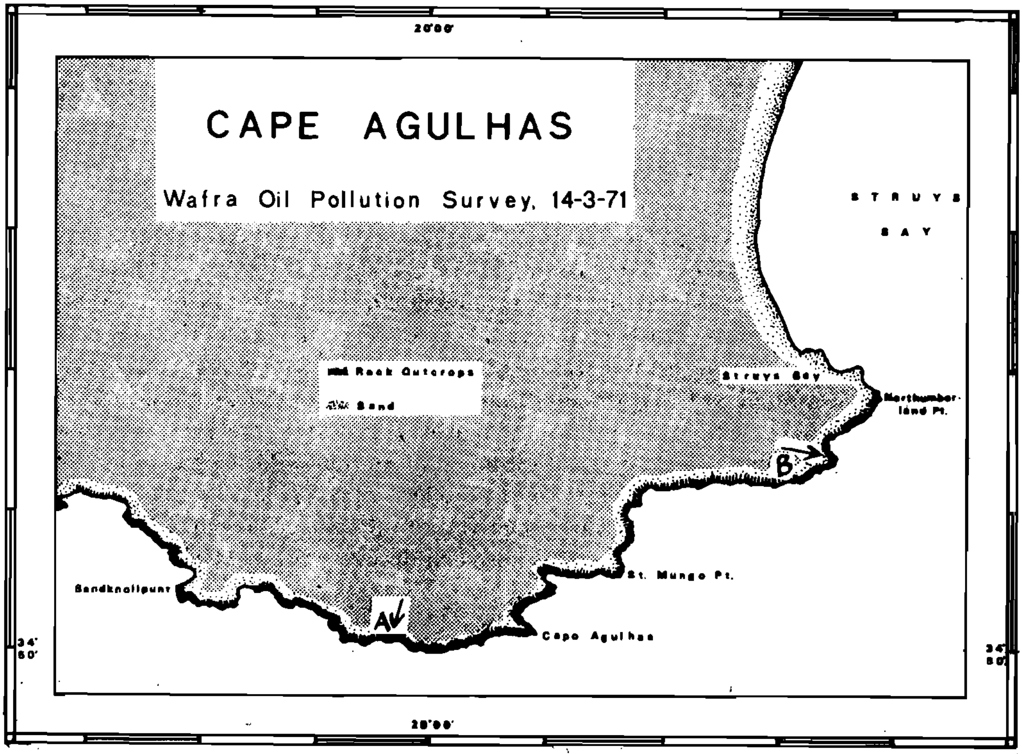

FIGURE 1

Map of the Cape Agulhas area. Point A indicates the position of the shore transect shown in Figure 2 and Point B indicates the heavily oiled cove where most of the observations were made.

states that she lost a total of 26 000 tons of crude oil. On 1st March, observers estimated that a patch of oil 50 km² in extent was moving towards Cape Agulhas. By 4th March, about 15 km of coast from Struisbaai in the north east to 5 km west of Sandknollpunt had been polluted and a light oil slick 32 km long and up to 5 km wide was seen moving westwards towards Danger Point but well offshore. Small patches of oil actually entered Walker Bay and came ashore at Gansbaai but these were easily mopped up by bales of straw and no trace of oil remained there on 8th March. No oil reached the mouth of the Klein Rivier Lagoon near Hermanus which was guarded by a hastily built sand barrier faced with bales of hay. No oil came ashore to the east of Struisbaai and fishermen stated that the oil did not reach the rich fishing banks 9 km offshore.

COUNTERMEASURES

Over 670 000 litres of "detergents" or surfactants were sprayed on and around the grounded tanker between 1st March and 8th March. Among the chemicals used were "Correxit", "Chem. Serv." and "B.P. 1002". The work was directed by the Division of Sea Fisheries and details are given by Stander (1971). No "detergents" were used on the shore but thousands of bales of hay were scattered on the polluted shores or dropped in the oil slicks.

THE ECOLOGY OF ROCKY SHORES IN THE CAPE AGULHAS AREA

The coast around Cape Agulhas (Fig. 1) is very flat and the shore is mainly rocky although there is usually sand above the high tide mark and at intervals there are small sandy coves. North-east of Struisbaai there is a 20 km stretch of unbroken sandy beach. The rock around Cape Agulhas is Table Mountain sandstone sloping down gently to seaward so as to form long low reefs which run out 100 to 150m into the sea. Loose boulders up to a metre in diameter are abundant and in some places these have been arranged to form primitive fish traps.

To estimate the damage caused by pollution, it is essential to know the normal ecology of an area. Fortunately the senior author (J.H.D.) had made a marine biological survey of Cape Agulhas, Arniston and Danger Point under the direction of the late Professor T. A. Stephenson in 1939. The dominant marine plants and animals at Cape Agulhas have been catalogued and their relative abundance and vertical distribution between tide marks has been recorded. A general description of the south coast biota with a list of the dominant species will be found in Stephenson (1944). A brief summary of the dominants at Cape Agulhas is given below in the same sequence as they occur on the shore.

From the spray zone in the supratidal fringe down to about HWN, the rocky shore is dominated by the small periwinkle *Littorina knysnaensis* and in the lower parts of the Littorina zone the alga *Porphyra capensis* and the winkle *Oxystele variegata* are both common on the surface of the rock while the shore crab *Cyclograpsus punctatus* hides itself under loose stones. Below the Littorina zone, the Upper Balanoid Zone extends down to about mean sea-level. The dominant animals are barnacles (*Chthamalus dentatus* and *Tetraclita serrata*), limpets (*Patella granularis*, *Siphonaria aspera* and *Helcion pectunculus*) and winkles—*Oxystele variegata* mainly on dry rocks and *Oxystele tigrina* confined to pools. The serpulid worm *Pomatoleios kraussii* builds coral-like masses of tubes among the boulders.

The Lower Balanoid Zone extends from MSL down to about LWN. It is easily distinguished from the Upper Balanoid by the greater abundance of algae. *Gelidium pristoides* and *Splachnidium rugosum* grow as tufts on dry rocks, *Ralfsia expansa* prefers moister situations and is often found as an incrustation in pools and runnels and *Sargassum* (?) *heterophyllum* is common there too. Barnacles are abundant, with *Tetraclita serrata* mainly on protected slopes and *Octomeris angulosa* preferring wave-washed ledges. There are of course many other animals as well: the limpets *Patella oculus* and *Patella longicosta*, the winkle *Oxystele sinensis* and the sandy-reef worm *Gunnarea capensis* are all common.

From about LWN to LWS and below, the rocks and even living shells are almost all encrusted with coralline algae of the "lithothamnia" group and feeding on this is the limpet *Patella cochlear* which is so abundant as to form a cochlear zone at low tide. Both *P. longicosta* and *O. sinensis* extend down from the Lower Balanoid Zone, while scattered clumps of mussels (*Perna perna*) and sea-urchins (*Parechinus angulosus*) are common in pools and crevices. It is not possible here to name all the other common species but from the point of view of oil pollution, it must be mentioned that the large grapsid crab *Plagusia chabrus* and its predator *Octopus granulatus* occur in pools at this level and below. A wide variety of seaweeds also

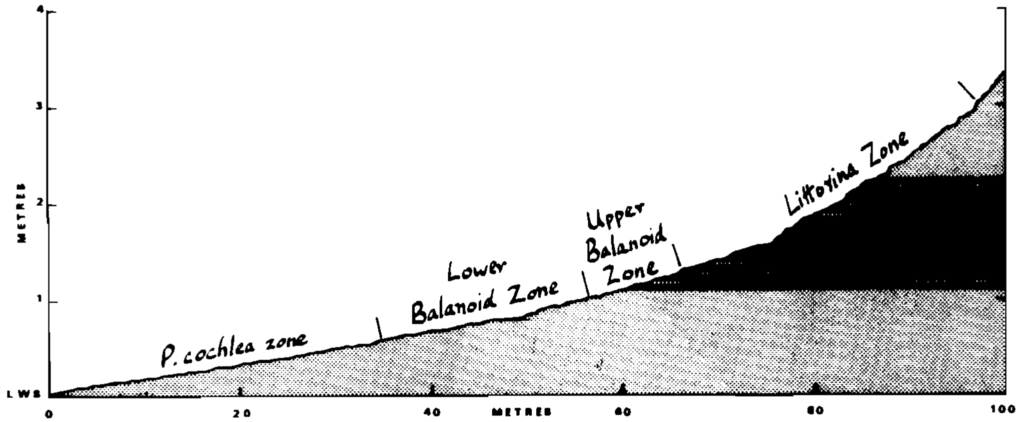

FIGURE 2
Transect of the rocky shore 3 km west of Cape Agulhas. Horizontal bars indicate heavy deposits of oil.

grow in the Cochlear Zone and among the most obvious are *Hypnea spicifera*, *Plocamium corallorhiza* and several species of jointed corallines; the latter become even more numerous below low tide.

Below the Cochlear Zone, the upper edge of the Infratidal Fringe is exposed between waves. As mentioned, corallines cover the rocks. On unapproachable offshore rocks, the commonest animal is the large ascidian *Pyura stolonifera* commonly known as "red bait". Fishermen cut it away from all accessible ledges. There are also numbers of large turban shells (*Turbo sarmaticus*) commonly known as "alikreukels" and smaller numbers of limpets (*Patella tabularis*), abalone (*Haliotis midae*) and rock lobsters (*Jasus lalandii*). Both abalone and rock lobsters are much more common to the west of Cape Agulhas than they are near Struisbaai.

THE EFFECT OF OIL POLLUTION ON THE ROCKY SHORES

Notes on the extent and effects of oil pollution were made on two occasions by parties of six to eight marine biologists and additional evidence was obtained from local fishermen particularly by Mr. Ian Gericke of the Atlantic Underwater Club, who is a property owner at Struisbaai. The first visit was made during the spring tides of 14th March which was 16 days after the oil spillage had started. The second visit was made during the spring tides of 11th April, 36 days after the grounding of the *Wafra*. The object of the first visit was to determine the extent and severity of the oil pollution and what damage it had caused. On that occasion, it was noted that while many animals had already died, others appeared weak but were still alive. The object of the second visit one month later was to determine whether these had in fact died or had recovered. In some cases, it was possible to ascertain the amount of growth or replacement that had occurred between the first visit and the second. For these reasons, the results of the two visits will be described together.

The inspection on 14th March showed that 15 km of shore from Struisbaai in the north east to 9 km west of Cape Agulhas was heavily polluted. On the surveyed transect 3 km west of Cape Agulhas shown in Fig. 2, and Plate 1a, thick tarry water-in-oil emulsion or "chocolate mousse" covered the rocks for a vertical height of one metre from mean sea-level to HWS. Streaks and splashes extended above HWS and decreased again below MSL. Since the intertidal reefs along most of the shore were even flatter than on the surveyed transect, the horizontal distance covered by the oil often extended over 50 m seaward of the high tide mark. Vertical rock faces were more thickly oiled than horizontal ones and rocks permanently submerged in pools were mainly clean. Below mid-tide the gullies were usually covered with an oily froth and fragments of straw which moved to and fro in the waves and the water was turbid. Divers reported no sign of oil below low tide. The most heavily polluted part of the coast was a cove just south-west of Northumberland Point (see point B in Fig. 1) and it was obvious that wave-washed reefs were less affected than sheltered rocks and quiet rock pools were more heavily oiled than open gullies.

The effect of oil and/or surfactants on individual animals and plants is described below in the same sequence as they occur on the shore.

Littorina knysnaensis. Periwinkles living in the lower part of the Littorina zone and in the Upper Balanoid zone where the chocolate mousse was most evident were jeavily oiled and many were dead. Those living on clean rocks higher up in the spray zone were not affected and those living in rock pools were healthy.

Oxystele variegata was conspicuous by its absence from oiled rocks but a number were found alive in rock pools.

Cyclograpsus punctatus. Only a few of these common shore crabs were found alive.

Porphyra capensis. Did not show any obvious effect on the first visit and a little new growth was evident on the second visit.

Helcion pectunculus, *Patella granularis* and *Siphonaria aspera*. Most of these common limpets were alive although many of the shells were blackened with oil.

Chthamalus dentatus and *Tetraclita serrata*. As shown in Plate 2 these barnacles were often covered with oil but gentle prodding of the opercular valves caused contraction on both visits showing they were still alive.

Oxystele tigrina living in pools showed no obvious effect.

Pomatoleios kraussii. The masses of twisted tubes growing on the faces of rocks where they dried in the sun were usually black with oil while those in moist crevices were not. On the first visit, it was not possible to determine how many of the worms were dead but on the second visit, 26 days later, it was noted that there was new growth on about half the blackened tubes so that the mortality is estimated as 50% in the worst oiled aggregates. The new clean shell growing from the edge of the oil-blackened tube was very obvious and permitted an estimate of the rate of growth which appears to be 2–3 mm per month.

Gelidium pristoides. Tufts of this alga showed no visible sign of injury on the first visit and some new growth was seen on the second visit.

Splachnidium rugosum. Tufts of this alga appeared shrivelled on the first visit and no regeneration was seen on the second visit.

PLATE 1
Heavy oil pollution above mid-tide on a rocky shore 3 km west of Cape Agulhas.

PLATE 2
Barnacles (*Tetraclita serrata*) covered with oil but still alive. Note the matted tubes of *Pomatoleios* to the left and submerged *Patella oculus* on the right slope of the rock pool below.

Ralfsia expansa. This encrusting alga appeared to be unaffected at low levels but was damaged at higher levels.

Octomeris angulosa appeared to be unaffected.

Patella oculus living on oil-covered rocks could be removed more easily than usual on the first visit and were absent on the second visit.

Patella longicosta which feeds on patches of *Ralfsia expansa* seemed to be little affected. On the second visit, a few empty "homes" of large limpets were seen but most of these had been recolonised by small individuals which had moved in from more densely populated areas.

Oxystele sinensis was severely affected and many dead shells were washed up on the drift line.

Gunnarea capensis. Aggregated tubes of this worm showed oiling but the worms inside were alive and on the second visit it was noted that the tubes of large individuals had grown 3–4 mm.

Lithothamnia. The encrusting corallines in the Cochlear Zone were obviously affected where they grew on rocks which dried in the sun at low tide. On the first visit, the lithothamnia appeared dirty instead of pinkish white and on the second visit it was obvious that they had been partially overgrown by a low quick-growing filamentous alga which was not identified.

Patella cochlear. This limpet was badly affected and on drying rocks in the sheltered cove 1 km south-west of Northumberland Point about 50% of the scars were vacant. Elsewhere particularly on rocks which were continually splashed at low tide, the mortality was much less. Considering the great abundance of this limpet it was surprising that so few shells were cast up at the high tide mark, since the shells of *Oxystele sinensis*, which is not so abundant, were cast up in hundreds. It was concluded that flat shells such as those of limpets are not so easily picked up by the waves and this is an important point to bear in mind when estimating mortalities from the shells of different animals cast up at the high tide mark. On the second visit, it was noted that many small *Patella cochlear* had occupied the vacant scars. This confirms the finding of Branch (in press) that juvenile *P. cochlear* often settle on the backs of older shells and eventually move off to occupy the scars left by dead individuals. Whether the high mortality among *P. cochlear* was primarily due to its own susceptibility to oil and/or surfactants or whether it was due to the death of the lithothamnion on which this limpet feeds was not determined.

Parechinus angulosus. Hundreds of dead oily shells with the spines still attached were cast shore and relatively few were found alive. In view of the fact that *Parechinus* retreats either into moist crevices or below the surface of the water and the floating oil would not make contact with the sea-urchin, it is concluded that *Parechinus* must be very susceptible to oil or surfactants dissolved or suspended as an emulsion in sea water.

Perna perna. This common rock mussel appeared to be unaffected.

Plagusia chabrus. No specimens of this crab were found but it has not been recorded as common on Cape Agulhas shores.

Octopus granulatus. No octopi were found in spite of extensive search and the fishermen who use octopi as bait reported that shortly after the grounding of the *Wafra*, dead octopi were found in rock pools and that subsequently no octopi were found in their usual habitats. The fishermen state that it takes two months before octopi move into the rock pools from deeper waters. It is concluded that octopi must be included among the species which are particularly susceptible to oil and/or surfactants.

Hypnea spicifera and *Plocamium corallorhiza.* Neither of these two algae seemed to be affected. Masses of drifting seaweeds including both of these species were found on the sandy shore of Struisbaai but this is reported to be normal and not due to oiling.

Pyura stolonifera. Little "red bait" was found even by divers but on the other hand, there was no evidence of rotting or empty tests. It would appear that the bait has been culled from the more approachable rocks.

Patella tabularis. Some fresh shells of this large limpet were found on the foreshore and some were found alive below LWS.

Turbo sarmaticus. Many stinking shells of the "alikreukel" were cast up on the shore and, as this species is not common above LWS, it is probable that it is easily poisoned by oil and/or surfactants dissolved or in suspension in the water.

Haliotis midae. The abalone or "perlemoen" is not common east of Cape Agulhas and none were found alive on the shore or by divers near Northumberland Point. Nevertheless, many residents and fishermen reported that dead "perlemoen" were washed ashore in various coves between Struisbaai and Sandknollpunt where "perlemoen" are more common.

Jasus lalandii. The rock lobster is not common at Struisbaai but residents and fishermen reported that some were found crawling out of the sea west of the harbour. This indicates that the rock lobster cannot tolerate the presence of oil and/or surfactants in solution. It is known that *Jasus* leaves the water due to high temperatures or oxygen depletion, but there was no evidence of such changes at Cape Agulhas.

A BRIEF NOTE ON THE EFFECT OF OILING ON SANDY BEACHES

Almost all the observations on oil pollution were limited to rocky shores. When the flat bathing beach at Struisbaai was visited on 14th March, there was little to be seen except oil stains on the sand near high tide mark but digging showed that more oil had sunk below the surface and had later been covered by fresh clean sand. This was more marked in the steeply sloping sandy coves west of Northumberland Point where the oil had impregnated the sand to a depth of 10 cm near the high tide mark and could be found as a subsurface band lower down the beach. There was no obvious change when the same area was visited 26 days later and from reports in the literature, it is probable that this oil will remain in the sand for many months.

The exposed sandy beaches near Cape Agulhas are almost devoid of marine life. The only obvious inhabitants of these beaches is the scavenging snail *Bullia* which feeds on jelly fish, *Physalia* and the bodies of other animals cast up by the waves. No *Bullia* were noted at Struisbaai but it was reported by Mr. Gericke that *Bullia* is normally very common at "Die Mond", some 13 km north-east of Struisbaai. After the wreck of the *Wafra* they disappeared from the beach and large numbers of dead shells were found at the high water mark. This was unexpected since this part of the shore was not polluted by oil. It is possible that the *Bullia* were poisoned by eating *Physalia* (locally known as "blue-bottles") which had been killed out to sea and later drifted ashore.

A NOTE OF THE EFFECT OF OIL ON OFFSHORE FISHES

While the *Wafra* was still fast on the reef off Cape Agulhas and spilling oil, the fishing all around Agulhas was said to be very good and large catches of pilchards (*Sardinops ocellata*) and albacore (*Seriola lalandii*) were reported in the press. Some fishermen suggested that the albacore were attracted to the oil and quite a number were seen to have their gills blackened with oil. Between 8th March and 10th March many albacore and other fish landed at Struisbaai were found to have black fluid (possibly oil) in their stomachs. On 11th March, so many albacore were in this condition that fishing was stopped on 12th March and those caught earlier were dumped as unsaleable.

CONCLUSIONS

We are here concerned only with an evaluation of the effect of the spillage of 15 000 tons of crude oil from the Persian Gulf on the fauna and flora of the rocky shores since insufficient evidence was obtained of the effects on plankton, or fish out to sea or on the fauna of sandy beaches. We may note in passing that the use of three different surfactants applied at the source of the spillage on the tanker makes it impossible to determine the effect of crude oil alone or the effect of crude oil plus any single surfactant.

The first and possibly the most important conclusion is that the most severe pollution was seen in coves and isolated pools where wave action was reduced. This suggests that even more severe effects will be found if oil penetrates into protected harbours, landlocked bays or the mouths of estuaries where wave action is minimal and the surface of the substrate dries out at each low tide. Again the severity of the oiling varied at different tidal levels. The black "chocolate mousse" formed a band on the rocks for a vertical range of one metre from mean sea-level up to high water of springs and was less marked both in the splash zone above and in the Lower Balanoid Zone below.

The effect of pollution on the flora and fauna at different tidal levels did not obviously correspond with the intensity of oiling at the same level. The barnacles *Chthamalus dentatus* and *Tetraclita serrata* and the limpet *Patella granularis* in the Upper Balanoid Zone often had their shells blackened with oil but there was no evidence of a correspondingly high mortality. On the other hand, *Oxystele variegata* suffered a high mortality and *Littorina knysnaensis* at the same levels on dry rocks had died and only those living higher up in the splash zone or submerged in rock pools had survived. Similarly, *Patella oculus* was eliminated from the upper part of its range at mid-tide but survived at lower levels. Nonetheless, we gained the general impression that the fauna and flora on the upper part of the shore is "tougher" and more resistant to oil pollution than species which live at lower levels.

This difference in sensitivity to oil pollution is not a simple distinction between browsers such as limpets and periwinkles on the one hand and filter feeders such as tubicolous polychaetes, mussels or barnacles on the other. The literature on oil pollution suggests that some taxonomic groups such as the echinoderms are more sensitive to oil than are others such as molluscs and certainly the sea-urchin *Parechinus* suffered a high mortality. On the other hand, the molluscs varied greatly in their susceptibility. Octopi died very quickly even though they are always submerged. This may be because they lack a protective shell. But the species of shelled molluscs varied in sensitivity even within a single genus. *Patella variegata* and *P. longicosta* tolerated the oil while *P. cochlear* and *P. oculus* died or were adversely affected. *Oxystele variegata* and *O. sinensis* were severely affected but *O. tigrina* was not.

It will be noted that in this account of the effect of oil pollution on the rocky shore fauna and flora has been given in comparative terms. It was not possible to state the mortality in terms of numbers per square metre or in percentages of the normal fauna and flora which occur there, for such information is not available nor have methods been developed to give such a quantitative assessment of densities on rocky shores anywhere in the world. Difficult though it is to develop a reliable technique, such a quantitative estimation is essential for further research into the effects of oil pollution. We need to know the density of plant and animal life on an unpolluted rocky shore before we can assess the severity of pollution in quantitative terms.

Possibly we will not need to assess the density of all species at different tidal levels since this would be a laborious task. Oil pollution at Cape Agulhas has shown that there are both oil-sensitive and oil-tolerant species at different levels and attention might be directed to these in any future estimation of the damage caused by oil pollution. Laboratory experiments might be used to supplement observations on the shore. We would suggest that at higher tidal levels the more tolerant species are *Patella granularis* and *Tetraclita serrata* while *Oxystele variegata* and *Cyclograpsus punctatus* are the more sensitive. At low tide *Octomeris angulosa*, *Patella longicosta* and *Perna perna* are more tolerant while *Octopus granulatus*, *Patella cochlear* and *Parechinus angulosus* are more sensitive. The commercially important species *Jasus lalandii* and *Haliotis midae* both appear to be unusually sensitive.

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