Effects of Fuel Oil on Sea Catfish: Feeding Activity and Cardiac Responses

R. T. Wang
Department of Zoology
University of Texas
Austin, Tex. 78712

J. A. C. Nicol
Port Aransas Marine Laboratory
University of Texas Marine Science Institute
Port Aransas, Tex. 78373

INTRODUCTION

Although fish have been used repeatedly in bioassays of toxicity of petroleum oils, little information is available for marine species (NELSON-SMITH 1970, 1972). ANDERSON and colleagues (1974) studied the effects of crude and fuel oil on survival of estuarine species. Using a marine catfish readily available, we have examined the effects of a fuel oil on survival, feeding behavior and heart rate. The latter has frequently been used as a sensitive test for environmental stress.

MATERIALS AND METHODS

Experiments were carried out with sea catfish, Arius felis (L.), which were caught in trawls near Port Aransas. Total body lengths ranged from 80 to 130 mm. They were kept in aquaria measuring 30 x 40 x 30 cm, holding 20 or 26 liters of sea water, 25 °/oo, which was recirculated by a pump. Six to eight fish were placed in each aquarium. Water returning to the aquarium aerated it and, when oil was added, caused the formation of an oil-water emulsion. The water temperature was 27°C. The oil tested was No. 2 fuel oil, kindly supplied by the American Petroleum Institute.

Activity and survival. Two series of experiments were carried out. In the first series, 20, 10, 5, and 2 ml of oil were added to the four aquaria, respectively; the aquaria contained 26 l of sea water. The fish were observed over four consecutive days, during which time they were not fed and the aquaria were not cleaned.

In the second series, 2, 1, and 0.5 ml of oil were added to three aquaria, respectively, while the fourth was used as control. The aquaria were drained and filled with sea water each day. Before the water was changed they were fed chopped shrimp; unconsumed pieces of shrimp were removed from the aquaria when it was drained. After refilling the aquaria, fuel oil, in the quantities that were used before, was added to them. A fish from each aquarium was sacrificed on the fourth day for histological examination, and another on the eleventh day, when the experiment was terminated.

Electrocardiograms (EKGs). One electrode, consisting of a short piece of platinum wire, was implanted

Bulletin of Environmental Contamination & Toxicology, Vol. 18, No. 2 © 1977 by Springer-Verlag New York Inc.

beneath the dorsal fin and the other, also platinum, was placed in the sea water. The fish was confined in a lucite tube. Signals were passed to an Argonaut Differential Preamplifier LRA 042 connected to a chart paper recorder. The aquarium contained 20 ml of sea water and tests were made with 0.2, 2, 16, and 20 ml of fuel oil, which was added to the water as described in the preceding experiment, forming a suspension of oil in sea water. EKGs were recorded before, during, and after adding fuel oil. Care was taken to avoid disturbing the fish because slight disturbances affected the heart rate (see Figure 2E).

Much time was spent preparing fish for this experiment, not all preparations were successful and it was necessary to terminate the research with the results presented herewith.

OBSERVATIONS AND RESULTS

Activity and survival

First series (20, 10, 5 and 2 ml of fuel oil per 26 l). Thirty min after adding the oil the fish swam near the surface and some actively sought to get out of the aquarium. Twenty hours after adding the oil some fish were dead, most of the surviving fish in 20, 10 and 5 ml of oil kept to the surface while most of the fish in 2 ml of oil remained at the bottom.

After 48 h most fish in 20 and 10 ml of oil were dead, about half the fish in 5 ml were dead, while most fish in 2 ml of oil survived. The LC_{50}'s for this experiment were 0.16 at 48 h and 0.14 ml l^{-1} at 96 h (see Figure 1). It was observed that the tail fins of all the dead fish were damaged, the skin was eroded, blood showed at the bases of the dorsal and ventral fins, and bleeding had occurred in the gills.

Second series (2, 1, 0.5 ml per 26 l of fuel oil and control). The eight fish in the aquarium containing 2 ml of oil swam near the surface; fish in the other aquaria remained on the bottom. Feeding responses were observed; they were divided into five arbitrary categories:

excellent — all fish in the same aquarium very actively sought food and ate it;
good — all fish in the same aquarium sought and ate food;
fair — most fish sought and ate food;
poor — most fish did not seek, find or eat food;
very poor — no response to food.

The results (Table 1) show that feeding of fish in 0.02 ml l^{-1} of fuel oil was the same as in the controls. Feeding responses deteriorated progressively in 0.04 and 0.08 ml l^{-1} of oil at 96 h, recovery was slower at the last concentration. It was also observed that fish after two days in 0.08 ml l^{-1} of oil regurgitated the

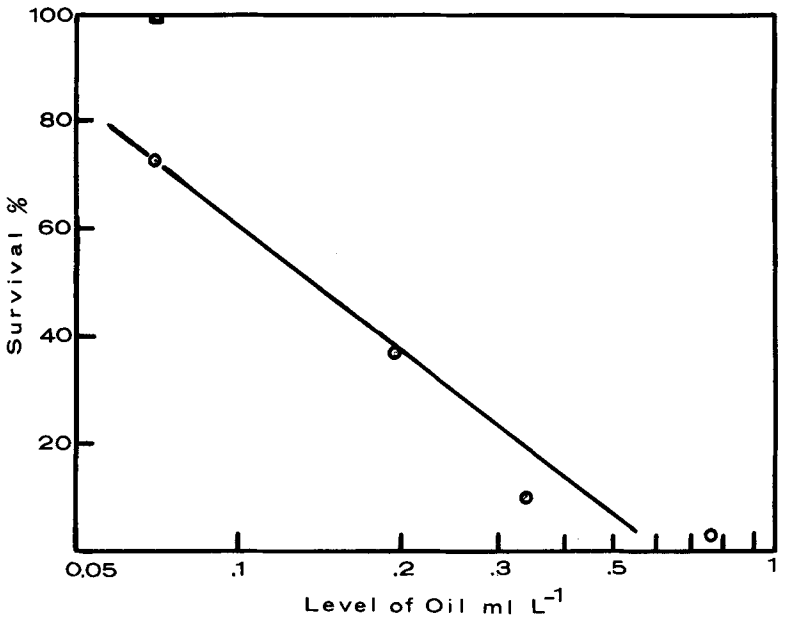

Figure 1. Survival of sea catfish in No. 2 fuel oil at 96 h (first experimental series; the point at 100 % survival is from the second series).

TABLE 1
Feeding responses to added oil.

Days in Oil	Amount (ml l^{-1}) of oil added			
	0.077	0.038	0.019	Control
0	excellent	excellent	excellent	excellent
1	excellent	excellent	excellent	excellent
2	poor	fair	excellent	excellent
3	poor	fair	excellent	excellent
4	very poor	fair	excellent	excellent
Recovery Days				
1	poor	fair	excellent	excellent
2	fair	good	excellent	excellent
3	fair	good	excellent	excellent
4	good	excellent	excellent	excellent
5	good	excellent	excellent	excellent
6	good	excellent	excellent	excellent
7	good	excellent	excellent	excellent

food which they ate. In this experiment all the fish survived to four days.

Histological examination of gills and barbels did not show any gross damage. However, the stomach from a fish treated with 0.08 ml l^{-1} of oil seemed to lack a mucus layer.

Cardiac responses

The normal cardiac frequency was 50 to 70 beats per min (20 to 25°C). When fuel oil in sufficient quantity was added to the circulating water, forming an emulsion, bradycardia (slowing of the heart) occurred after a latency of 3 min. The response was dramatic after 20 ml of oil was added (1 ml l^{-1}) (Figure 2), and barely detectable in 0.2 ml (0.01 ml l^{-1}). The rate returned to normal after a half-hour.

TABLE 2
Cardiac responses to added oil (EKGs).

Oil added (ml l^{-1})	Change of heart rate, beats per min (before, after 4 min, after 30 min)			Change of rate B/A %
	A	B	C	
0.01	66	62	65	95
0.1	61	56	60	92
	63	36	58	57
0.8	77	64	82	83
	44	38	57	86
1	52	33	65	63
				51

DISCUSSION AND CONCLUSIONS

Catfishes use olfactory and gustatory senses for locating and selecting food. Having sensed food by smell, sea catfishes start searching for it in a frenzy of activity and come to recognize it on contact with their barbels which bear extraoral taste buds (KLEEREKOPER 1969; HARA 1971).

Sea catfish were killed by fuel oil at concentrations >0.08 ml l^{-1}; the LC_{50} for 96 h was 0.14 ml l^{-1}. Prior to death there was much damage to surface tissue. At 0.038 ml l^{-1}, feeding responses of catfishes deteriorated and the animals could not retain their food. A parallel study is, perhaps, that of FOSTER et al. (1966) on the flagfish, who found that fish in ABS (an alkyl benzene sulfonate mixture) had difficulty feeding and threw out food after seizing it.

Some values of lethal levels for fishes in the literature are the following. For carp it was 0.4 ml l^{-1} of Ischimbaev crude (VESELOV 1948). For young shad the TLm at 48 h was 167 ml l^{-1} of diesel fuel, and 2417 ml l^{-1} of heavy residual fuel oil (TAGATZ 1961). For the cyprinodonts Fundulus simulus and Cyprinodon variegatus the TLm at 96 h were 33 and 93 ppm of No. 2 fuel oil (ANDERSON et al. 1974). For the mummichog Fundulus heteroditus the TLm at 96 h was 16 ml l^{-1} of a crude oil

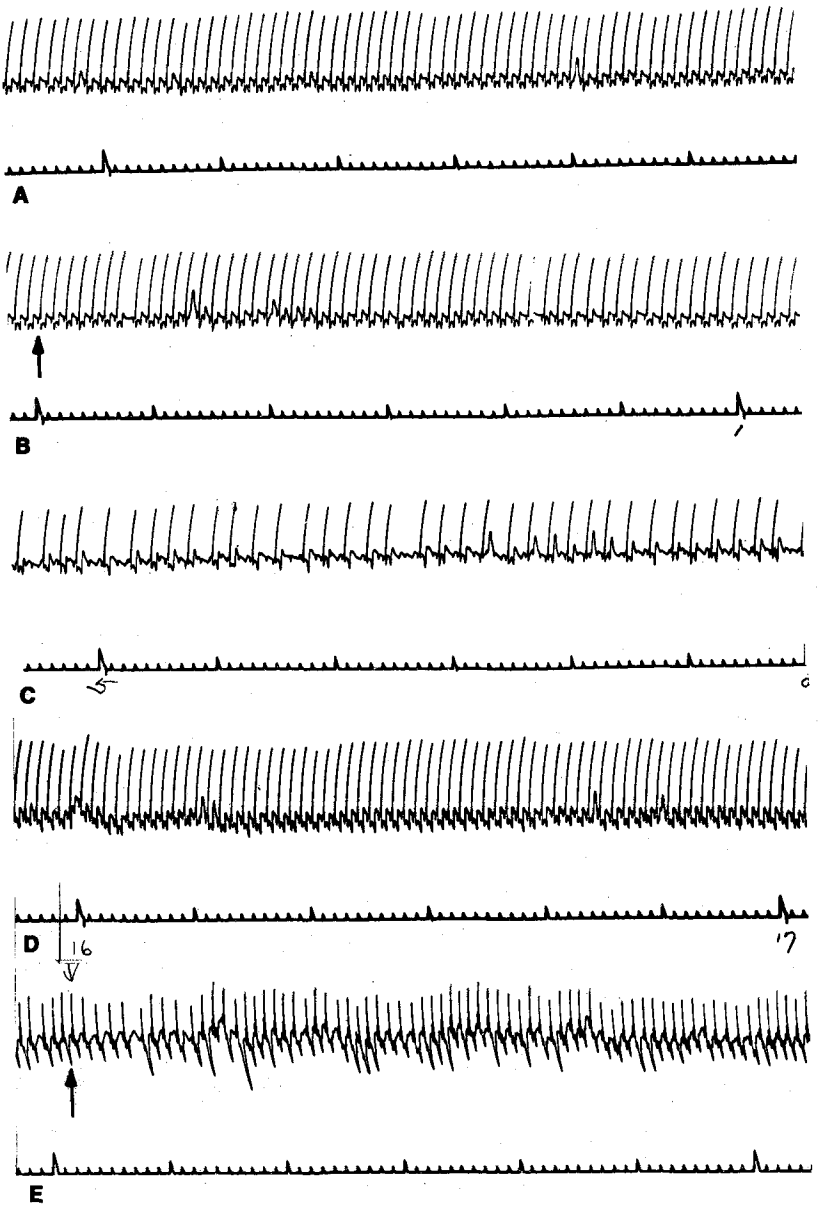

Figure 2. Electrocardiograms (EKGs) of catfish Arius felis. Time scale below each record, 1 min, 10 sec, 1 sec. Record A, normal EKG immediately before adding fuel oil. B, fuel oil, 20 ml, added at arrow. C, D, 5-6 min and 16-17 min after adding fuel oil. E, the effect of a disturbance (a black screening cloth was moved at the arrow).

(LAROCHE et al. 1970). For salmon fry the LC_{50} at 96 h was 13.1 ppm of Prudhoe Bay crude (THOMAS and RICE 1976). Ruff and dace were killed by naphthanic acids of Baku crude at 16 ppm (CHIPMAN and GALTSOFF 1949; MIRONOV 1970; NELSON-SMITH 1970, 1972). Some volatile monoaromatics, that occur in petroleum oils, at concentrations of 50 ppm or more killed young coho salmon. They also resulted in an increased blood ionic concentration (MORROW et al. 1975).

Several minutes after adding fuel oil the heart rate slowed. Threshold was about 0.01 ml l^{-1}; at 0.1 ml l^{-1} bradycardia was pronounced and behavior of some fish was affected. External events affect the activity of the fish heart through cardiac reflexes mediated by the vagus nerve, and bradycardia has been observed in response to a wide variety of external changes, such as salinity and anoxia (RANDALL 1968, 1970; MARVIN and BURTON 1973). Training and conditioning techniques have revealed a wide range of olfactory sensitivities to various aromatics in teleosts, e.g., $<5 \times 10^{-4}$ ppm for phenol and p-chlorophenol in the bluntnose minnow (HASLER and WISBY 1950); 3.9×10^{-3} ppm for benzene and 1.01×10^{-2} ppm for phenol in the roach (MARCSTRÖM 1959; HARA 1971); 0.011 ppm for benezene in the striped bass (MEYERHOFF 1975).

In terms of organic material (by weight) present in the sea water, the oil-in-water dispersions used in our experiments with catfish were toxic at higher levels than aqueous extracts to a wide variety of marine invertebrates and fishes (ANDERSON et al. 1974). The difference (140 vs 10-15 ppm) presumably lies in the higher concentration of water-soluble aromatics in the water-soluble extracts. However, if the two are compared on the basis of water-soluble fractions present in solution, then the oil dispersions are more than ten times as toxic as the water-soluble extracts. The explanation probably lies in the particulate condition of the oil in the dispersions. Other investigators, studying salmon parr, found that the toxicity of crude oil dispersions decreased on exposure to air (MORROW 1973). Indeed, insofar as the experiments can be related to an environmental condition, they could suggest how fish might react to a fresh oil spill, and the adverse effect upon fish in the immediate vicinity. Experiments of MORROW (1973) with Prudhoe Bay crude were designed to simulate an oil spill in shallow water where 500 to 3500 ppm of oil might occur at the surface. Oil at these levels caused mortalities up to 100% at 96 h. These toxic levels of oil concentration are probably within the range of those found for sea catfish (see Figure 1). The mortality rates for young coho salmon are inversely related to temperature (range explored, 3° to 13°C), and our experiments were carried out at 27°C.

ACKNOWLEDGMENTS

This research was supported by the Office of the International Decade of Ocean Exploration, National Science Foundation, Grant No. IDO73-09740.

REFERENCES

ANDERSON, J.W., J.M. NEFF, B.A. COX, H.E. TATEM, and G.M. HIGHTOWER: Mar. Biol. 27, 75, 1974.

CHIPMAN, W.A. and P.S. GALTSOFF: U.S. Fish Wildlife Service (Spec. Sci. Rept. 1), 1949.

FOSTER, N.R., A. SCHEIER, and J. CAIRNS: Trans. Am. Fisheries Soc. 95, 109, 1966.

HARA, T.J.: Chemoreception. In W.S. Hoar and D.J. Randall (eds.), Fish Physiology, Vol. 5, pp. 79-120. New York-London: Academic Press, 1971.

HASLER, A.D., and W.J. WISBY: Trans. Am. Fisheries Soc. 79, 64, 1950.

KLEEREKOPER, H.: Olfaction in Fishes. Bloomington, Indiana-London, 1969.

LAROCHE, G., R. EISLER, and C.M. TARZWELL: J. Water Poll. Control Fed. 42, 1982, 1970.

MARCSTRÖM, A.: Arkiv. Zool. 12, 335, 1959.

MARVIN, D.E., Jr., and D.T. BURTON: Comp. Biochem. Physiol., A. Comp. Physiol. 46, 755, 1973.

MEYERHOFF, R.D.: J. Fish. Res. Bd. Canada 32, 1864, 1975.

MIRONOV, O.G.: The effect of oil pollution on the flora and fauna of the Black Sea. FAO Tech. Conf. Mar. Pollut., Rome, pap. E-92, 1970.

MORROW, J.E.: J. Marine Research Sears Foundation 31, 135, 1973.

MORROW, J.E., R.L. GRITZ, and M.P. KIRTON: Copeia 1975, 326, 1975.

NELSON-SMITH, A.: Adv. Mar. Biol. 8, 215, 1970.

NELSON-SMITH, A.: Oil Pollution and Marine Ecology. London: Elek Science, 1972.

RANDALL, D.J.: Am. Zool. 8, 179, 1968.

RANDALL, D.J.: Gas exchange in fish. In W.S. Hoar and D.J. Randall (eds.), Fish Physiology, Vol. 4, pp. 253-292. New York-London: Academic Press, 1970.

TAGATZ, M.E.: Chesapeake Sci. 2, 65, 1961.

THOMAS, R.E. and S.D. RICE: J. Fish. Res. Bd. Canada 32, 2221, 1975.

VESELOV, E.A.: Rybnoe Khozy. (Fish Economy) 12, 2, 1948.