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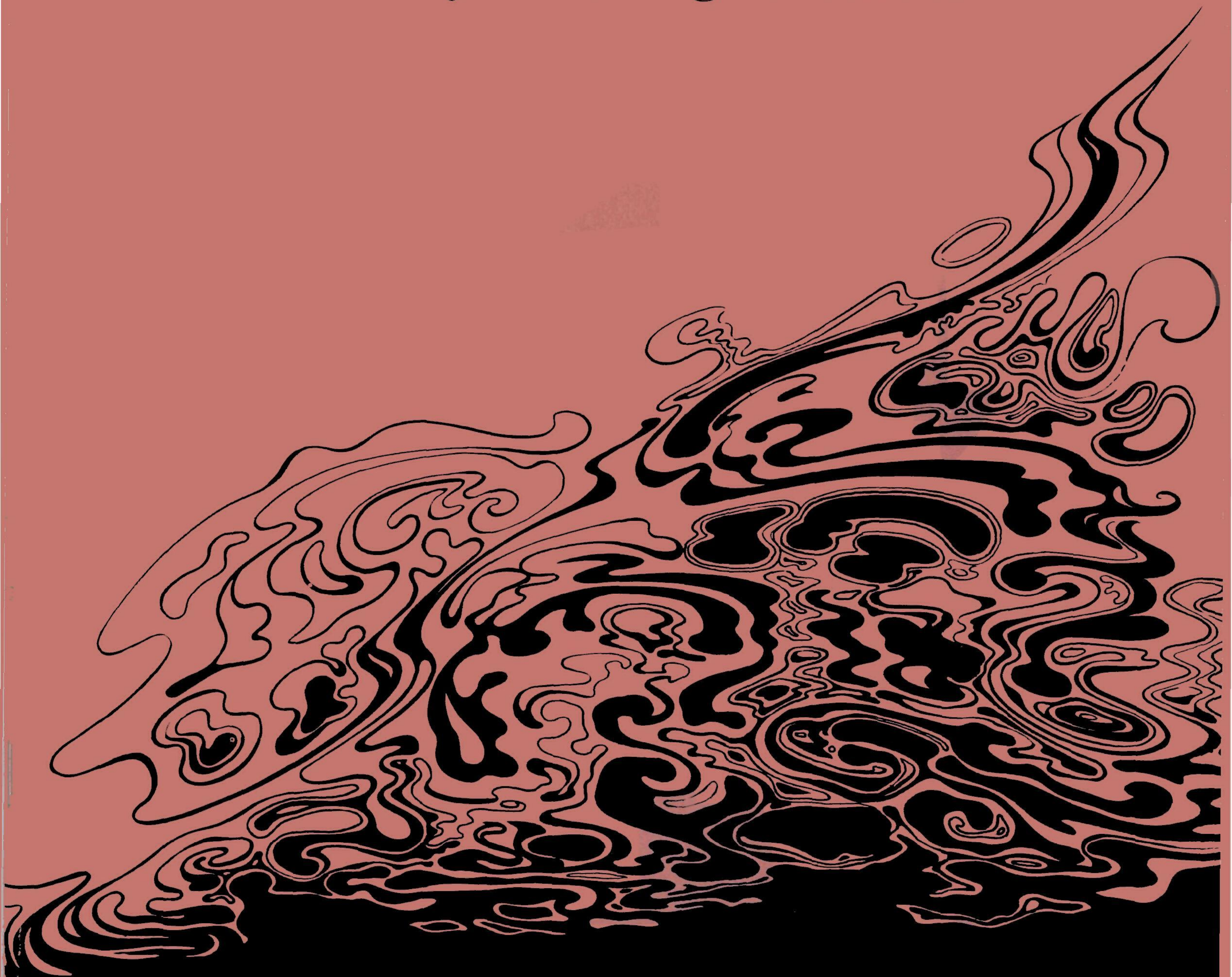
Effects of Oil Pollution on Waterfowl A Study of Salvage Methods



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EFFECTS OF OIL POLLUTION ON WATERFOWL

A STUDY OF SALVAGE METHODS

by

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SECTION I

ABSTRACT

A study was made of salvage methods for waterfowl subjected to oil pollution. Mallard ducks were the primary test species used. Aspects of the pathology of some of the waterfowl species involved in the Santa Barbara oil slicks were also investigated.

Although some refined petroleum products contain toxic compounds, the Santa Barbara crude used as a test oil in this study produced no apparent ill effects.

Polycomplex A-11 was found to be a rapid and effective cleansing agent for the removal of oil from bird plumage. Oil on bird plumage alters feather structures by replacing the small air pockets between barbules of the feather, thereby decreasing buoyancy and insulation. Removal of oil from down feathers is more difficult than from the contour feathers.

Ducks and geese are more amenable to treatment and post-treatment care than are the more aquatic fowls, such as grebes, loons, auks and murres. Confinement times should be as brief as possible, as the incidence of mycotic and other infectious diseases increases under long periods of close confinement.

This report was submitted in fulfillment of Research Grant No.14-12-574 between the Federal Water Quality Administration and the University of California at San Diego.

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SECTION II

INTRODUCTION

This project developed from a meeting held in Santa Barbara, California, on March 4, 1969, with Mr. Warren Shanks of U.S. Sport Fisheries & Wildlife Service, and representatives of the California Fish & Game Department. The purpose of the meeting was to discuss methods that might be employed to salvage waterfowl contaminated with oil which had spilled onto the ocean surface at Santa Barbara from a leak in an offshore Union Oil Company well. The objectives of the project were:

1. To determine factors contributing to the death of waterfowl which had become contaminated with oil.

2. To determine methods which might be used to remove contaminating oil from the plumage of waterfowl.

3. To study alterations in feather structure following oil contamination and oil removal and to determine value of wax substitution to feather structure.

4. To determine methods for management and treatment of cleansed birds that would contribute to increased viability.

5. To determine the pathologic effects of the oil on waterfowl.

6. To attempt to analyse records made on contaminated waterfowl at Santa Barbara by "A Child's Est ate" zoo and the Union Oil Company.

The objectives and actual experiments were designed in a loose manner to permit adaptations as the studies proceeded, and to accommodate unforeseen situations that might develop. The project was financed by the Federal Water Quality Administration, and was administered by the University of California at San Diego, Pathology Department, in cooperation with the Health Department of the Zoological Society of San Diego. All work was conducted at the San Diego Zoo.

The project personnel included: Principal investigator, Lynn A. Griner, D.V.M., Ph.D., comparative pathologist, San Diego Zoo, associate pathologist-in-residence, University of California, San Diego; Robert Herdman, research assistant; Murray Malcom, animal caretaker.

SECTION III

REVIEW OF LITERATURE

The uropygial or preen gland is the only sebaceous gland found in birds. This gland secretes an oily substance that the bird distributes over its plumage by means of the beak when preening. During preening, the bird oils and waxes the feathers and arranges the feather structures and feather layers.

The serious hazard of oil pollution to waterfowl has been reviewed by Hawkes (1961), Erickson (1963), Boos (1964), Beer (1968), and Hartung (1967).

Odham (1967), studied the chemical structure of the preen gland wax of 10 species of waterfowl. He found considerable variation in the structure of the preen gland waxes and postulated that the chemical structure might be used in systematics. In his studies he prepared synthetic fatty acids of known configuration. Later Odham (1968) formulated a three component cleansing agent (Larodan 127) for use in cleansing oil from feathers and at the same time waterproofing them with a synthetic feather wax.

Many methods and agents have been used to remove contaminating oil from the plumage of birds, some of which are perhaps more damaging than the oil, since some solvents and detergents are toxic or irritating. Some birds can remove much of the contaminating oil by preening. Hartung and Hunt (1966) claimed that in some situations birds can remove sufficient oil to produce toxic effects through ingestion.

In their study of the toxicity of oils, they found that a number of industrial oils were toxic to waterfowl when administered by stomach tube. The oils studied were: a light fuel oil with less than 1% phenolic compounds; a diesel oil containing less than 1% organically bound phosphorus and phenols; a simple sulfretted low additive SAE 10W motor oil; a sulfretted SAE 10W-30 motor oil of high detergent content; a high pressure cutting oil additive containing 30% chlorine and 10% phosphorus; and a cutting oil formulated with 10% of this additive and 10% triglycerides, and 80% mineral oil. No crude oils were used. Some of the effects observed were lipid pneumonia, gastrointestinal irritation, fatty change in liver and adrenal hyperplasia. All of the oils used produced undesirable results.

Following the Torrey Canyon grounding and release of "sour" Kuwait crude oil, Beer (1968) reported on post mortem findings in auks dying during attempts at rehabilitation. It was stated that practically all birds which died were emaciated, with a complete loss of subcutaneous and visceral fat. This would suggest that some time had lapsed between the birds' involvement in the oil spill and autopsy, or that the birds were in poor condition when they became involved, or both. The patterns of mortality and pathologic changes suggested to Beer that there was severe stress and that a powerful irritant or poison was present in the gut. It is readily accepted that the combined stress of involvement in the oil, and cleaning and rehabilitation, would have deleterious effects on the birds. Beer also described the attempted rehabilitation of oiled sea birds resulting from the Torrey Canyon disaster. He believed that some of the cleansing agents acted as irritants. It was also recognized that the maintenance of auks in artificial environments has generally been unsuccessful.

The metabolic rates of ducks covered with known quantities of oils were measured indirectly by Hartung (1967). Regression analyses of the metabolic-rate-temperature plots enabled him to assess the heat conductivities of ducks with normal and oiled plumage. Mortalities in ducks at very low temperatures occurred only after body fat reserves had been exhausted. Oiled birds usually had a reduced food intake, and their increased metabolic rate would result in an accelerated rate of fat depletion and early starvation. The increased energy metabolism in oiled ducks appeared to be due to a breakdown in insulation. The studies by Hartung, using ducks, indicate that oiled ducks can survive extended exposure to low temperatures as long as they have readily available energy stores. This indicates the urgency of increasing food consumption by contaminated birds.

SECTION IV

MATERIALS AND METHODS

Physical Layout

Mallard ducks were the principal subjects used in these experiments. One hundred and three Mallard ducks were supplied by the McGraw Foundation of Dundee, Illinois. They were shipped to San Diego via air freight. The ducks were divided into six groups of twenty birds and housed in eight feet by twelve feet wire enclosures. The pens were six feet high and were covered with two inch poultry netting. The floor of the pens was covered with four inches of decomposed granite. Each pen of birds was supplied with a four foot poultry feeder, a galvanized waterer, and a thirty inch by thirty inch by six inch epoxy-covered plywood swimming tank. A group of thirty-six cross-bred ducks (wild x domestic) trapped at Carlsbad Lagoon, were used in some of the experiments. Permission for the capture of these birds was granted by the Fish and Game Department. These birds were obtained prior to the receipt of the mallards from the McGraw Foundation.

In addition to the above birds, twelve wild pintail ducks were taken from the waterfowl exhibits within the Zoo. These birds were migratory fowl wintering at the Zoo. All birds were fed a ration of equal parts of a complete poultry mash without grit, and milo. The poultry mash was formulated by the San Diego Poultry Cooperative. The feed was given ad lib.

The mallards and cross-bred ducks were given two weeks to acclimate after capture and shipment. During this time, body weights and skin and rectal temperatures were recorded three times on each of the one hundred and three mallards. These recordings were made prior to assigning birds to specific experimental groups. In order to establish a normal temperature and body weight pattern for the birds, temperature readings were obtained by rectal and skin probes on a battery-powered telethermometer and body weights were made, using a hanging spring balance autopsy scale, accurate to 5 grams.

Oiling Method

The oil used in these experiments was supplied by the Union Oil Company, and was obtained from the offshore well that had leaked oil into the ocean at Santa Barbara. Oil to a depth of approximately one-eighth of an inch was layered over the surface of one of the swimming tanks, containing approximately five inches of domestic water. The density of the oil increased after twenty-four hours exposure to the air, due apparently to the loss of some volatile components. For this reason, the oil used to contaminate the experimental ducks was exposed to the air for a minimum of twenty-four hours. This procedure produced an oil more comparable to that which occurred at Santa Barbara. The birds used in this experiment were placed in the oil and water and left for approximately ten minutes.

Cleansing Agents

Two cleansing agents were used to remove oil from the birds. These agents were Polycomplex A-11 and Larodan 127. Polycomplex A-11, a product of Guardian Chemical Corporation, is a water-soluble organic formulation which contains no hydrocarbons. For removal of oil from the ducks' plumage, Polycomplex was used as a 1% solution. Larodan 127 is a 3-component cleansing and waxing system, consisting of surface-active monoglyceride crystals, to which is added about 1% of liquid Pur-cellin oil. Larodan 127 is produced by Skandinavisk Olje, Goteborg, Sweden. The liquid Pur-cellin oil used in Larodan 127 is manufactured by Dagoco Chemical Company in Germany. In washing oil from bird plumage, Larodan 127 was used full strength, as recommended.

In one experiment, to determine the value of Polycomplex as a cleansing agent, sixty mallards were oiled in the manner previously described. The experimental design and use of these sixty birds is presented in Table I. The oiled birds were immersed in the solution, care being taken to keep their heads out of the Polycomplex. The birds were scrubbed, using the hand, in the direction of the feathers. In more severe cases, some ruffling of the feathers was necessary. After washing, the birds were rinsed in clean water. In addition, five normal unoiled ducks were washed in Polycomplex.

Artificial Waxes

Two preparations, lanolin and spermacetti wax, were used as substitutes for normal feather wax on birds washed with Polycomplex. One percent solutions of lanolin and spermacetti wax were made in Hexane. These solutions were layered over the surface of water in a large plastic basin. After washing the mallards in Polycomplex, the test birds (see Table I) were immersed once in the respective preparations and permitted to air dry. The efficacy of this treatment was tested by water uptake of the plumage.

In a second experiment, to determine the efficacy of Larodan 127 as a cleansing agent, thirty mallards were oiled in the manner described. The design of the experiment and use of the birds is shown in Table I. The oiled birds were placed in the Larodan, and cotton sponges, saturated in Larodan, were used to help remove the oil. The plumage was stroked with the sponges along the grain of the feathers. After washing with Larodan, the birds were rinsed in clear water.

Water Uptake

In addition to the above experiments designed to test cleansing agents, thirty mallards

Table I Experimental design of the Mallard duck experiments

Sixty Mallards - Oiled	Water Uptake	Temp.	Weight	Blood Chemistry
10 washed with Polycomplex - 5 hours after oiling				
5 treated with lanolin		5	5	
5 without lanolin		5	5	
45 washed with Polycomplex - 24 hours after oiling				
15 treated with lanolin	15	5	5	
15 without lanolin	15	5	5	4
15 treated with spermacetti	15			
5 oiled - no further treatment	5	5		
5 - no oil, but washed in Polycomplex	5			
Thirty Ducks - Oiled				
30 washed in Larodan (full strength) - 24 hours after oiling	15	8		4
Fifteen Ducks - Oiled				
15 oiled - no further treatment	15			5
15 untreated controls	15			5

were allocated to two lots of fifteen birds each. In lot number one the fifteen birds were oiled but received no further treatment. These birds were used for water uptake studies of plumage and blood chemistry determinations were made on five of the fifteen. The fifteen mallards in lot number two served as untreated controls.

The efficacy of the cleansing and waxing procedures was tested by the water uptake of plumage. The purpose of this study was to determine approximate amounts of water that would remain in the plumage of oiled, Polycomplex-washed plus lanolin, and Polycomplex-washed plus spermacetti, unwashed, and normal ducks. For this experiment each bird was weighed then immersed in water for two minutes. They were then removed and water was permitted to drain for one minute before reweighing. The difference in respective weights indicated the amount of water retained in the plumage.

Feather Structure

Lateral breast feathers were carefully plucked by means of thumb forceps applied to the base of the calamus of five normal mallard ducks, and five mallards that had been dipped in oil, five oiled ducks following a wash in Polycomplex, five oiled ducks following a wash in Larodan, and five oiled ducks washed in Polycomplex and treated with lanolin.

The feathers were mounted on microscope slides by means of cover slips. A small amount of cement was applied to the four corners of cover slips and the cover glasses were then placed on the slides over the feathers, care being taken to keep the cement off the feather. Application of slight pressure to the cover glass flattened the feathers on to the slide. The feathers were examined microscopically and microphotographs were made.

Pathology

Gross and histopathologic studies were made on thirty-two waterfowl involved in the oil pollution incident at Santa Barbara, California in January of 1969. This group of birds included ten which were dead on arrival at "A Child's Estate" zoo; four which died shortly after washing; nine which died four to seven days after treatment; and nine which died ten to fourteen days after treatment. Table 2 presents a listing of these birds by species and time after treatment. A group of four California murres was received from Nye Beach in Oregon. These birds had been involved in a small local oil spillage. Complete details were not included with the bird shipment.

The body cavities of the two above groups of birds were opened after death, and the entire carcass placed in containers of buffered 10% Formalin. The birds were then shipped to the San Diego Zoo hospital for further examination. Each bird was identified by species and given an oil pollution accession number. They were then opened and the viscera examined for gross lesions. Tissue samples were taken from

Table 2 Santa Barbara birds used for pathology work

Species	Dead on arrival	Just after treatment	4-7 days after treatment	10-14 days after treatment	Total Birds
Western Grebe	7		6	4	17
Gull	2				2
Surf Scoter	1	1	1		3
Common Loon		1			1
Common Murre		2	2	4	8
Eared Grebe				1	1

heart, spleen, proventriculus, ventriculus, multiple sites of intestine, lung, kidney, brain and frequently the adrenal. These tissues were embedded in paraffin, cut into sections 3-5 microns thick and stained by Harris' alum hematoxylin method. The slides were examined for histologic alterations. Smears of intestinal contents of some birds were stained by Sudan III and examined for oil globules.

Internal Oil

One seagull and three cormorants were brought in to the Zoo hospital from local beaches. All were in weakened condition. The gull and two of the cormorants had spots of oil on their plumage and were washed in Polycomplex. They died shortly thereafter and post mortem examinations were made. Pathologic studies were made on all experimental birds which died during the course of this study, and on six mallard ducks that were euthanized following force-feeding of oil. The treatment of the latter birds is shown in the following tabulation:

Species	O.P.#	Amount of oil administered	Time sacrificed after treatment
Mallard	42	1 cc	24 hours
Mallard	44	1 cc	72 hours
Mallard	46	1 cc	120 hours
Mallard	41	3 cc	24 hours
Mallard	43	3 cc	72 hours
Mallard	45	3 cc	120 hours

Blood Chemistry

Blood was drawn from the brachial vein of four mallards washed with Polycomplex, four washed with Larodan, five oiled ducks and five normal controls, to determine blood glucose and blood urea nitrogen level. These two tests were made by means of Dextrostix and Azostix methods, made by Ames Laboratories, to determine whether changes related to the oiling had occurred in the function of the liver and kidney.

Bacteriological Examinations

Bacteriological studies were limited to attempts to isolate enteric pathogens. Small (approximately 1/2 gram) aliquots of feces or intestinal content were inoculated into bottles containing 50 ml of Selenite broth. Following overnight incubation at 37 C, transfers of the culture were made to differential culture media plates.

Colonies showing morphological characteristics of enteric pathogens were transferred to triple sugar iron agar slants. Colonies which produced reactions on this media characteristic of pathogens, were sub-cultured in sugar fermentation tubes, and checked for biochemical reactions.

SECTION V

RESULTS

Duck Behaviour after Oiling

The ducks used in the oiling experiments showed no outward signs of fear of the oil. Many birds entered the "oil pool" without hesitation, began bathing and drinking. The ducks after oiling appeared similar to the average oiled cases seen at Santa Barbara. The birds just after oiling displayed a disturbance in coordination and equilibrium. When they tried to walk, some would fall, others tried to stabilize their balance by flapping their wings, only to fall backwards in the process. After several attempts at walking, most ducks sat quietly and preened. Some birds bathed and a significant number drank water. Some shaking of the body and plumage was noticed.

Cleaning Methods

Approximately two gallons of one percent Polycomplex was required to wash one duck. Polycomplex removed most of the oil from the sixty mallards used in this experiment. Little difference was noted in the time required to clean birds washed twenty-four hours after oiling from those washed five hours after treating. A thorough washing could generally be completed in ten to fifteen minutes. In a few cases, where spots of oil were thick and tarry, some difficulty was experienced in removing all of the oil. After the oil was washed from the feathers there was evidence that the feathers had been stained a darker color.

Larodan 127 proved to be less effective as a cleansing agent. Approximately one-half gallon of Larodan was required to wash each bird. To conserve on Larodan, the washing process was started in that used on a previous duck and completed in fresh Larodan. Total washing time was over fifteen minutes for each bird. An oil residue was still discernible after washing. The outer layer of contour feathers was moderately well cleaned, but the underlying down remained oily. Larodan did not have a good cutting or dispersing action on the oil. Most of the oil had to be removed by rubbing with sponges. Considerable difficulty was experienced in removing oil from the down feathers. Staining of the feathers after Larodan washing was more apparent than when Polycomplex was used. The washing process was more tedious.

Skin and Cloacal Temperature

Skin and cloacal temperatures were taken on all ducks over a period of three weeks prior to any treatment. These temperature readings served as control temperatures for comparison, with temperatures taken after treatment. Skin temperatures of mallard ducks prior to oiling and under variable ambient temperatures, ranged from 99.0 F to 109.0 F, with an overall average of 104.4 F. The cloacal temperatures of the same group of mallards, and under the same ambient temperatures, ranged from 101.0 F to 110.0 F, with an average of 107.4 F. For five ducks which were oiled but received no further treatment, the pre-oiling temperature averaged 105.2 F, with a range of 104.0 F to 108.2 F. Immediately after oiling, temperatures ranged from 103.6 F to 107.8 F, with an average of 105.2 F. From this point on, over a thirty-day period the skin temperatures showed a moderate decline, with a range from 100.0 F to 105.6 F and an average of 102.2 F after oil treatment, as shown in Fig.1. Twenty oiled mallards were washed in Polycomplex, ten of them five hours, and ten of them twenty-four hours after oiling, and half of each group received a lanolin treatment. A slight decline in skin temperature was seen in each group during the first six days. All groups returned to the normal temperature range during the following three-week period.

The same group of ducks had an insignificant elevation of cloacal temperature, possibly due to handling, during the first twenty-four hours after washing, followed by a decline in average temperature of approximately 1 F during the following six days. Thereafter their cloacal temperatures remained near the pre-treatment normal. This is in contrast to the oiled but no treatment group. The effects of the above treatments on skin and cloacal temperatures are presented in Figs.2 and 3.

Skin and cloacal temperatures of sixteen ducks washed in Larodan are presented in Fig.4. The average skin and cloacal temperatures for three readings over a ten-day period prior to oiling, range from 103.6 F to 104.0 F and 106.8 F to 107.6 F respectively. Oiling and washing with Larodan had little or no effect on these two temperatures. Both skin and cloacal temperatures declined only a fraction of a degree and returned to normal.

Skin and cloacal temperatures of pintail ducks were recorded five times between November 24 and December 11. On December 8 these birds were oiled, then washed in Polycomplex on December 9. Temperature records were stopped on December 11 because two of them had died. The average skin temperatures for three readings prior to oiling ranged from 102.3 F to 104.2 F. Three days after oiling and washing, the average skin temperature was 101.1 F. For the same period the cloacal temperatures ranged from 107.0 F to 108.8 F and three days after oiling and washing the average temperature was 105.3 F. This decline of approximately 2 F may have some significance.

Body Weights

On August 28, five days after arrival of the mallards, the body weights ranged from 715 to 1170 grams, with an average of 1048 grams. The average body weights declined to 1025 grams on September 4 and 1022 grams on September 8, before any of the birds had been oiled. The average body weights on September 23 for sixteen ducks which had received no treatment, was 1141 grams, indicating that

Fig. 1 CLOACAL AND SKIN TEMPERATURES OF OILED DUCKS WASHED IN LARODAN–127

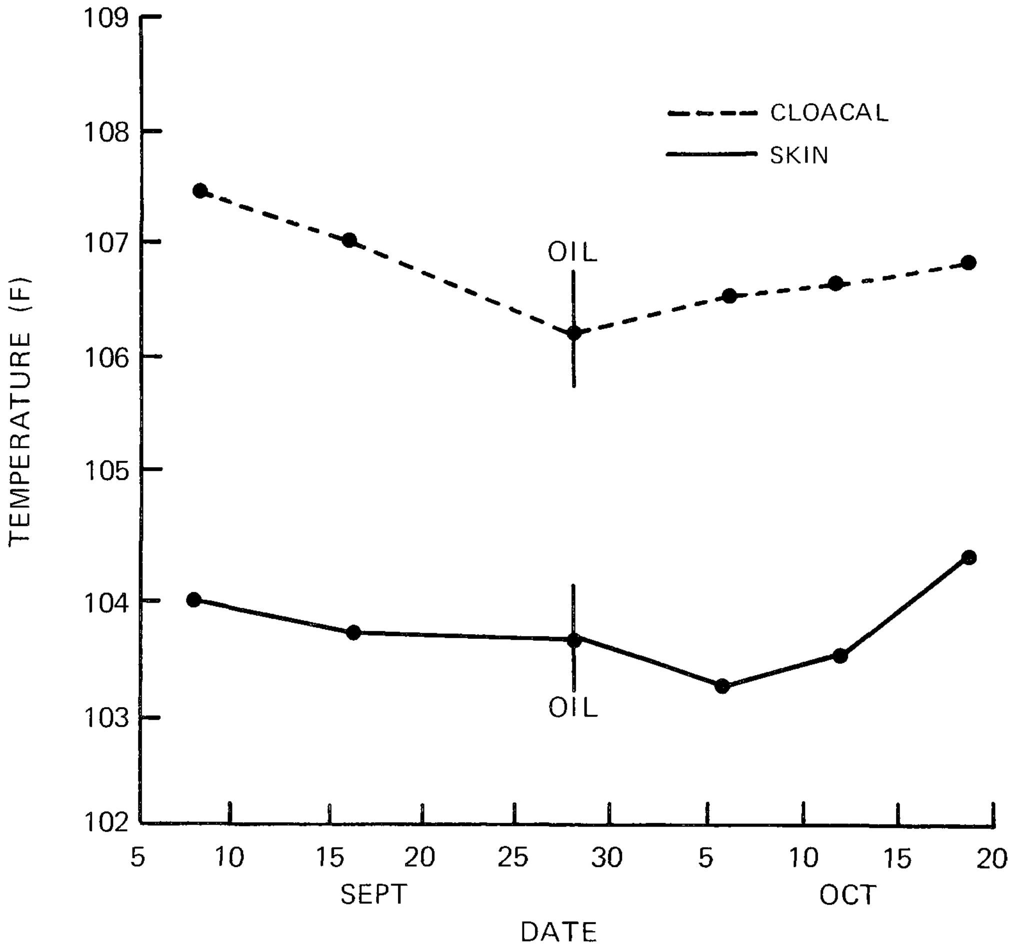


Fig. 2 SKIN TEMPERATURES OF MALLARD DUCKS WASHED IN POLYCOMPLEX

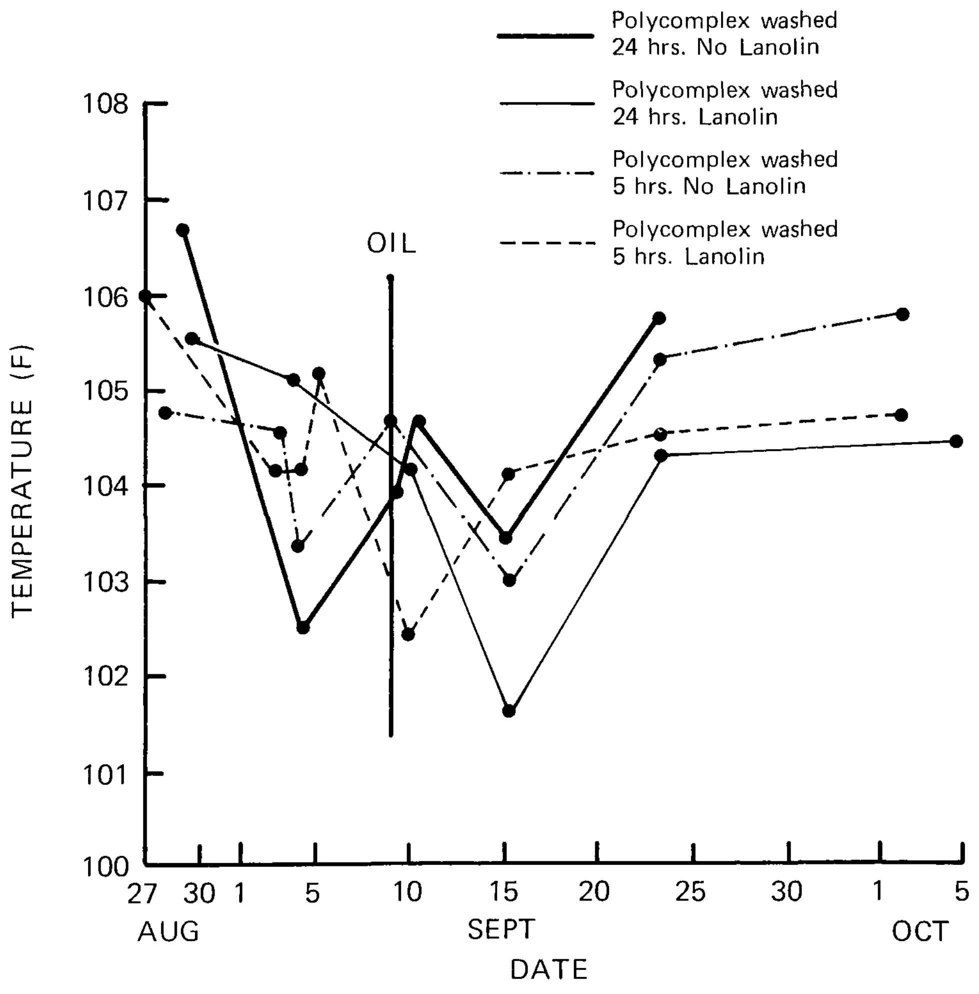


Fig. 3

CLOACAL TEMPERATURES OF MALLARD DUCKS WASHED IN POLYCOMPLEX

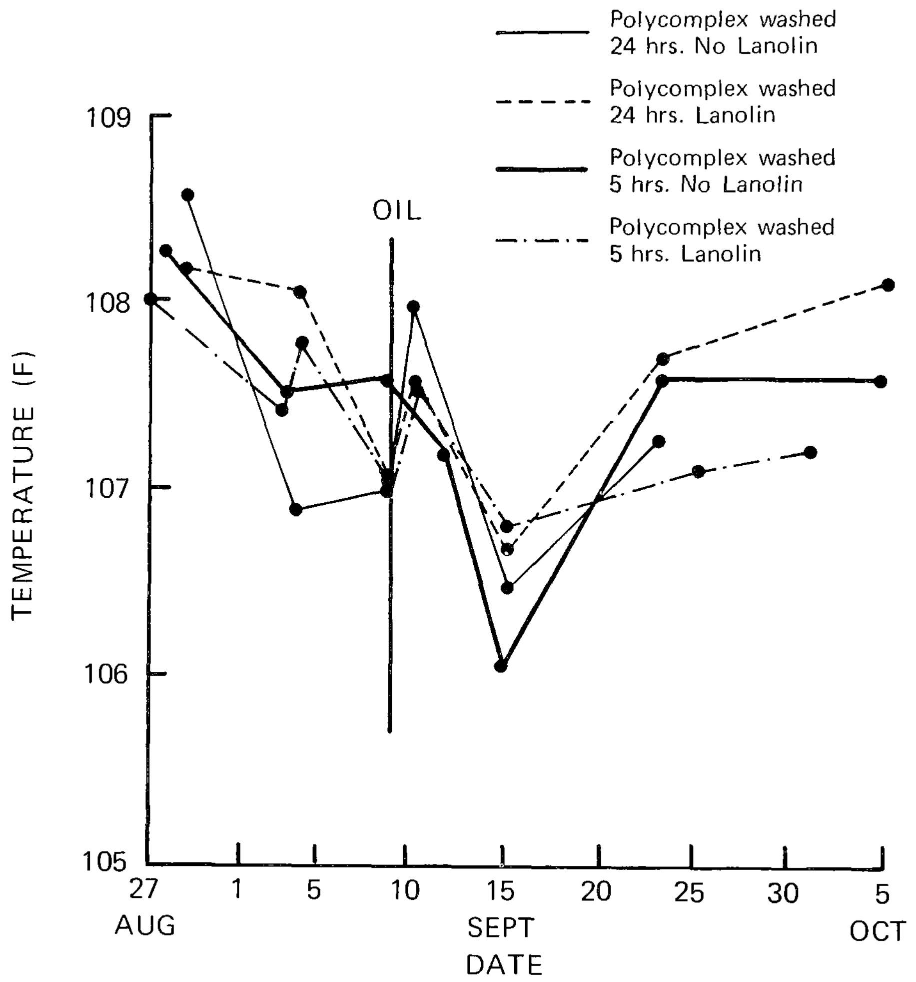
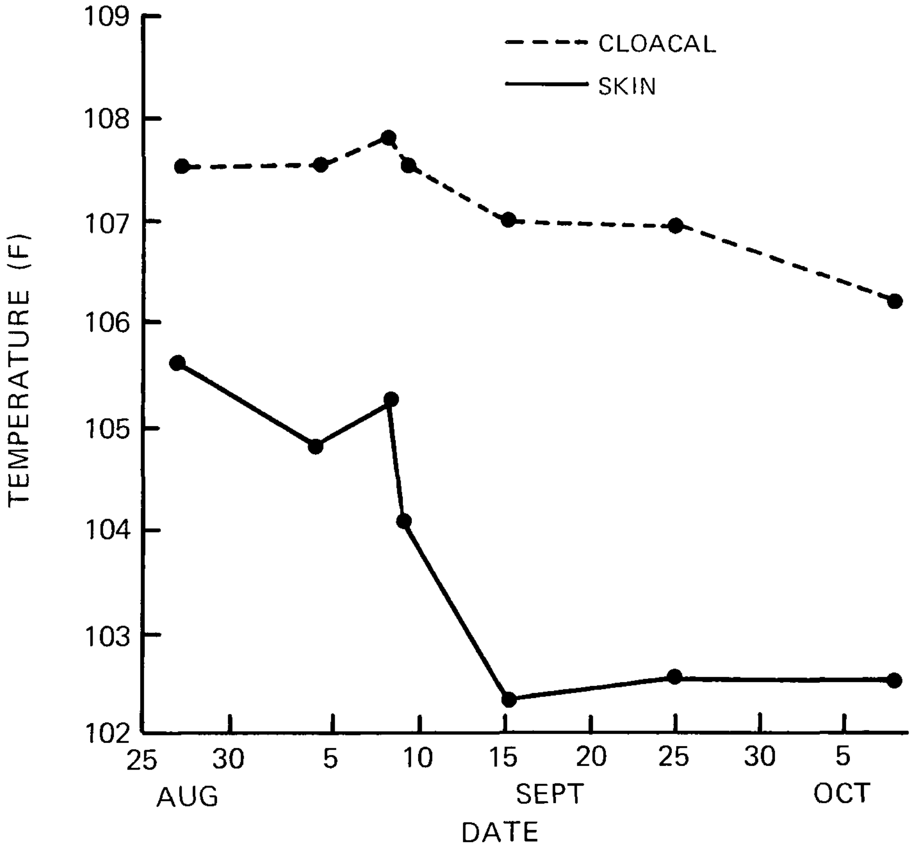


Fig. 4

CLOACAL AND SKIN TEMPERATURES OF OIL-NO TREATMENT DUCKS



body weight loss was leveling off at or near the time that the first birds were oiled. Oiling and washing in Polycomplex had no effect on body weights of the twenty ducks used in this experiment, as can be seen in Fig.5. By September 15, six days after oiling, the average body weights had started to increase and the rate of increase continued until September 23, when the weights leveled off or declined slightly.

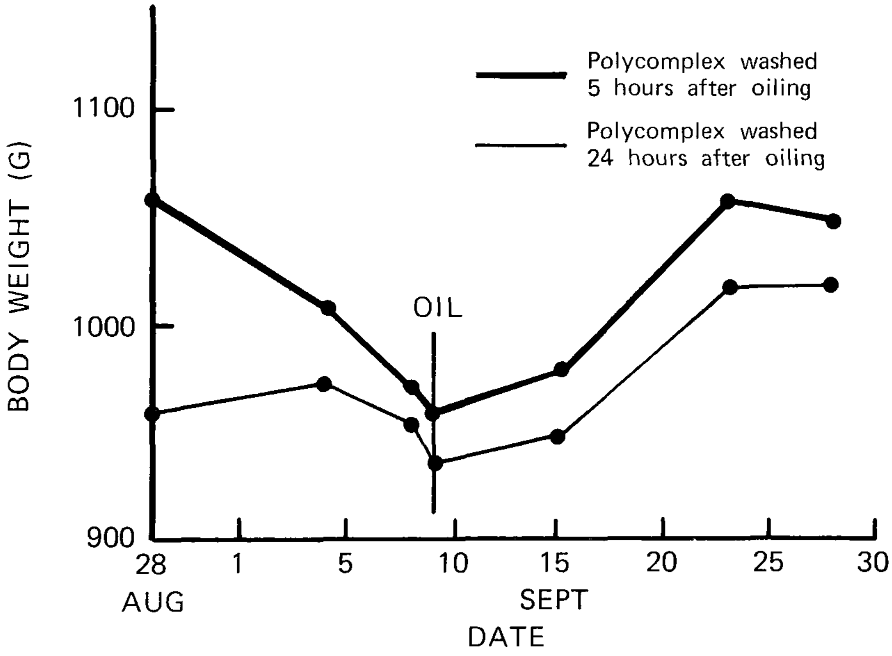
Body weights of eight ducks which were oiled and received no further treatment, followed the same general pre-oiling trend of weight loss as for all other groups of birds. The weights of these birds showed an increase from 1018 grams prior to oiling on September 8, to 1028 grams on September 9 and up to 1100 grams on September 15, but then declined to 1020 grams on October 5. This increase in weight can probably be attributed to oil on the feathers and to the dirt and sand that adhered to the feathers. The decrease in weight to the level of the washed ducks may be due to loss of some oil and dirt by preening. These birds showed no clinical ill effects from oil and there were no death losses.

The sixteen ducks washed in Larodan had an average body weight of 1142 grams on September 23 prior to oiling. One week after oiling and washing, their average weight had declined to 1106 grams and by October 15 their weight had increased to an average of 1160 grams. From these experiments it is apparent that the stress of oiling and washing resulted in a short term weight loss, but that the effects of the stress were of short duration, as evidenced by recovery of lost weight and a continued weight gain. It is also apparent that the oil itself had no toxic effects.

Water Uptake

The purpose of the water uptake test was to provide some qualitative data which could be used to evaluate the cleansing agents and the feather treatment methods. The results show that the plumage of normal ducks would retain on the average 29.3 grams of water. The range of water retention for the normal ducks was 15 to 45 grams. The five ducks which had not been oiled but had been washed in Polycomplex, had an average water uptake of 30 grams, which is comparable to the normal ducks. Ducks which were oiled but not cleaned had an average water uptake of 41 grams, with a range of 30 to 60 grams. The water uptake of oiled ducks washed in one per cent Polycomplex, ranged from 30 to 150 grams, with an average of 76 grams. Lanolin treatment of Polycomplex-washed ducks decreased the average water uptake by approximately twelve per cent. However, the range was wider, varying from 30 to 180 grams. Only two of the fifteen ducks retained more than 100 grams of water. The median for this group was 50 grams. Spermacetti treatment of the Polycomplex-washed plumage was less efficient as a water repellant than was lanolin. The average water uptake of spermacetti-treated Polycomplex-washed ducks was greater by three per cent than for the Polycomplex-washed group. The results for spermacetti-treated ducks reveal an average water retention of 79 grams with a range of 60 to 125 grams and a median of 70 grams. According to these tests, Larodan treatment of oiled ducks was the least effective

Fig. 5 BODY WEIGHTS OF MALLARD DUCKS WASHED IN POLYCOMPLEX



from the standpoint of water retention by treated plumages. The average water uptake for the Larodan-treated ducks was 142 grams, with a range of 60 to 195 grams. The median for this group was 150 grams.

Feather Structure

Normal, oiled, washed, and treated feathers were examined microscopically, to determine effects of oil and treatments on feather structure. A normal feather (Fig.6) has a long central shaft, supporting smaller branches or barbs angling toward the tip of the feather. The branches form the vane of the feather. The central shaft has two parts: (1) a hollow base or calamus; (2) a solid shaft or rachis. The barbs have additional branches called barbules. The barbules on the two sides of the feather are dissimilar; the anterior barb (toward the tip of the feather) has small branches called barbicels, which bear hamuli along the middle portion of the underside. The posterior barbules have no hooks but they form ridges in which the hamuli hook. (See detailed drawing in Fig.6). Fig.7 illustrates the latticework and regular spaces created by the barbules and barbicels. Fig.8 shows an oiled feather which has not been washed. It is apparent that the oil has dislocated many of the barbule and barbicel attachments, leaving comparatively large spaces which have been filled with oil. This disruption of the fine feather structure decreases the amount of air retained in the plumage, decreasing the buoyancy and insulation of the bird. Oil adhering to the feather structure permits water to penetrate deeper into the plumage.

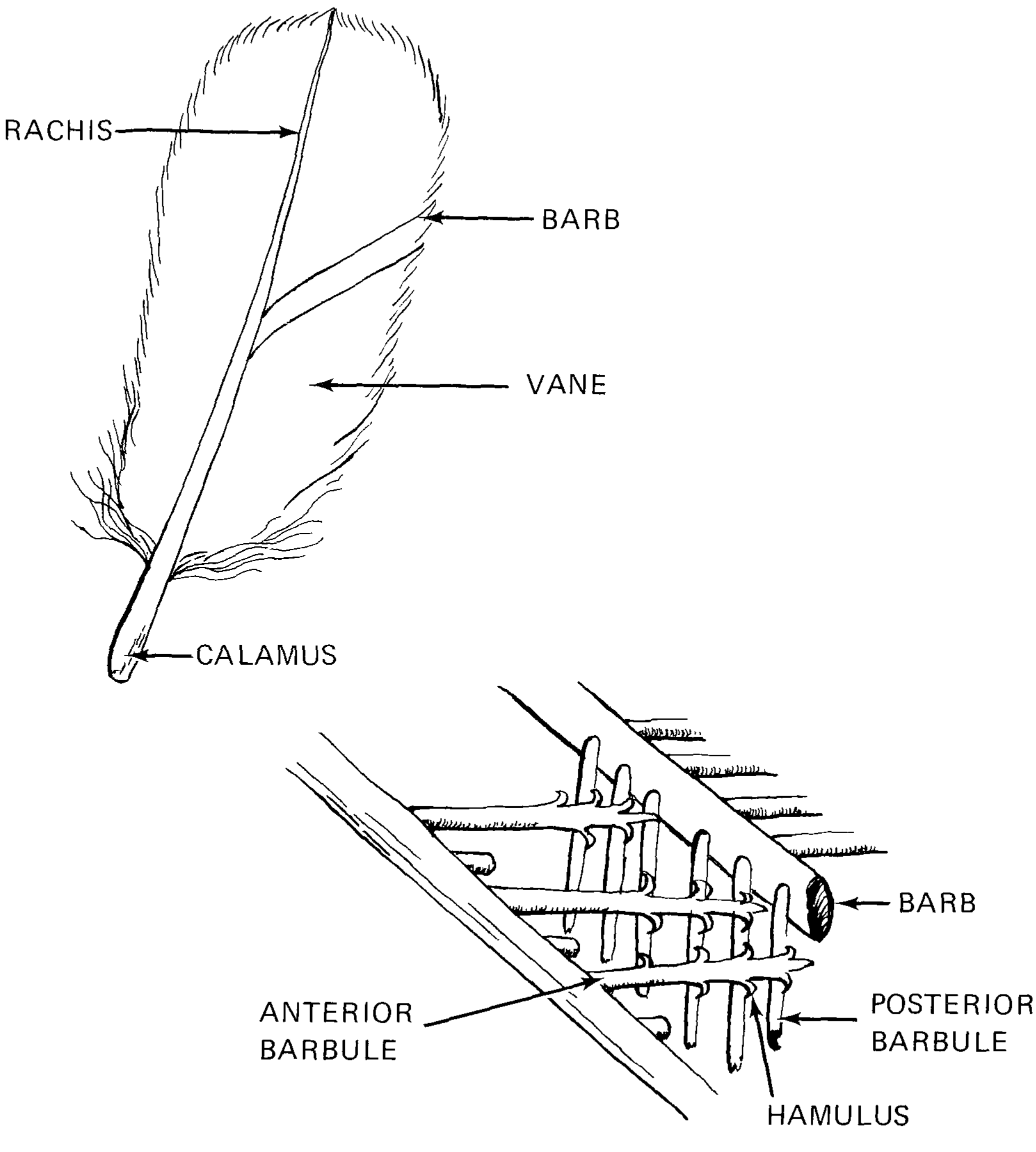
Feathers washed in Polycomplex showed similar disarrangement of latticework but only a few areas had the "oil film" adhering to the vane. (Fig.9) Feathers *treated with lanolin could not be readily differentiated from those that were* simply washed in Polycomplex. (Fig.10)

Down feathers occupy the area under the contour feathers; they help in insulation and inhibit water resorption. The feather itself lacks a vane and only has a short rachis. When oiled, these feathers clump and mat together. It is likely that contamination of the down feathers breaks down the insulation by permitting water to penetrate to the skin.

Feathers removed from mallards which were oiled then washed in Larodan, showed a much greater amount of oil coating the barbs and barbules. (Fig.11) This oil appeared thicker, and small particles of dirt and extraneous material adhered to the feathers. Several feathers, removed two weeks after treatment, were much cleaner and showed little oil between barbules. Structurally these feathers appeared nearly normal. Oiled feathers may lose a great part of their insulation effectiveness when the down feathers are matted and when the contour feathers are structurally disarranged.

Pathology - Birds from Santa Barbara

Carcasses of thirty-two waterfowl were received from Santa Barbara for pathology



STRUCTURE OF A NORMAL FEATHER

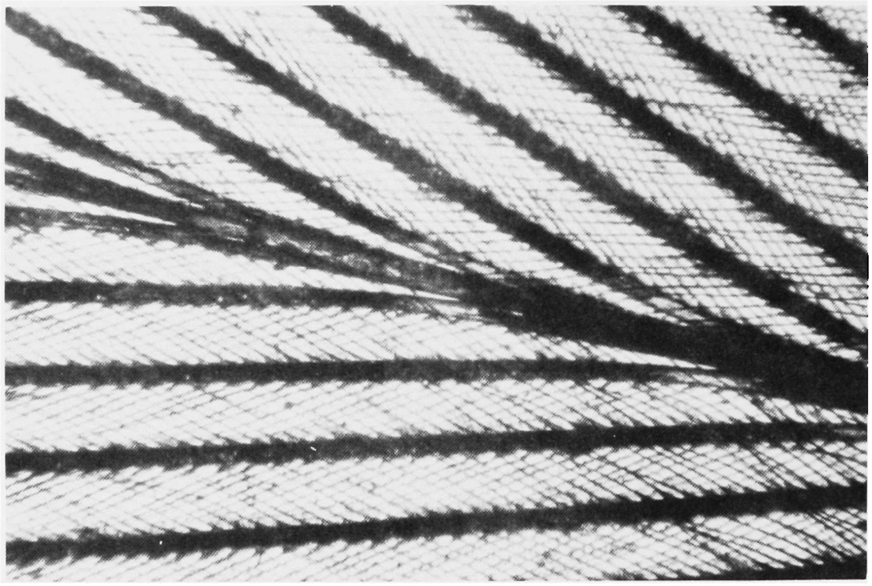


Fig. 7 Normal feather

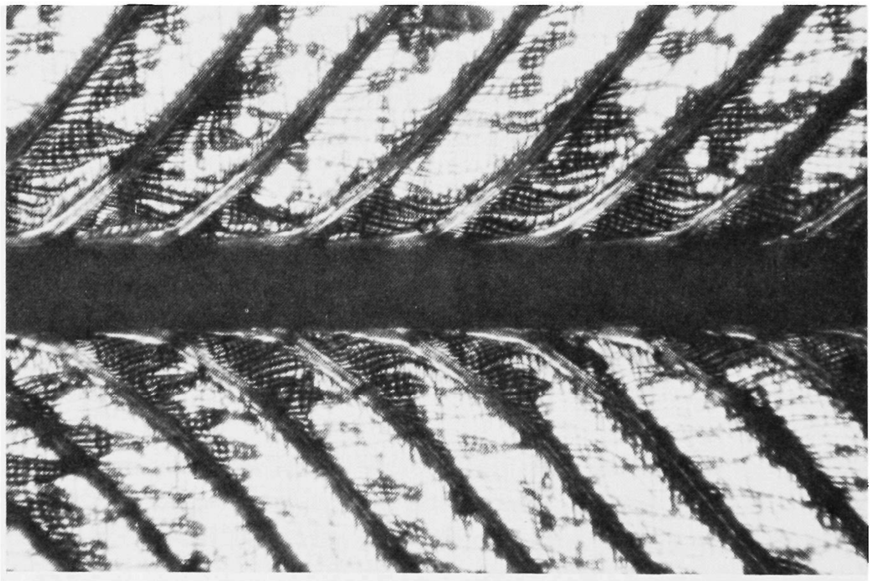


Fig. 8 Oiled feather

Fig. 9 Oiled feather washed in Polycomplex

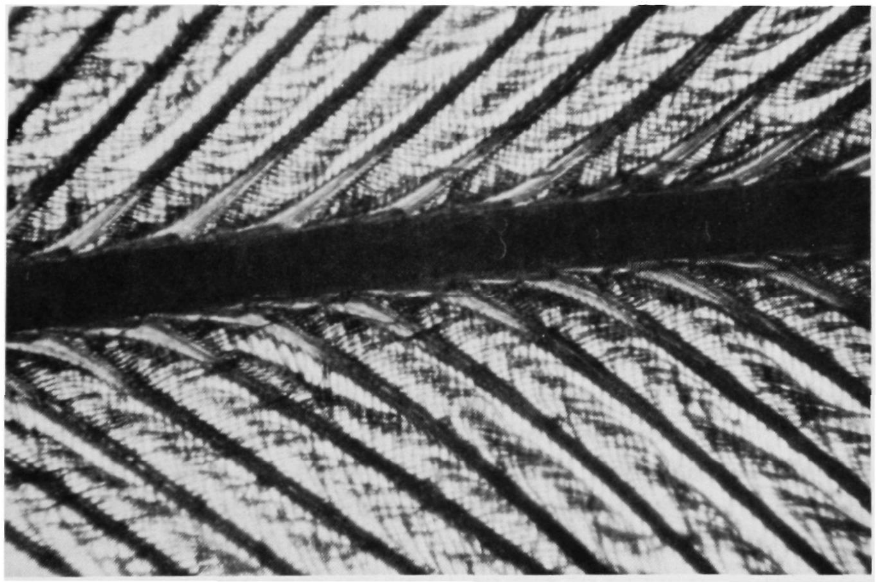


Fig. 10 Oiled feather washed in Polycomplex and treated with lanolin

Fig. 11 Oiled feather washed in Larodan

studies. Of these, ten were dead on arrival, four died very soon after treatment, nine died four to seven days after treatment, and nine died ten to fourteen days after treatment. It is assumed that all were cleaned in Polycomplex. Gross and microscopic examinations were made on all of these specimens.

The ten birds in group #1 which were dead on arrival at the treatment center consisted of one male California gull, one female Ring-billed gull, one male Surf scoter and seven Western grebes (four females and three males). The California gull was emaciated. The gall bladder contained a large quantity of whitish-green, gritty precipitate, and the liver had a marked retention of bile pigment. Many cestodes were present in the small intestine and a few nematodes were present in the proventriculus. Emaciation and heavy parasitic load were contributing factors to the death of this bird. No evidence of oil toxicity or pneumonia was observed. Emaciation was pronounced in the Ring-billed gull. The proventriculus contained a few trematodes, and the intestine contained nematodes and trematodes. Multiple small granulomatous lesions were found in the intestinal mucosa and they appeared to be associated with embedded parasites. There was also evidence of a few intestinal ulcers. These pathologic findings, along with the stress of being contaminated with oil and its inability to feed normally, contributed to the bird's death. The Surf scoter was in a fair state of nutrition, but like the Ring-billed gull, the intestines contained many parasites and small intestinal parasitic granulomas. The ventriculus was completely empty and there was no evidence of recent food ingestion. Advanced emaciation was noted in only one of the Western grebes; however, none of them was observed to contain normal fat deposits. The most interesting observation was that the ventriculus of all of the grebes contained a firm mass of dry, deeply bile-stained feathers and no evidence of food material. A marked excess of bile was found throughout the alimentary canal. These two observations would indicate that little or no food had been recently ingested. All but one of the grebes were found to have a heavy cestode infestation of the intestine. A few parasites, including nematodes and trematodes, were found embedded in the glands of the proventriculus of most of the grebes. Inflammatory responses to these parasites were minimal. Moderate degrees of peribiliary hepatitis were observed in most of these birds. One of the grebes was found to have a hepatitis associated with what microscopically appears to be toxoplasma or an unidentified protozoa. Moderate interstitial nephritis with a few tubular microcalculi were observed in three grebes. Glomerular enlargement and hyalinization were noted in one of the grebes. Vascular congestion was the only finding observed in the respiratory system. In general, it can be concluded that malnutrition due to reduced or total loss of food intake, along with heavy parasitism, played a role with the stress of oiling, in the death of the birds.

The birds in group #2, dying soon after treatment, consisted of one male Surf scoter, one female Common loon, and two male Common murres. In general, the findings in this group were similar to the first. There was no evidence of oil toxicity in the liver or kidney. The Surf scoter was in a poor state of nutrition.

A chronic thickening of the intestinal lamina propria with a few granulomatous foci due to parasites, was observed. A moderate degree of focal interstitial nephritis was also noted. The alimentary canal of the Common loon was empty. There was considerable bile present in the gall bladder and intestine. A focal peribiliary hepatitis of little significance was observed. Malnutrition was a major factor in the death of this bird. A portion of fish was present in the proventriculus of one of the two murres, but this bird was severely emaciated. This bird also appeared to be anemic. The other murre was in a better state of nutrition. The proventriculus contained many nematodes, but only a few were found in the intestine. Focal peribiliary hepatitis was also noted. Malnutrition played a role in the death of these birds.

The composition of group #3, nine birds dying four to seven days after treatment, was one male Surf scoter, two Common murres, and six Western grebes. All of these birds were in a fair to poor state of nutrition. The Surf scoter was emaciated, the alimentary canal contained no feed. A few cestodes were present in the intestine, and on the serosal surface were a number of small cysts containing small nematodes. The lungs were congested. Severe pathologic changes were observed in the kidneys. These lesions were characterized by infarction, necrosis, and interstitial inflammation. Glomerular enlargement and fibrosis were also observed. Trematodes were seen in the renal pelvis. Death can be directly attributable to the renal disease. A chronic granulomatous proventriculo-esophagitis was found in the female Common murre. These lesions, which also involved the anterior or cervical air sacs, were characterized by periarteritis and infiltration of mononuclear cells into the serosa and wall of the proventriculus and esophagus. The lesions were suggestive of a mycotic infection but no fungi were observed. No parasites of consequence were found. The lungs and kidneys were normal. The male murre was found to have a similar, but more advanced, inflammatory disease involving the proventriculus, air sacs, and lungs. Granulomatous lesions were marked in the lung and many myceliae, of what may be aspergillus, were present in these lesions. The bile ducts were thickened and hemorrhagic lesions were noted in the duodenum. An interstitial nephritis with microcalculi was noted. It appears that both murres suffered from a mycotic infection of air sacs and lungs.

The six Western grebes in group #3, like those of group #1, had a mass of dry, bile-stained feathers filling the ventriculus, indicating reduction in feed intake and regurgitation of bile. All of these birds had many cestodes in the intestine. Focal biliary hepatitis was noted in five of the six; and, in two, there were lesions of some severity. Occasional parasites were also seen in the proventriculus. Focal broncho-pneumonia of undetermined cause was noted in three grebes, and one of these also had an airsacculitis. Moderate interstitial and glomerular nephritis were noted, with some microcalculi. A possibility of a hematoprotozoa was observed in the heart of one grebe.

From the pathologic study of the group #3 birds, it would appear that respiratory infections may become established soon after the birds were brought in to the holding pens, and that a reduced feed intake contributes to the lowered resistance of the waterfowl.

The species composition of the nine birds in group #4 was four male Common murres, one male Eared grebe and four Western grebes (three males and one female). These birds died ten to fourteen days after washing and treatment.

A severe mycotic pneumonia and airsacculitis were the primary pathologic alterations in three of the murres. The lungs of the fourth murre contained a few focal areas of broncho pneumonia. The mycotic infection had spread into the heart and liver of two murres and into the esophagus and proventriculus of another murre. A few nematodes were seen in the proventriculus of the murres. The murre with the least pulmonary involvement was found to have a generalized suppurative nephritis. The pattern of the pathologic changes suggest that this was an ascending renal infection.

The ventriculus of the Eared grebe contained no feathers but was distended with gravel. Cestodes were abundant within the intestine. Along the serosal surface of the intestine were many cysts and foci of granulomatous inflammation, resulting in a peritonitis with multiple adhesions. Amyloid has been laid down in the liver and kidney; in addition, focal granulomas were observed in the liver.

The Western grebes of group #4 were in a poor state of nutrition. The ventriculus contained dry, bile-stained feathers. Two of the four grebes harbored many cestodes and a few trematodes in the intestine, and in one of these no other pathologic changes of significance were noted. The other had a biliary cirrhosis, probably related to a hepatic protozoa as well as early focal broncho pneumonia. Granulomatous hepatitis of bacterial origin was found in one of the grebes. The fourth Western grebe also had a parasitized intestine with focal granulomas of the mucosa and, in addition, a generalized mycotic airsacculitis and an ascending nephritis. From this group of birds, it appears that the incidence of mycotic and other infectious diseases increases with time in the captive environment. It should be mentioned that no pathologic alterations were present in the brains of the birds from Santa Barbara. There was also no evidence of toxic changes in any of the tissues.

Pathology - Birds from Nye Beach, Oregon

The four murres involved in a local oil pollution at Nye Beach, Oregon, included one male Common murre and three California murres (one male and two female). The Common murre was emaciated. A few nematodes were in the glands of the proventriculus. A moderate cestode infestation was found in the intestines. A few sarcocyst-like structures were found in the proventriculus. The heart of this murre contained focal areas of myocardial degeneration but no cause was apparent. The liver, lungs, kidneys and brain were normal. A female California murre had a few nematodes in the proventriculus and in the muscular layers were observed sarcocyst-like structures. This bird also had some peribiliary hepatitis. No parasites of significance were discernible in the other two California murre. Both birds had interstitial nephritis of considerable distribution.

Western Grebe Comparison

In order to determine the significance of the masses of dry, bile-stained feathers in the ventriculus of the Western grebes, a request was made that a small group of normal Western grebes be collected for post mortem examination. Mr. Ronald Clawson arranged for the collection of five Western grebes from Tule Lake. All of these birds were in a good state of nutrition. Fat was deposited in both subcutaneous tissues and in the body cavities. Post mortem examination of the ventriculi revealed the presence of feathers in this organ. The feathers, however, were gray in color and moist, due to the presence of recently ingested fish in various stages of digestion. There was no evidence of bile in the contents. It is therefore evident that feathers form a portion of the normal content of the ventriculus of Western grebes. However, when the feathers are dry and bile-stained, and when no evidence of feed is present, it is proposed that this can be interpreted to indicate that feed intake has ceased or has been depressed when these birds are involved in oil-polluted waters.

It was further noted that small oval red nodules in the glandular portion of the proventriculus (Fig.12) contain nematodes, and that most of the grebes are parasitized, but that the parasites have little pathologic significance. Four of the five grebes carried considerable numbers of cestodes and trematodes in their intestines. Focal biliary hepatitis and interstitial nephritis can be expected in many normal grebes.

Pintails

Four of the twelve wild pintails used in the oiling and washing procedure using Polycomplex, died. These birds were in a fair to poor state of nutrition. No gross or microscopic lesions of consequence were found. The cause of death could not be ascertained. The only conclusion that can be considered is that the stress and shock of the capture and handling during oiling and washing added to their general poor condition and was sufficient to cause their death.

Oral Administration of Oil

As previously stated, six mallards received oral administrations of oil, three receiving 1 cc and three receiving 3 cc. One bird of each group was sacrificed at twenty-four, seventy-two and one hundred-twenty hours following treatment. Considerable amounts of oil were observed in the feces of these birds during the first twenty-four hours. Gross oil in the feces was also observed during the first twenty-four hours, of other birds that were placed in the oil bath.

Necropsy of the mallards in this experiment revealed no evidence of gross pathologic changes. Oil could be seen on the intestinal mucosa of those ducks

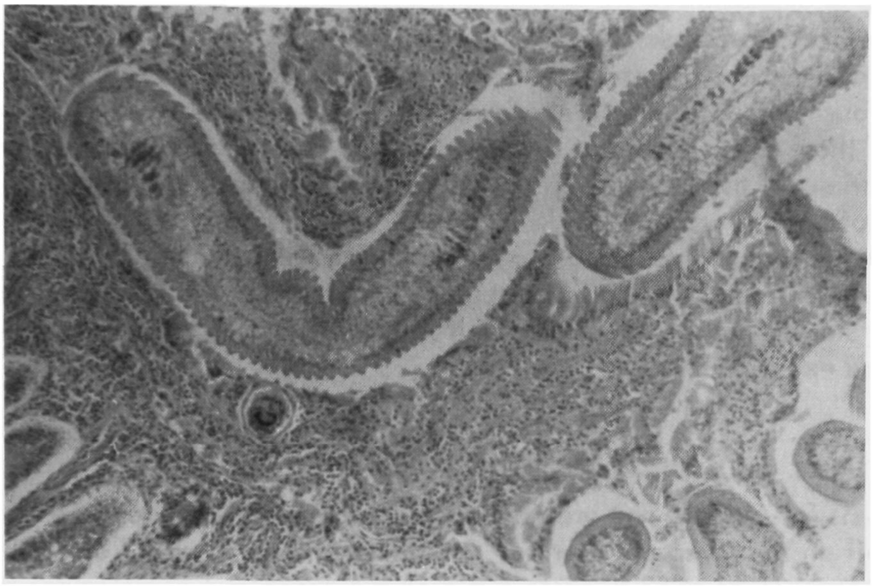


Fig. 12 Section through the intestine of a Western grebe showing trematodes in the mucosa and cestodes in the lumen.

sacrificed at twenty-four hours; and the oil was demonstrated microscopically in the intestinal contents. Lesser amounts of oil were demonstrable in the intestine of the birds sacrificed at seventy-two and one hundred-twenty hours.

Tissues were prepared for histopathologic examination by the standard paraffin block method with H & E stain, and by frozen sections with Sudan III stain. Microscopic examination of these tissues revealed no pathologic processes of significance. In the frozen section, oil globules were present in abundance along the intestinal mucosa and between the mucosal villa of the two ducks sacrificed at twenty-four hours. Progressively fewer oil globules were noted in the intestine of those ducks killed at seventy-two and one hundred-twenty hours. Paraffin sections of the lungs of all six ducks were observed to contain focal peri-bronchial nodules of macrophages, histiocytes and lymphocytes. The cytoplasm of these macrophages contained brownish-black pigment particles. Some of the particles seen in these cells had a morphology indicative of a crystaline material. Smaller but similar nodules were observed in the lungs of many of the other ducks used in these experiments.

Blood Chemistry

Blood analysis for glucose and urea nitrogen were employed as tests for the toxic effects of oil on the liver and kidney. Blood urea nitrogen could also indicate an increase in catabolism of body protein during the process of emaciation, when feed intake is insufficient to maintain the normal metabolic rate. The results of thirty-six blood glucose determinations on eighteen ducks prior to any treatment showed a range of 90 to 130 mg per cent. The same range in blood glucose was observed in the thirty-six determinations made following oiling and washing in Polycomplex and Larodan. There was no evidence that the treatment of the ducks produced toxic effects that would cause a change in the blood glucose levels. Blood samples from the same ducks were used for measuring blood urea nitrogen. The same level, 10 mg per cent, was found for all birds before and after treatment.

Bacterial cultures made from feces of normal ducks and intestinal contents of birds dying during this study did not produce colonies of known enteric pathogens. It would appear that enteric pathogens were not a problem in this study.

Data Analysis - Santa Barbara

Two reports of birds handled during the Santa Barbara oil disaster were obtained for analysis. The Union Oil Company kept records of all birds maintained at the Carpenteria cleaning station, and records were also kept at "A Child's Estate" zoo.

The first entry at Carpenteria was dated February 3, 1969, the last entry March 11, 1969. During this time 812 birds were treated: 62% were Western grebes, 11% were loons, 8% scoters; the other 19% were mainly cormorants, murres and Eared grebes. Unfortunately, due to incomplete recording of bird deaths and disposition, a survival percentage would be misleading. Most birds died, the Western grebe having the greatest mortality, while the gulls seem to have the highest survival ratio.

"A Child's Estate" zoo records showed that 558 birds were treated: 38% were Western grebes, 13% loons, 12% Surf scoters, 11% cormorants and 4% murres. The remaining 22% were mainly Eared grebes, Ruddy ducks and gulls. Again a percent survival would be misleading. Only twenty birds were indicated as being released in the report. There were one hundred and five birds in which neither death or release had been recorded.

Most of the birds treated died within the first ten days; however, several birds lived longer than twenty days. Grebes showed the longest survival time. An Eared grebe lived twenty-five days before dying, and several Western grebes lived twenty days.

SECTION VI

CONCLUSIONS

The results of this investigation strongly indicate that the oil from the Union Oil Company well at Santa Barbara did not produce toxic changes in the birds studied. Literature pertaining to other oil pollution studied however, indicates that there do exist petroleum products that are toxic to waterfowl and other aquatic life. It is therefore concluded that when oil spillage occurs, it may be advantageous to identify the petroleum product involved, and to assay it for known toxic constituents.

The species of waterfowl that are involved or might be involved in oil polluted waters, will influence management methods. Management methods will of necessity have to be varied according to the types of birds involved. It appears that fowl which are both terrestrial and aquatic (ducks, geese) can be handled and cared for more readily than those species which are almost entirely aquatic (grebes, loons, murres etc.) This might also be restated on the basis of diet: that is, those species which have a herbiverous or omniverous diet are more readily managed than those which have a carniverous diet.

The removal of contaminating oil from bird plumage was more effectively achieved by the use of one per cent Polycomplex. This product dispersed the oil with less effort and manipulation of the birds' plumage than did Larodan. The use of a sonic machine, as tried at Santa Barbara, may perhaps reduce the time required to cleanse the oil from the birds' feathers.

One per cent lanolin in Hexane as a surface film on water, produced some water-proofing of feathers washed in Polycomplex. Further study of lanolin at 0.5 or 0.1 per cent might prove to be of greater value since feathers treated at 1.0 per cent were somewhat too oily. On the basis of water uptake by plumage, lanolin applied after Polycomplex was superior to Larodan.

Preening of oiled feathers made ingestion of oil possible, and if the oil contained toxic substances this would further reduce the potential salvage of contaminated fowl. No evidence was found to indicate that oil pollution impaired the ducks' ability to regulate and/or maintain a normal body temperature. This conclusion was also reached by Hartung, providing feed intake equaled metabolic needs and that the stored caloric reserves were not depleted.

For successful salvage of oiled waterfowl it is essential that feed intake equal to basal metabolic needs, be established as soon as possible. For fish-eating species this will present a management problem. Little difficulty was experienced in getting ducks to accept grain and complete poultry rations. The post mortem and histopathologic studies of birds from Santa Barbara indicate the need for a good plan of nutrition to offset catabolic loss from stress and anorexia.

The longer the aquatic species were held in close confinement, the greater was the incidence of pulmonary mycosis. It is also probable that the internal parasite load of normal birds involved in oil polluted waters might increase the rate of expenditure of stored metabolic reserves leading to emaciation and increased susceptibility to infectious processes. It is therefore imperative that management programs include a supply of acceptable or normal foodstuffs such as live fish, for the more aquatic species.

It would seem desirable to have a ready source of supply of Polycomplex or any other form of cleansing agent that may be found to be efficacious, so that it could be placed into immediate usage when further oil spillages occur. A facility for the care and treatment of aquatic fish-eating birds should be of sufficient size to prevent over-crowding and to also provide a shallow source of clean water which could be supplied with small fish. Such a facility could be designed for fresh or salt water areas. A sketch of a possible treatment area is included. (Fig.13)

The sides and back of the thirty by fifty foot rehabilitation pen could be wire netting to a height of six or seven feet. The top of the pen for a distance of twenty or so feet from the back could be covered by wire or nylon netting, or a more permanent cover that could also supply sun and rain protection as might be required. The front and side wings of the pen should have a water impounding structure of wood, metal or other material that would be able to impound water to a depth of about two feet. The impounded water should project back into the pen for a distance of eight to ten feet and thus provide a beach-like area. Wire netting two feet high should extend across the top of the water impounding structure. As birds recover sufficiently to fly over this netting and out into open water, they could be considered sufficiently recovered for release. The impounded water could be supplied with a fresh source of water by means of a pump. The impounded water should be stocked with a constant supply of suitable fish or other forms of aquatic animal life that may be available for food. During the period of heavy bird losses associated with the oil spill at Santa Barbara, there was some concern regarding the finding of small marine fish that contain a thiaminase enzyme. Many marine and fresh water fish contain thiaminase, which when added to the diet of ranch mink and fox, produce an encephalopathy which can be prevented by cooking of the fish or addition of thiamine to the diet. No evidence was found in the literature to indicate that this disease condition occurs in birds. Many waterfowl normally feed almost exclusively on small fish, without clinical evidence of central nervous system disturbances. The absence of information indicating pathologic effects of thiaminase from fish on fish-eating birds, would discount the concern which had been expressed in feeding live fish to birds involved in polluted water.

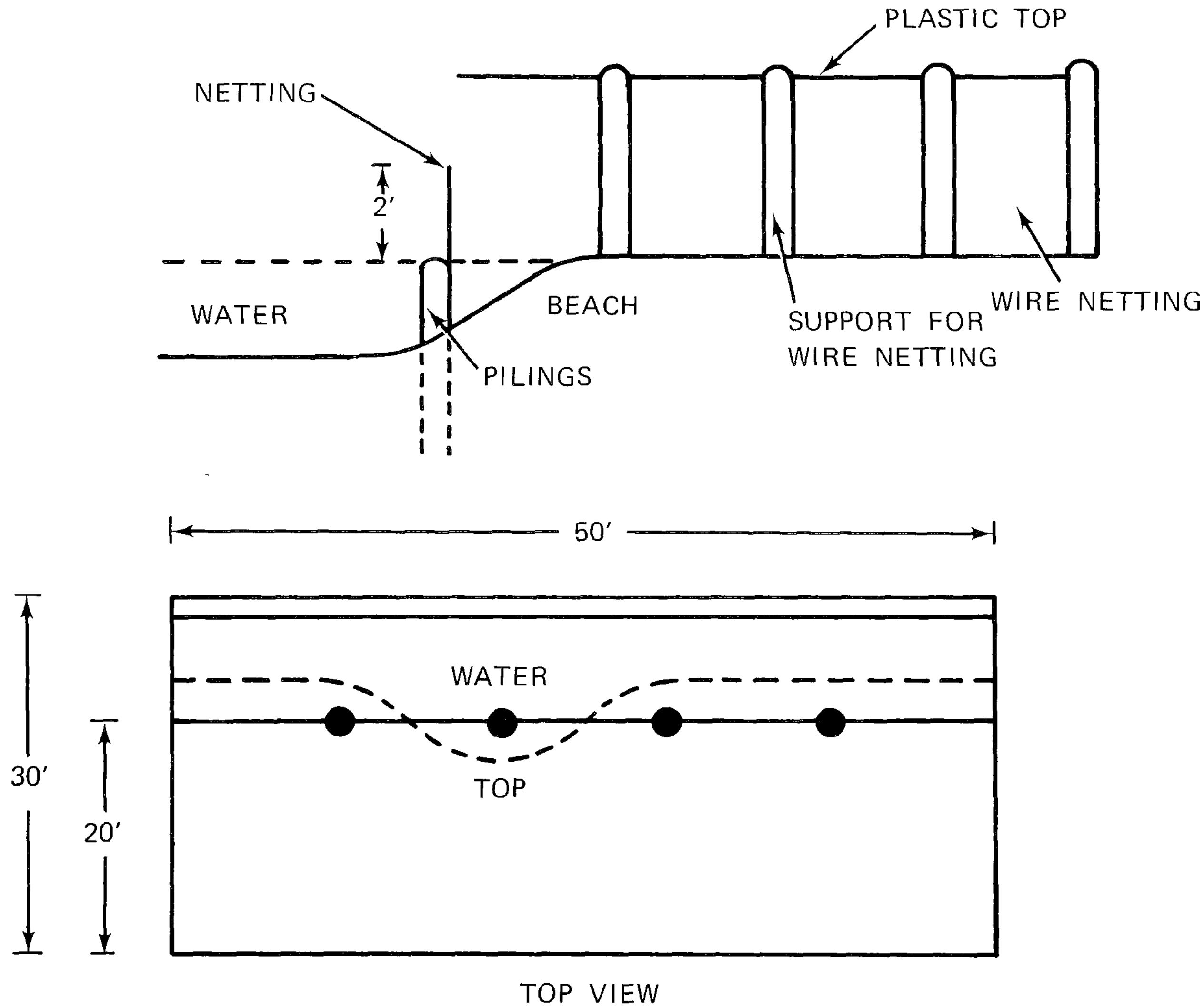


Fig. 13 REHABILITATION PEN FOR OILED BIRDS

SECTION VII

RECOMMENDATIONS

It is recommended that the Federal Water Quality Administration prepare plans for waterfowl management facilities for the cleaning and care of oiled birds. Plans for several types of facilities to care for the different types of waterfowl should be developed. Suggestions for such a plan are included in the conclusions.

It is recommended that no attempt be made to remove the intestinal parasites by means of anthelmintic, since such drugs would in all probability add further stress and upset the feed intake.

It was noted that many birds at Santa Barbara were dried using towels and heat lamps. It is possible that these efforts do more damage than good. Structural impairment to the feather can easily occur, and our results show that ducks are able to maintain body temperatures with adequate food intake. It is suggested therefore that the birds dry normally, thus reducing the possibility of further feather damage and also eliminating further behavioral stress problems. For successful salvage of waterfowl involved in areas of oil polluted waters, it is imperative that the birds be induced to return to a normal rate of food consumption. There appears to be little need for increased environmental temperatures if treated birds can be induced to feed. Increased temperatures in a rehabilitation area may also increase the possibilities for infections with mycotic or other agents. It is recommended that in the advent of future oil spillages, oil samples be immediately submitted for chemical analysis so that management of soiled birds can utilize the information so obtained.

If oil of a highly toxic nature is involved in polluting a water area, efforts should be directed toward a rapid clean up. Depending on local situations, it may be possible to devise methods such as distress calls to prevent birds from entering the polluted area.

SECTION VIII

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable assistance rendered by the following:

Mr. Ronald Clawson of United States Department of the Interior, Federal Water Quality Administration, supplied the normal Western grebes for comparison studies. Mr. Clawson also assisted in a general advisory capacity and in reviewing the manuscripts.

The crude oil from the Santa Barbara oil wells, used in these experiments, was supplied by the Union Oil Company of California.

Mr. Edward Green of the California State Fish and Game Department, advised and assisted in the trapping of waterfowl at Carlsbad Lagoon.

The McGraw Foundation generously donated the mallard ducks, which were the primary subjects used in these studies.

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SECTION IX

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ACCESSION NO.

ABSTRACT

A study was made of salvage methods for waterfowl subjected to oil pollution. Mallard ducks were the primary test species used. Aspects of the pathology of some of the waterfowl species involved in the Santa Barbara oil slicks were also investigated.

Although some refined petroleum products contain toxic compounds, the Santa Barbara crude used as a test oil in this study produced no apparent ill effects.

Polycomplex A-11 was found to be a rapid and effective cleansing agent for the removal of oil from bird plumage. Oil on bird plumage alters feather structure by replacing the small air pockets between barbules of the feather, thereby decreasing buoyancy and insulation. Removal of oil from down feathers is more difficult than from the contour feathers.

Ducks and geese are more amenable to treatment and post-treatment care than are the more aquatic fowl, such as grebes, loons, auks and murres. Confinement times should be as brief as possible as the incidence of mycotic and other infectious diseases increases under long periods of close confinement.

This report was submitted in fulfillment of Research Grant No. 14-12-574 between the Federal Water Quality Administration and the University of California at San Diego.

KEY WORDS

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Waterfowl

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Physiologic Effects

Pathologic Effects

Salvage

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