Research Unit # 96 - 77

Annual Report

Effects of Petroleum Exposure on Hatching Success and Incubation Behavior of Glaucous-winged Gulls (*Larus glaucescens*) in the Northeast Gulf of Alaska

by

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT IN THE NORTHERN GULF OF ALASKA:

This annual report of Research Unit 96 - 77 is addressed to the following task:

An analysis of the effects of petroleum exposure on hatching success and chick survival of Alaskan Glaucous-winged Gulls (*Larus glaucescens*) on Egg Island, Copper River Delta.

This investigation provides information on the effects of both North Slope Crude Oil and mineral oil on the hatching success and incubation behavior of a key seabird species nesting on the Copper River Delta barrier islands. Oil spill danger in the Copper River Delta barrier islands is high due to proximity to Valdez tanker lanes, offshore oil leases, counter-clockwise onshore currents, strong tidal interchange, shallow slope of the islands, and huge concentrations of birds including the largest gull colonies in the northeast Gulf of Alaska.

Colonial nesting and synchronization of the breeding cycle leave such marine bird populations as gulls open to catastrophic events such as major oil spills which could eliminate the productivity of the breeding season. In addition, bird species may be susceptible to chronic low-level oil pollution since recent evidence indicates high toxicity to eggs with very low levels of oil exposure.

Initial efforts in this study have been concentrated at one colony and with one marine bird species, since all species are likely to react similarly in the shell to oil. Research has been focused on Egg Island, where a control group and reproductive data are available from previous years.

We report egg oiling experiments had decided effects: North Slope Crude led to nearly complete mortality of all samples, approaching LD_{100}. We also report high mortality with mineral oil applied to gull eggs: hatching. success was 14.6% compared to the normal range of 69-77% in the adjacent control colony.

Oil application to egg surfaces causes not only high egg mortality, but behavior of the adult birds is altered and they do not renest during the season due to extended periods of incubation.

The combination of high egg mortality and alteration of adult behavior virtually eliminates gull reproduction in experimentally oiled areas.

II. INTRODUCTION

The Larinae (gulls) have a world-wide distribution with 42 species. Sixteen species of gulls are found in the North Pacific. Birds of this family are both inshore feeders and essentially marine species. Gulls are highly social birds; the forage and nest together. Gulls are suitable for population analysis, especially productivity because of their colonial breeding tendency.

An important reason for studying gulls is their use as indicators of the health of the environment. Chemical pollution of the environment poses an increasing and immediate threat to all organisms, including man. A recent survey of chemical residues in marine avifauna showed gulls to be among the most contaminated birds examined. Since gulls nest in colonies, changes in breeding populations can be monitored and related to environmental conditions, among which are industrial development and the concurrent changes in food supply.

The Glaucous-winged Gull (*Larus glaucescens*), which breeds along the coast from Washington State to the Aleutians, is an intrusive commensal species currently increasing in numbers due to availability of artificial food such as refuse and fish scraps. These gulls, nesting on island meadows, are excellent subjects for a study of reproductive success because eggs and young are readily accessible.

This report presents initial results of a study of the effects of petroleum exposure on meadow-nesting gulls in the northeast Gulf of Alaska. The study site has been selected for research because of the incipient development of offshore oil resources in the vicinity and the proximity to Valdez tanker lanes.

III. CURRENT STATE OF KNOWLEDGE

The devastating effects of massive oil spills on seabird survival are widely reported, but little is known of the effects of oil on avian reproduction (Grau et al, 1977). Although the effects of external applications of oil to eggs of marine birds are not well known, previous studies suggest that matchability can be markedly reduced (Gross, 1950; Birkhead et al, 1973). Rittinghaus (1956) reported Cabot's Terns Thalasseus sandvicensis) and other shorebirds became contaminated by oil washed up on shore. Eggs subsequently oiled by the plumage of incubating females did not hatch even after 50 days of incubation. Erickson (1962) reviewed the extent of the serious hazard of oil pollution *to* waterfowl. Hartung (1963) demonstrated experimentally that oiled ducks will injest significant quantities of oil in preening. Hartung (1964) found the average amount of polluting oil on the plumage of ducks was 7 grams, and noted that incubating birds turn eggs regularly, with oiling of eggs by breast feathers a thorough and continuous process until the termination of incubation. Hartung (1965) also found that mallards (Arias platyrhynchos) stopped laying for two weeks after injesting 2 gin/kg of "relatively non-toxic" lubricating oil, and that very small quantities of mineral oil applied to mallard eggs reduced matchability to 21% compared to 80% in normal controls of unoiled eggs. Experimentally oiled mallards continued to incubate clutches, but eggs did not hatch even though females continued incubation for longer than normal periods. The incubating hens were oiled with 4-5 ml of mineral oil on breasts and abdomens, and when released resumed incubation immediately. The mallard eggs did not hatch after 30 days of incubation, after which the eggs were opened for examination. Most were badly decomposed and no living embryos were found.

Abbott, Craig and Keith (1964) reported that coating of eggs with oil by spraying reduced hatching, presumably by interfering with normal respiratory exchange through the shell. Szaro and Albers (1976} found matchability of common eider (Somateria mollissima) eggs was significantly reduced by external applications of 20 microliters of an API oil; hatch-ability of mallard eggs treated with 5 microliters of oil after eight days of incubation was also significantly reduced. Eggs were particularly sensitive to small amounts of oil applied during early stages of development. Levels of oil used in these laboratory experiments may be well below levels encountered in the environment (Szaro and Albers, 1976); Hartung (1963) estimated that 3.5 gms was an average lethal level of oiling for lesser scaup (Aythya affinis) under natural conditions.

Grau et al (1977) reported that yolk structure, egg production and matchability are affected by single doses of bunker C oil to laboratory Japanese quail (Coturnix coturnix); bunker C oil had additional effects on yolk of chickens (Gallus g. domestics) and Canada geese (Branta canadensis) but effects on matchability were not tested in these species. Grau et al (1977) reported quail egg production was halted for 6 to 8 days by injestion of a 500 mg. dose of No. 2 fuel oil; 500 mg. of bunker C oil halted egg production for the duration of the two week trial. A dose of 200 mg. bunker C oil caused a reduction in quail egg production, but 100 mg had no apparent effect on egg production. Grau et al (1977) used mineral oil as a control for the above experiments; mineral oil injestion (500 reg.) did not reduce egg production. Kuwait and Louisiana crude oils, bunker C and No. 2 fuel oil all affected bird yolk structure. In addition, oil injestion was often followed by formation of thin eggshells which cracked.

The physiological mechanisms by which oil after injestion has its effects upon the avian reproductive system are unknown. Grau et al (1977) speculated that toxic components of oils are absorbed from the intestinal tract and transported in the plasma to the liver and ovary, where they are deposited in the yolk. Their literature review also indicated that petroleum products inhibit sodium and water absorption by the intestinal mucosa of ducklings and that disturbances in sodium and potassium metabolism might influence yolk formation and embryo survival. The birds most at risk from oil pollution, namely seabirds and waterfowl, have features in common with the quail studied by Grau et al (loc. cit.), but direct studies of oil upon wild seabird reproduction are few.

We have found several instances where oiling has been used to control gull populations. Attempts have been made to control the New England Herring Gull population with a mixture of formaldehyde and oil (Gross, 1950). An egg destruction program was planned to inhibit the growth of the gull population. During the first years of the gull control program, Gross " (F&WS) punctured eggs. However, the eggs so treated then rotted, burst, and the gulls again laid complete clutches in the usual pattern. Gross then shifted to spraying eggs with formaldehyde and oil. The adult birds continued to incubate the unhatched eggs for long periods and did not re-nest during the season. Gross (1950) found 95% mortality of gull eggs so treated, and reported the numbers of gulls nesting on treated (oiled) islands decreased more rapidly than could be attributed to adult mortality, indicating a net emigration of adults from these colonies.

Egg oiling has been used as a wildlife management technique to control gulls on several western waterfowl refuges. Eggs of Ring-billed Gulls (Larus delwarensis) and California Gulls (Larus californicus) were oiled to limit the gull population in order to reduce predation on duck eggs. Refuges involved were the Ogden Bay Wildlife Management Area, Utah, and Bear River Migratory Bird Refuge, Utah (R. King, pers. comm.).

In summary, literature on the effects of oil exposure on the reproduction of marine birds is virtually nil. What few studies that do exist suggest high toxicity of petroleum to matchability of eggs, and marked effects upon the reproductive productivity of females. Complete knowledge of the effects of petroleum exposure in various forms is needed to evaluate the full impact of oil pollution in marine bird populations.

IV. THE STUDY AREA

The largest and probably most important gull colonies in the northeast Gulf of Alaska are located on sandbar islands off the Copper River Delta. The Copper River flows into the Gulf of Alaska south of Cordova, Alaska. The Copper River Delta has been one of the most productive and important breeding and migration routes for waterfowl in North America. Millions of birds pass through on migration and tens of thousands remain to breed (Fig. 1).

A few kilometers offshore from the mouth of the Copper River a series of low sandbar-dune islands has been formed by deposition from the Copper River. Recent earthquake activity (2 m uplift in '64) and subsequent plant succession is providing increasing nesting space for gulls. Discarded salmon and crab gurry in Cordova provides a major food source to increasing numbers of gulls around the canneries and fish-packing houses (Fig. 2). .

The trans-Alaska pipeline is nearing completion from Prudhoe Bay on the North Slope to Valdez on Prince William Sound, less than 150 km north of the study area. Tanker traffic will pass just offshore from the barrier islands through the entrance to Prince William Sound. A consortium of oil companies is presently involved in exploratory research offshore. The first leasing of offshore gas and oil sites took place on 13 April 1976 and included an area near Middleton Island and a large group of tracts between Kayak Island and Icy Bay. Banding returns and sightings of color-marked gulls indicate this *lease* area is repeatedly traversed by gulls under current investigation

Our study site is located on Egg Island, the largest gull colony in the NEGOA, 10 km SE of Point Whitshed and 20 km south of Cordova (Fig. 1,2,3) (60° 23′ N, 145° 46′ W). Egg Island is vulnerable to contamination from oil tankers passing through Hinchenbrook Entrance, oil lease sites around

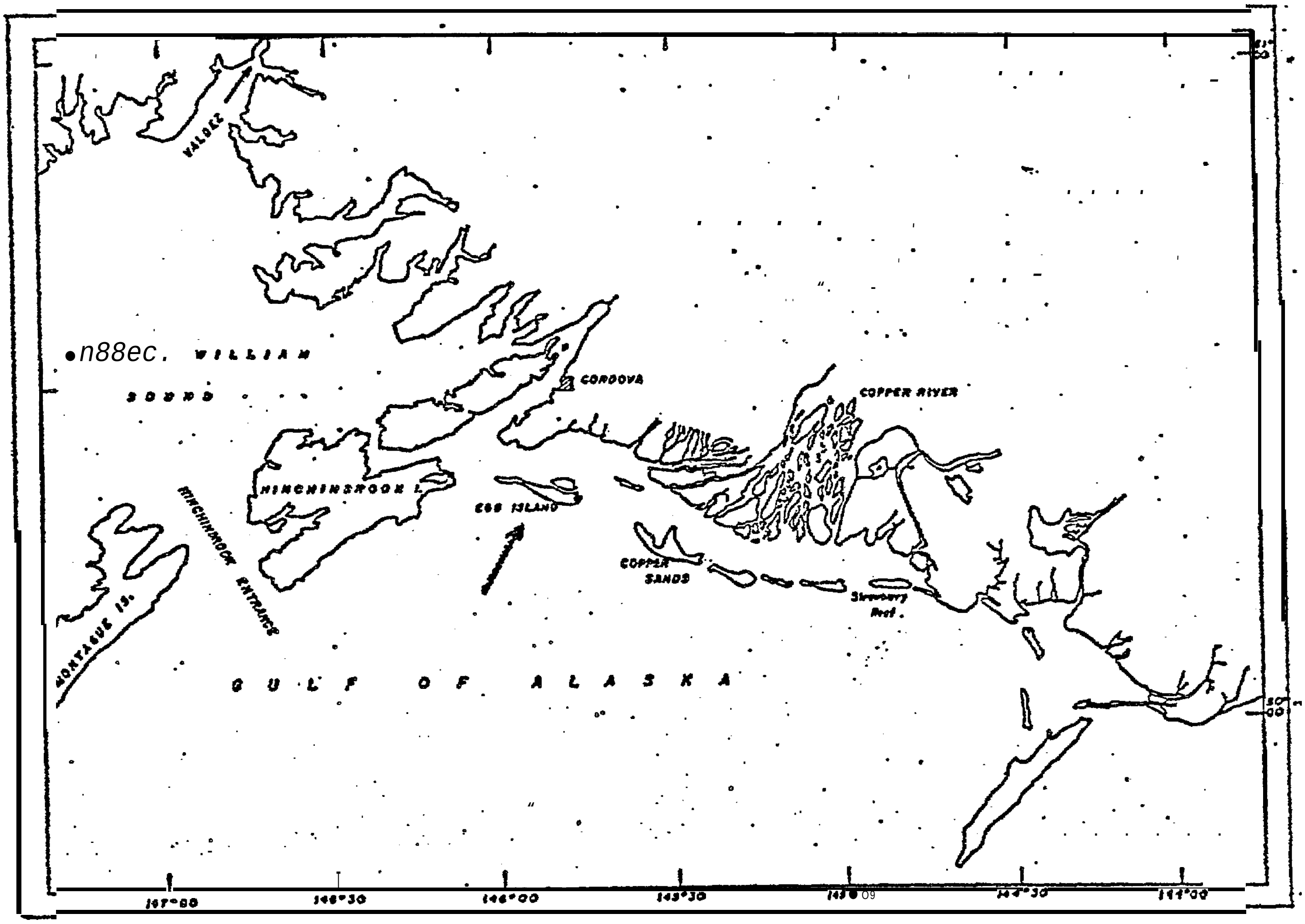
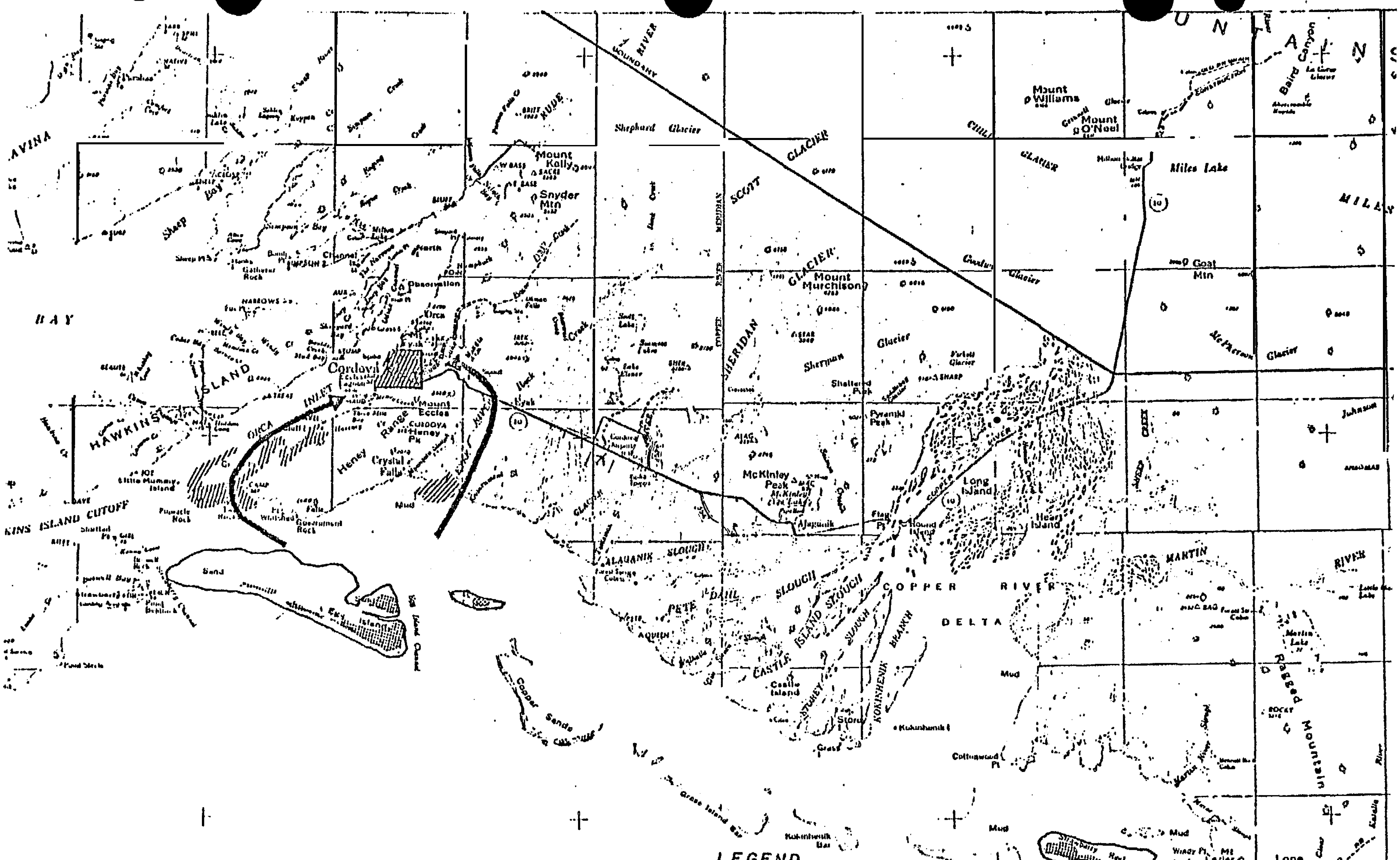


Figure 1. Map of the Copper River Delta region and Prince William Sound, showing location of Cordova, the Copper River, Egg Island (arrow), Copper Sands, and Strawberry Reef.



LEGEND
NESTING COLONIES OF *Larus glaucescens* OFF COPPER RIVER DELTA
MAJOR FEEDING AREAS
TRANSIT ROUTES INTO CORDOVA

Figure 2.

0 ___ km

Figure 3. National Ocean Survey aerial photograph of E end of Egg Island, Off Copper River Delta, 9 July 1971, at low tide. Study Area (arrow) is located near the Light Tower. New ridges of sand dunes have formed after the 1964 earthquake, joining the series of islets together. Scale 1:30,000.

Middleton Island, and those between Cape Suckling and Icy Bay.

V. MATERIALS AND METHODS

Colony Selection and Investigation Dates

We selected Egg Island as a principal location for the initial aspects of this study because of the large meadow-nesting gull population and availability of control areas with previous (RU #96) data. We began our 1976 field work on 18 May and continued through 24 August, choosing our experimental and control areas southwest of Egg Island Light to coincide with our established study site (Figs. 4, 5). There were 75 nests in the experimental area, compared to 186 in the adjacent control colony. The experimental and control areas are located on the ocean slope of stabilized meadow-covered dunes at the east end of Egg Island near the Coast Guard Light (Figs. 3, 4). Kenton Wohl of the BLM has suggested a series of additional colonies which are under consideration for further studies (Wohl, pers. comm.)

Reproductive Cycle

We used a method devised in previous gull studies to mark the nests we inspected. We marked nests with flagged wire stakes at the beginning of the field season. Since growth of vegetation tends to obscure the stakes, each was marked with an additional numbered fluorescent streamer.

North Slope Crude Oil provided to us in May 1976 by NMFS Auke Bay Laboratory under sponsorship of Dr. J. Quast was used to test toxic effects on eggs. Commercially available mineral oil (non-toxic) was used to test neutral blocking effects on respiration (gas exchange) of eggs. The first season of tests was to determine if there is, indeed, a problem.

Oil was delivered to completed clutches of three eggs about the tenth day of incubation. Fifty clutches (150 eggs) received lee/egg surface application of North Slope Crude Oil, and 25 clutches (75 eggs) received the

Figure 4. Study area southwest of Egg Island Light, showing gulls on territories and nest survey markers, June 1975.

This area served as the control colony of 186 nests.

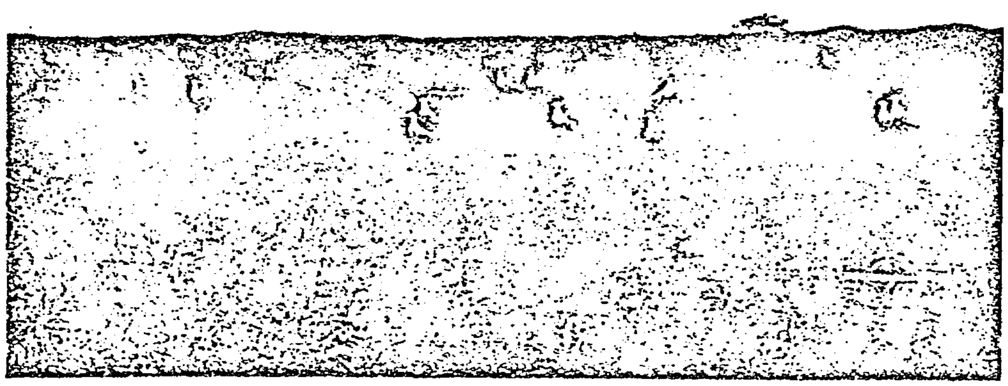


Figure 5. Survey Area, Egg Island, West View, June 197S.

This area became the experimental oiling site for 75 nests.

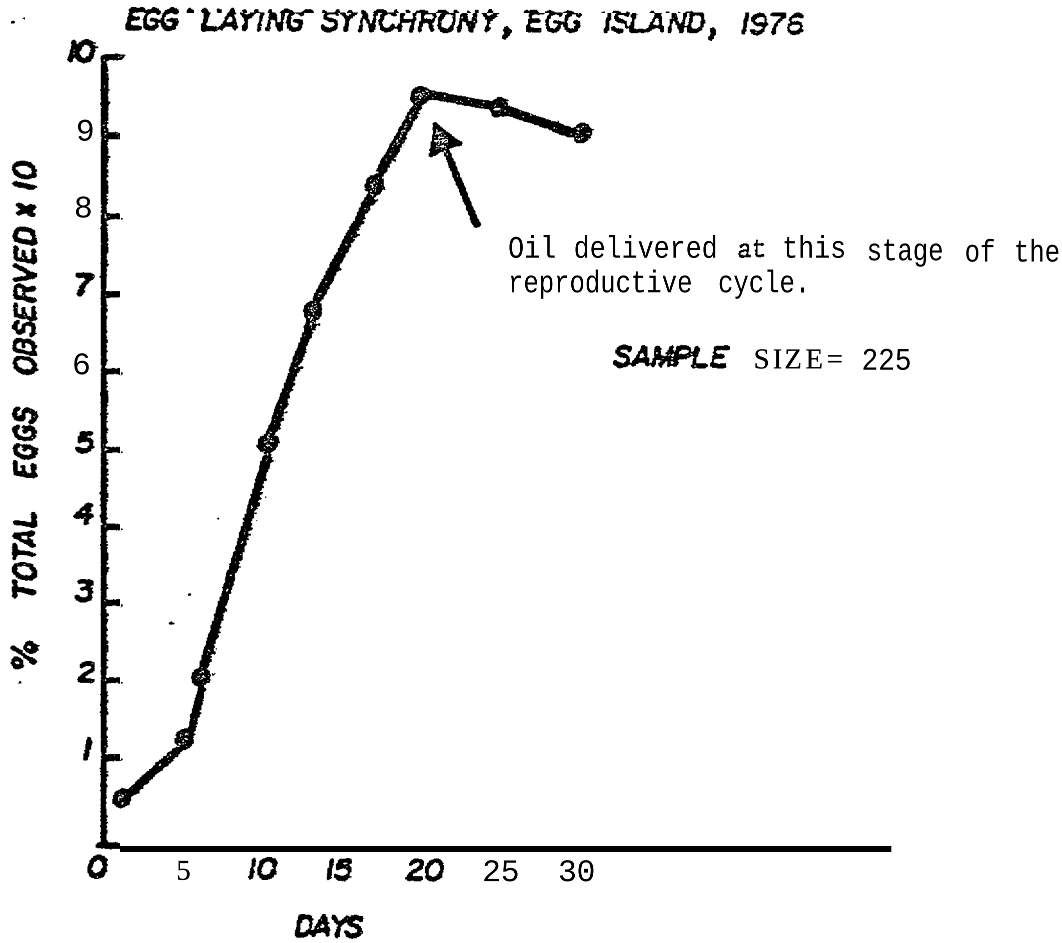


Figure 6. Oil was delivered to completed clutches of three eggs in each of 75 nests immediately after clutch completion and before any egg loss occurred.

Synchrony of the breeding cycle makes marine bird populations such as gulls vulnerable to catastrophic events such as major oil spills.

identical amount of mineral *oil.* Both treatments were delivered by drops from calibrated syringes. Delivery date was 11 June The initial oil dosage was selected to be well below the average lethal level of oiling for' adult waterfowl (7,0 - 3.5 gins) reportedly Hartung (1963).

North Slope Crude was more viscous. than mineral oil and covered approximately 25% of the egg surface. Mineral oil at this dose covered about 50% of the egg surface. Air temperature at the time of the application was 60^{o}F, winds were variable from NW to SW, with bright sunshine. Clutches in the experimental area were inspected the next day. Most evidence of oil exposure had disappeared except for slight petroleum odor. Clutches were then inspected at weekly intervals to keep disturbance to a minimum. Each time we visited a nest site we recorded the number of eggs or chicks. Egg loss was calculated at the end of the incubation period from the number of eggs remaining from the initially observed clutch. Incubation in the experimental area was prolonged 100%, at which time we terminated the experiment.

We continued our RU#96-76 investigation of the adjacent control colony using methods identical to 1975 but with an attempt to lower disturbance in the study area." On other parts of Egg Island we banded 2500 chicks and color-dyed 15 adult birds to determine local and migratory movements,

Data Analysis

As part of each sequential visit through the gull colonies we recorded numbers of eggs and chicks from each nest site inspected. The numbers are included in NODC Formal 035 in File Type 'F' - Flat Colony Survey, and used to compute clutch *size* , hatching success , egg loss and fledging success. Results have been compared to the control colony and to North Marble Island south of the current study area in Glacier Bay (see RU#96 - 76).

VI, RESULTS

Surface application of test oils to shell surfaces led to 3.3% of eggs treated with North Slope Crude and 5.3% of eggs treated with mineral oil noticeably cracking within nine days of application. The cracked eggs subsequently dessicated. We observed an additional 2% of eggs exposed to NS Crude outside nest perimeters within 15 days. The untended and presumably discarded eggs were opened for inspection, revealing dead embryos approximately a week old. The stage of embryonic development indicated mortality soon after NS Crude was applied to the egg surfaces.

Observed clutch size in the oiling experimental area initially (Fig. 7) declined at a rate compatible with normal predation from other gulls, but in July egg loss accelerated due to adult birds abandoning unhatched clutches. A month after hatching began in the adjacent control colony, on 15 July, 33% of eggs oiled with North Slope Crude and 24.4% of eggs to which mineral oil had been applied remained in the nests. This can be compared to 2% of eggs in the adjacent control area remaining in nests at the end of incubation (Figs. 8, 9).

Hatching Success in eggs exposed to North Slope Crude was .67% (Fig. 10). Mineral oil applied in equivalent amounts to gull eggs led to a hatching rate of 14.6%. Hatching success in the adjacent control colony was 77%; normal range for these gulls in Alaska is 67% - 77%. Adults continued to brood almost all unhatched clutches at least 20 days longer than normal. Eggs opened at the close of the experiment were highly decomposed, and no living embryos were found. Adult gulls nesting in the oiling area produced no more replacement clutches than the neighboring control colony (4% vs. 4.8%). The combination of high egg mortality and alteration of adult behavior virtually eliminated gull reproduction in the experimentally oiled area (Figs. 11, 12, 13).

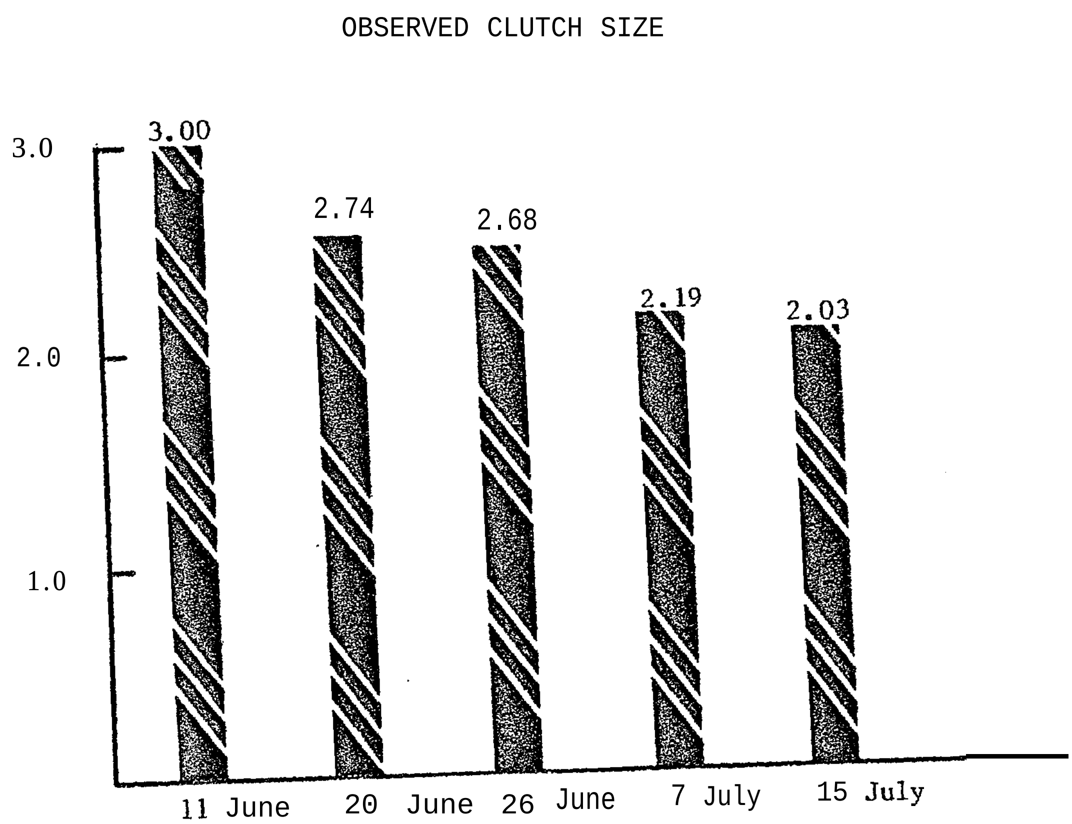


Figure 7. Observed clutch size in the oiling experimental area initially declined at a rate compatible with normal predation from other gulls.

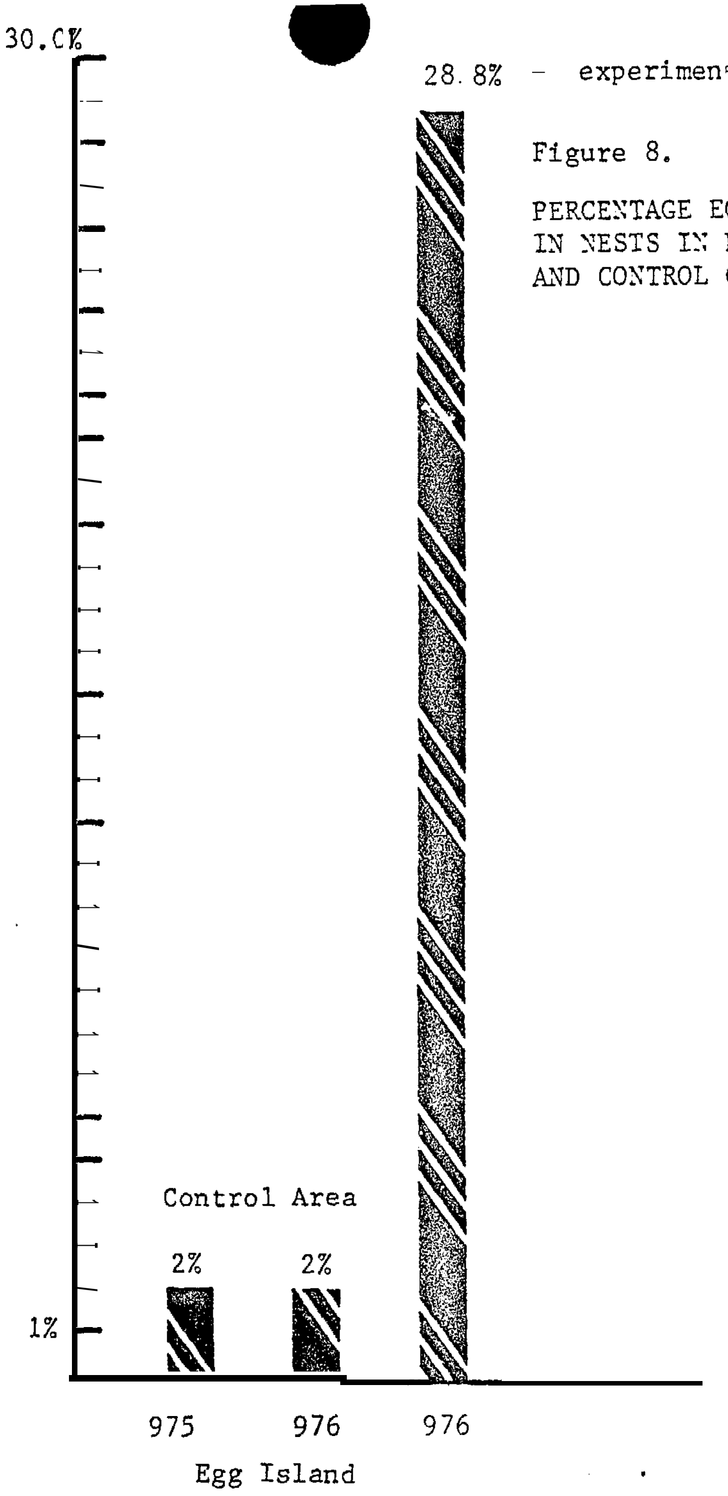


Figure 8.

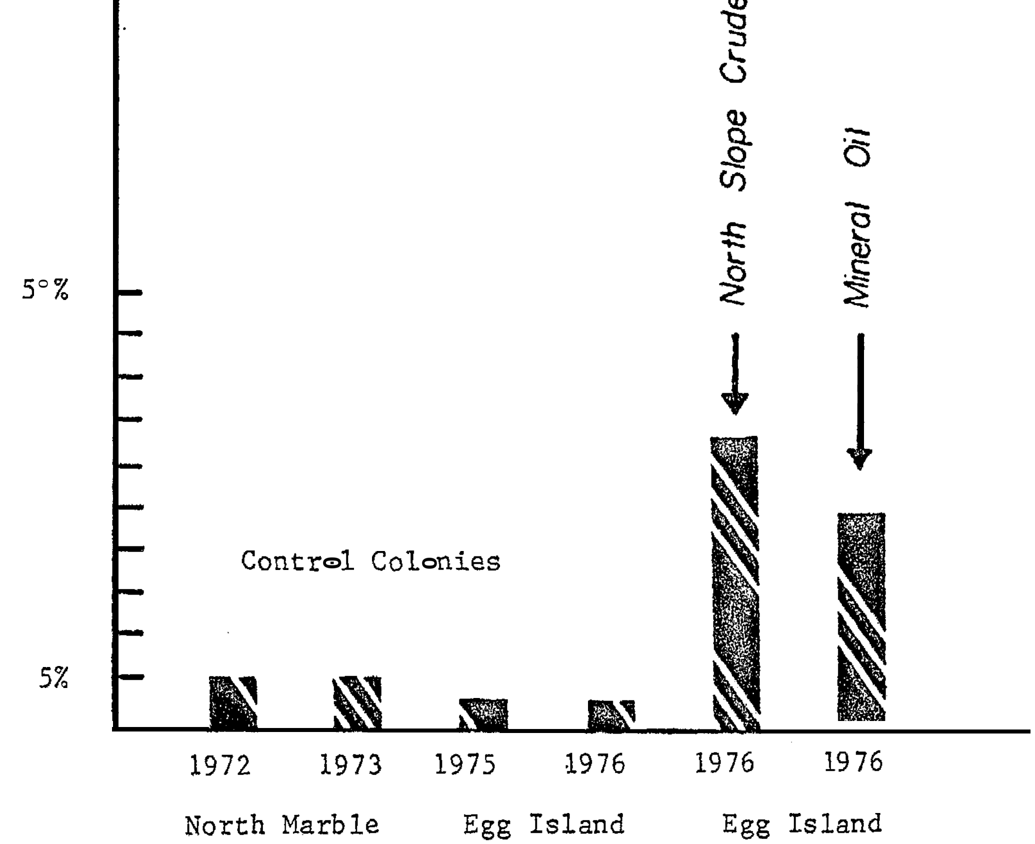
PERCENTAGE EGGS REMAINING IN NESTS IN EXPERIMENTAL AND CONTROL COLONIES

Figure 8. Percentage eggs remaining in nests at close of incubation or experimental period, experimental and control colonies, Egg Island, 1975-76.

Figure 9. A month after hatching began in the adjacent control colony, 33% of eggs oiled with North Slope Crude and 24.4% of eggs to which mineral oil had been applied remained in the nests.

Figure 9.

PERCENTAGE EGGS REMAINING IN NESTS WITH NS CRUDE OR MINERAL OIL



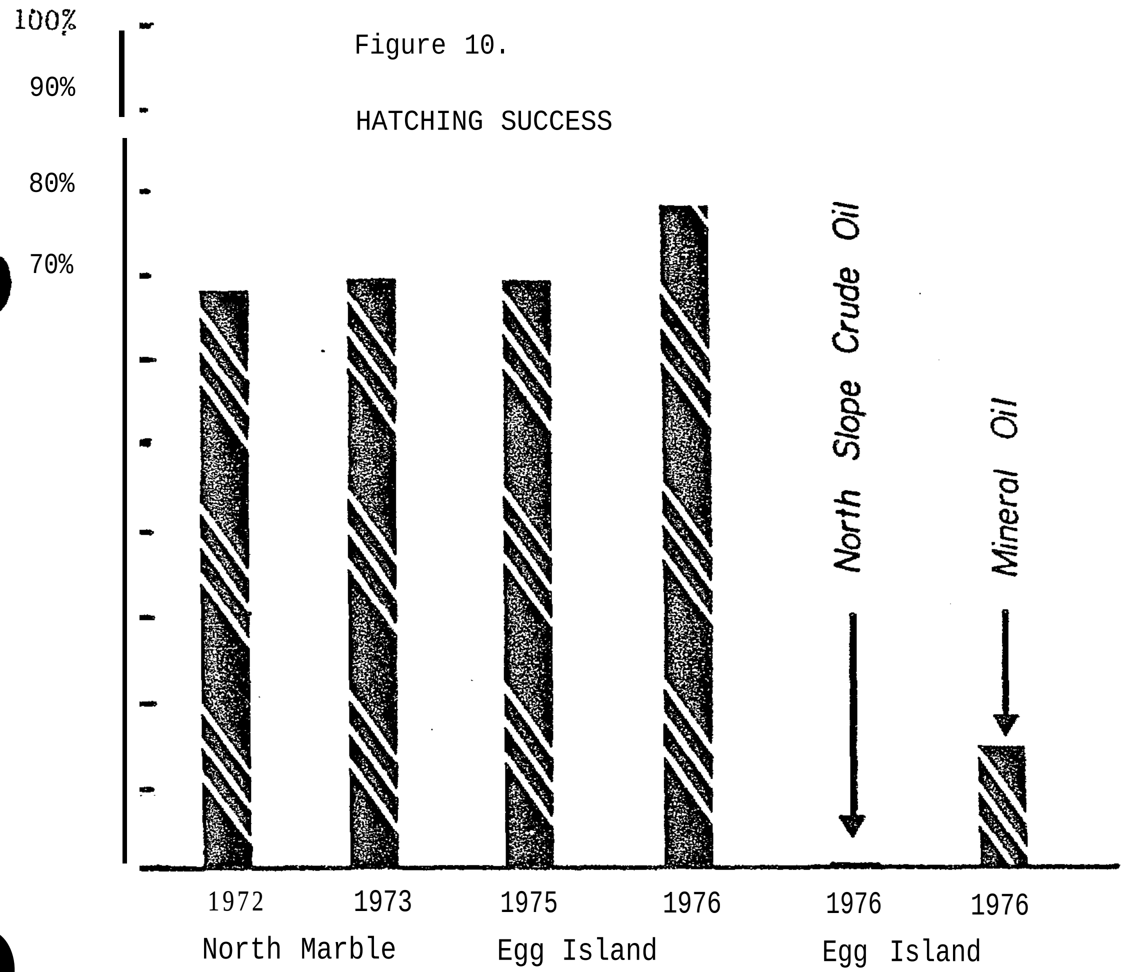


Figure 10.

HATCHING SUCCESS

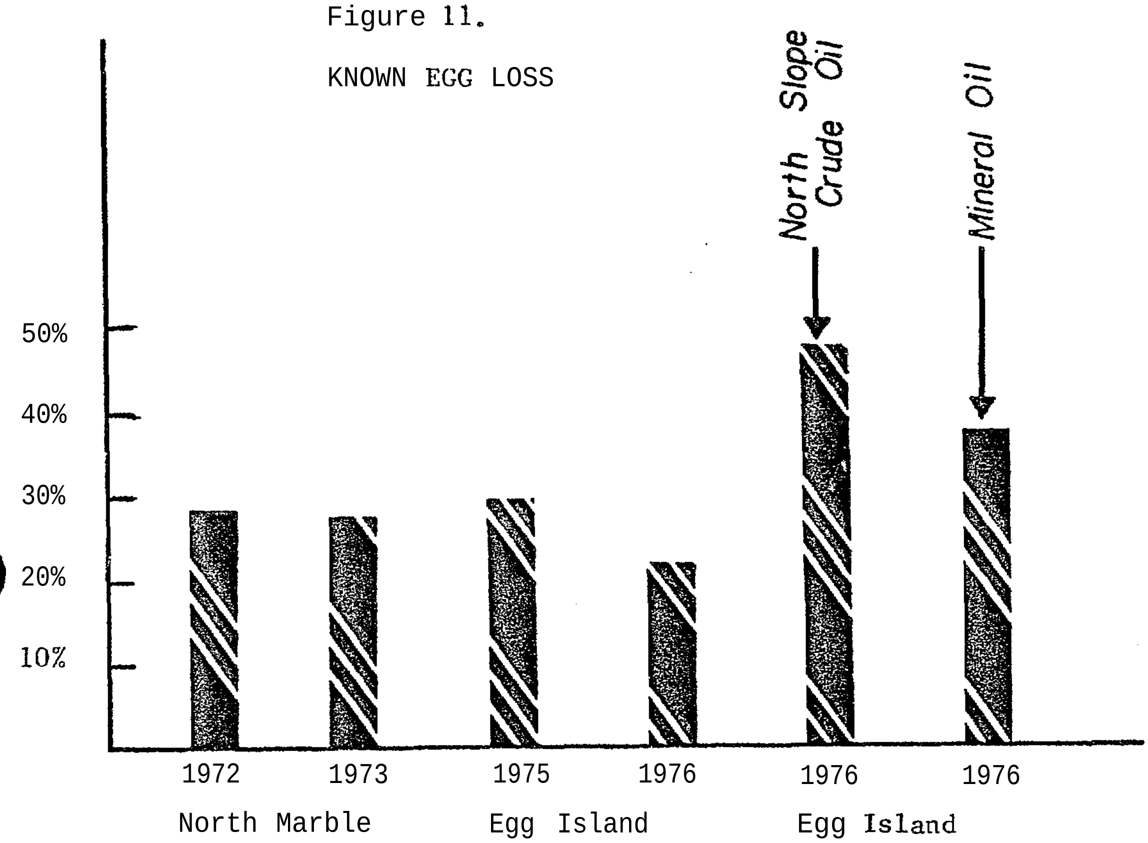


Figure 11.

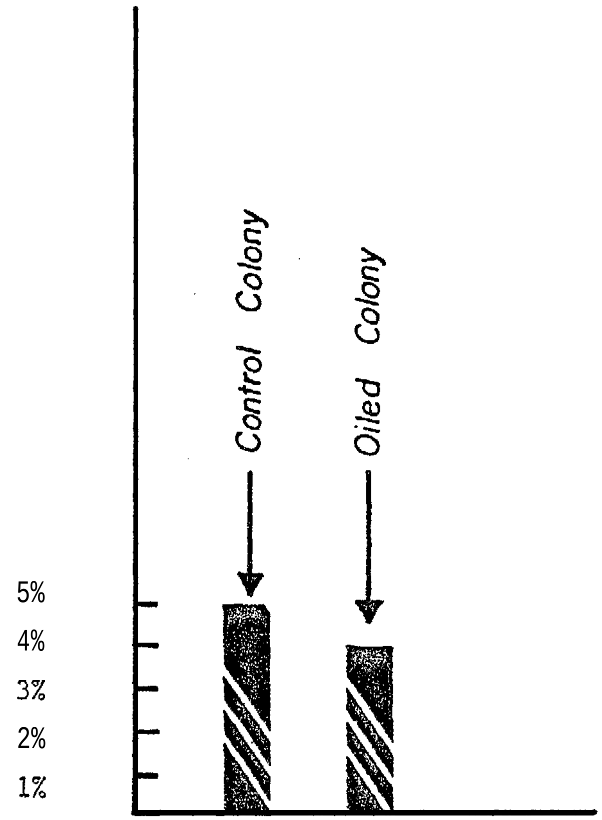
KNOWN EGG LOSS

Figure 12.

MEDIAN INCUBATION PERIODS,
EXPERIMENTAL AND CONTROL COLONIES

Figure 13.

PERCENTAGE REPLACEMENT CLUTCHES,
EXPERIMENTAL AND CONTROL COLONIES



VII. DISCUSSION AND CONCLUSIONS

Oil applied to gull eggs has apparently both physical (smothering) and chemical (toxic) consequences to developing embryos under field conditions. North Slope Crude Oil used in this experiment caused 22 times more egg mortality than an equivalent amount of mineral oil. The high mortality of eggs treated with North Slope Crude suggests active toxic compounds. Eggshell and outer membranes do not prevent penetration of North Slope Crude, since both become stained on inner surfaces. The effect of mineral oil is most likely a function of egg surface covered, pores sealed, and respiration inhibited.

Dosage in further experiments should be reduced. The 14.6% hatching rate of eggs treated with mineral oil (1.0cc) suggests an ,D50 of .25 cc for further investigation. The .67% hatching success of eggs contaminated with 1.0 cc North Slope Crude indicates dosage should be reduced approximately 100-fold. LD_{50} under field conditions could be .01 cc North Slope Crude Oil. Since dose-reponse curves may not be linear with oil exposure, research should continue with various small amounts applied to egg surfaces.

These results suggest high egg mortality under field conditions with very low levels of oil exposure, well below those necessary to cause adult mortality.

The literature on effects of petroleum exposure to marine bird reproduction is scanty, and the field is open for continued experimentation. For instance, resistance to toxicity may vary with the age of the embryo, and certain petroleum compounds may be volatile than others; thus continued exposure to the atmosphere (weathering) may reduce toxic activity.

VIII. NEEDS FOR FURTHER STUDY

The first season of experiments has indicated that surface application of North Slope Crude Oil causes high mortality to gull eggs. Equivalent amounts of mineral oil also reduce hatching *success,* suggesting both physical and chemical activity. Continued experiments are necessary, using very small amounts of petroleum, to ascertain LD_{50}"

Effects of petroleum exposure hinge on transfer to egg surfaces by adults at egg-laying or during incubation. A key feature in additional research will be capture of incubating adult birds and subsequent oiling of breast feathers, feet or food in artificial oil slicks to test transfer to eggs and chicks. We are planning experiments *to* test all likely pathways of oil exposure, including possible transport by wind or debris from oiled beaches.

We emphasize that behavior pathologies resulting from oil exposure are equally as important as toxic effects in depressing marine bird reproduction. Namely, incubating oiled clutches 100% longer than normal causes subsequent failure to re-nest during the season, Such behavior plays equally as important *a* function in effects of petroleum exposure as direct studies of toxicity , and such behavior studies can be only completed in the field. Such studies may require additional field seasons, since behavior may vary from species to species.

Oil will be administered to adult and young gulls during the 1977 field season. Effects on chicks may include external thermoregulatory disturbance, internal. metabolic disturbance due to injestion or inhalation, or disruption of the visual patterns by which adults recognize young. Gulls have an increased chance of transferring oil to eggs, since both male and female incubate the clutch, whereas in ducks only *the* female covers the eggs.

The recent NEGOA synthesis meeting revealed oil spill trajectories, impingement areas, and "key" seabird species for further exploration (Wohl - ELM, pers. comm.). Key seabird species designation has been given to Glaucous-winged Gulls , Black-legged Kittiwakes, Tufted Puffins, Common Murres and Sooty Shearwaters. Where key seabird colonies coincide with impingement areas, such as around Hinchenbrook Entrance, Cape St. Elias, Pt. Riou in Icy Bay, Middleton Island, and Yakutat Bay Islands, a prospective tanker terminal site, the significance for further research becomes apparent.

We point out the inherent difficulty of working on cliff-nesting species such as kittiwakes, murres and puffins; shearwaters nest in the South Pacific. Meadow-nesting Glaucous-winged Gulls clearly provide the best subjects for initial oiling experiments. Logistically, Yakutat Bay Islands, Pt. Riou and Middleton Island are most accessible and contain key seabird species except shearwaters. Middleton Island seems most promising as a further research site because nests of key cliff-nesting species and gulls are more accessible there than anywhere else. Szaro and Albers (1976) have suggested that eggs of certain bird species may be more resistant than others to oil exposure. Studies should be expanded in further field seasons to include additional species where access is possible and logistics feasible.

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Note: for all references to study area and gull population dynamics, refer to OCSEAP RU#96 - 76 Final. Report (1977).