ECOLOGY AND BEHAVIOR OF SOUTHERN HEMISPHERE SHEARWATERS (Genus *Puffinus*] WHEN OVER THE OUTER CONTINENTAL SHELF OF THE GULF OF ALASKA AND BERING SEA DURING THE NORTHERN SUMMER

(1975-1976)

by

Juan R. Guzman and M.T. Myres

Department of Biology
University of Calgary

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 239

October 1982

TABLE OF CONTENTS

LIST OF FIGURES

Figure

16. Distribution of shearwaters in the NWGOA in 1975-1976 by Distance Zones from the nearest land. In this presentation NWGOA includes Kodiak Island and adjacent waters.

17. Distribution of shearwaters in the Bering Sea in 1975-1976 by Distance Zones from the nearest land.

18. Monthly distribution of shearwaters on the NEGOA and Kodiak Shelf in relation to Depth Zones, during May-July, 1976 (and also 1978). All shearwaters (C) includes unidentified shearwaters.

19. Monthly distribution of shearwaters in the NWGOA, in relation to Depth Zones during June-August, 1975-1976.

20. Monthly distribution of shearwaters in the Bering Sea, in relation to Depth Zones, during June-August, 1975-1976.

21. Mean sizes of the largest ovarian follicle and largest testis from all specimens each month.

LIST OF TABLES

Table

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Several millions of Sooty Shearwaters (*Puffinus griseus*) and Short-tailed Shearwaters (*P. tenuirostris*) visit Alaskan coastal waters (OCS) during the northern summer months. They breed in Australia, New Zealand and Chile during the Northern Hemisphere's winter.

In accordance with Work Statement R.U. No. 239, attached to Contract No. 03-5-022-78, between the U.S. National Oceanic and Atmospheric Administration and the University of Calgary, data collected on the distribution, ecology and behavior of shearwaters during their non-breeding season, during the field work for this environmental assessment, have been used by Juan Guzman in partial fulfillment of the requirements for a Ph.D. degree at the University of Calgary (Guzman, 1981).

A. OBJECTIVES

The objectives were to learn something about the activities of these Southern Hemisphere seabirds and to delineate:

i) their distributions

ii) their regional movements and responses to environmental influences,

iii) the ecological requirements of these shearwaters, and

iv) whether shearwaters would be at serious risk from oil drilling and production.

B. CONCLUSIONS AND IMPLICATIONS

1. The Southern Hemisphere shearwaters are the predominant seabird species (over 90%), in terms of the total numbers of birds counted at sea from May to September each year, in Alaskan waters.

2. They mainly occupy the Continental Shelf of Alaska, rather than zones close inshore, and do not appear to overlap in their feeding areas or habits with local breeding species of seabirds to any significant extent.

3. Their distribution patterns are patchy, but what determines their movements remains undetermined.

4. The visiting shearwaters molt while in Alaskan waters.

5. Serious oil leaks that become widespread around the source, or continuing pollution down-current, could in certain localities or times alter the food chains upon which shearwaters are dependent. This might drastically reduce their numbers, or their ability to survive through the summer season and remain well-fed and healthy enough to successfully make the return migration to their breeding grounds in the Southern Hemisphere.

6. Because they breed in Australia, New Zealand and

Chile, interest in the fate of these birds assumes an international aspect that cannot be ignored.

II. INTRODUCTION

A. GENERAL NATURE AND SCOPE OF THE STUDY

The reproductive biology and the migrations of those shearwaters (Order Procellariiformes, Genus Puffinus) that breed at high latitudes in the Southern Hemisphere, but avoid the hazards of the southern winter season by making trans-equatorial migrations to visit rich feeding grounds in the North Pacific Ocean during the northern summer season, have been described by various authors in Palmer (1962) and by Richdale (1963), Phillips (1963), Ashmole (1971), Serventy et al. (1971), Shuntov (1974) and Guzman et al. (in prep.). Nevertheless, the ecology and behavior of these shearwaters during the non-breeding season in the North Pacific Ocean has not been studied in any depth until recently, even though many millions of these seabirds visit and evidently depend, as an integral part of their life cycle, upon the marine resources of the Bering Sea and Gulf of Alaska for several months each year. This project was devoted to their ecology and behavior during this period (May - September) when Short-tailed Shearwaters and Sooty Shearwaters occur over the Alaskan Outer Continental Shelf.

It is necessary to refer to both species together in most of this report, sometimes as 'unidentified shearwaters', because most were usually seen only at distances at which separation of the species was not possible. The differences are noted by:

i) Croxall (1971) who refers to "heavy build, white flash on linings of long narrow wings" in Sooty Shearwaters, and the body of Short-tailed Shearwaters as "very short behind long narrow wings";

ii) Serventy et al. (1971, in captions to Figures 71 and 72 on pages 127-128), who state that in Sooty Shearwaters "the white areas in centre of the [under] wing can be seen from a considerable distance" and distinguish them from the grey underwing coverts of the Short-tailed Shearwater, and who state that the bill of the Sooty Shearwater is also "longer and more slender";

iii) Falla et al. (1970), who state that the Sooty Shearwater has a "conspicuous silvery flash of the underwing coverts", while the Short-tailed Shearwater is "usually lacking the pale areas under the wings.. .The bill is proportionately shorter.. .and the general smaller size is also a useful field character"; and

iv) Fullagar (1970) who refers to the Short-tailed Shearwater as "slightly smaller" and to the Sooty Shearwater as having "pale wing linings" and a "longer bill".

The above descriptions were all obtained from Southern Hemisphere authors. In the Northern Hemisphere, when these shearwaters are molting, observers generally describe distinguishing the two species as from difficult to extremely difficult (e.g. Isleib and Kessel, 1973; Wahl, 1975; Stallcup, 1976). British Columbian Patrick W. Martin (personal communication) notes that during molting "many of the characteristics of colour break down...I have found underwing colour to be wholly unreliable as a diagnostic character, probably owing to the fact that these are wintering birds and continually molting when in the North-eastern Pacific". However, J.R.G. found that, under good conditions and within 50 meters, up to 60 per cent could be distinguished. The large size and long bill were used to identify the Sooty Shearwater, and the shorter bill and abrupt forehead were used to distinguish the Short-tailed Shearwater.

Because of the devotion of this Research Unit to shearwaters, and because shearwaters formed over 90% of the several million seabirds recorded by J.R.G. during cruises on R/V DISCOVERER and R/V SURVEYOR, the text of this Final Report does not deal with other seabirds. Nevertheless, all other seabirds encountered were counted, and these counts have been submitted as raw data in a magnetic data tape and separate tabulations, submitted previously.

The latest information on the likely impact of petroleum on shearwaters is considered, insofar as this is yet predictable, in relation to their known distribution in Alaskan waters.

B. SPECIFIC OBJECTIVES

The revised objectives of this project, based on field experience and what proved to be practicable in 1975, became to obtain data on:

1. The latitudinal-longitudinal distribution of the Short-tailed Shearwater and the Sooty Shearwater in four regions, the Northeastern Gulf of Alaska (NEGOA) , the Kodiak Island Shelf, the Northwestern Gulf of Alaska (NWGOA) and the Southeastern Bering Sea and, in particular, the relationships between the distribution of these shearwaters and a) the distance from the coast of Alaska, and b) whether the birds were most abundant over the Continental Shelf or beyond it.

2. The sizes of the flocks in which shearwaters are observed, and the behavioral dynamics of aggregated shearwaters when these were encountered.

3. The plumage and molt condition of these Southern Hemisphere visitors during the months May - August.

C. RELEVANCE TO THE PROBLEMS OF PETROLEUM DEVELOPMENT

Extensive direct ('acute') kills of seabirds have been recorded as a result of oil spills in various sites around the world. Few if any have, so far, threatened the extinction of a species. This should not lead to complacency, however, because extinction of a species is a possibility in Alaska. This is because the Bering Sea - Aleutian Islands region is 'home' to several endemic species of seabirds not found elsewhere.

Perhaps more significant, but far less easy to evaluate, are the longer term ('chronic') effects of oil pollution of the sea upon the food resources, proper reproductive functioning and traditional livable habitat requirements of seabirds. Some aspects of these questions are reviewed in the next section.

From this field study in 1975 and 1976 it is only possible to say that, before it is possible to determine whether offshore oil development in Alaska would or would not have a serious impact on the survival of populations of visiting (non-breeding) shearwaters, more prolonged study of the movements and distribution of shearwaters over the OCS area is required. The dispersal of oil over the surface of the water depends upon several environmental factors (e.g. winds and currents) , some of which are also involved in bringing about the actual distribution and movements of certain elements in the food chain that lead up to those that are the food of shearwaters. Data from other data sources that might make such an assessment feasible have not yet been obtained.

Analytical techniques for petroleum fractions in animal tissues, and trace metals in feathers or bones derived from identifiable or 'signature' oils from particular oil fields, are still in their relative infancy (but see references provided later). Yet, these are essential as baseline data against which pollutant levels in future years can then be compared. It is necessary, for example, to establish now what such pollutant levels in shearwaters are that can be 'labelled' as having been derived from Middle Eastern tanker-borne oils, so that the degree of pollutant uptake of Alaskan oils may be correctly assessed during the 1980's. To what extent, for instance, do such pollutants currently disappear from the visiting shearwaters' bodies during their sojourn in Alaskan waters, and how will this be altered now that North Slope oil has begun to move by tanker down the west coast of Canada from Valdez?

111. CURRENT STATE OF KNOWLEDGE

A. AN INTERNATIONAL RESOURCE

Although the Short-tailed Shearwater and the Sooty Shearwater are the most numerous species of seabirds over the Outer Continental Shelf of the Gulf of Alaska and the Bering Sea away from the immediate coastline in the summer months, neither species breeds in Alaska. They visit subarctic North Pacific waters during their non-breeding season, occurring in Alaskan waters during the period of winter in the Southern Hemisphere, from April to September.

Green (1916) described a migration of shearwaters in April 1915 as "a three days' constant stream. ..in an almost unbroken line past Langara Island [British Columbia] , all heading from Dixon Entrance and disappearing to the north-west towards the Aleutian Islands . . ..migrating hosts, returning to spend their winter in our summer seas after breeding" . Gabrielson and Lincoln (1959) in The Birds of Alaska describe "the endless swarms. ..[of Sooty Shearwaters]. ..one of those great spectacles . ..never to be forgotten...one of the most spectacular panoramas of life which this continent has to offer." The Sooty Shearwater is described by Johnson (1965) in The Birds of Chile as "probably the sea-bird which in sheer numbers surpasses all others" .

Isleib and Kessel (1973) describe the Sooty Shearwater as "the most numerous" in the North Gulf Coast area east of Kodiak Island. They reported "tremendous concentrations totalling millions" of Sooty Shearwaters on 1 July 1965 in inner Kennedy Entrance between the Chugach and Barren Islands (over 2,600,000), and in June 1965 "square miles of sitting birds" in Hinchinbrook Entrance.

Estimates of the numbers of both species of shearwaters "wintering" in the Bering Sea have been attempted (Shuntov 1974, Sanger and Baird 1977) and are around 10 million birds, making them the most abundant species there during the northern summer (Hunt et al. 1981b).

The Short-tailed Shearwater is the Tasmanian "mutton bird" of Australian commerce, and Serventy et al. (1971) state, in The Handbook of Australian Sea-Birds, that 54,000 Short-tailed Shearwaters had been banded by Australian Government agencies up to 1965, in the course of studies upon this economically-important species of seabird. Estimates of the total world population of Short-tailed Shearwaters are hard to obtain but Dr. Naarding of Tasmania has recently calculated that there are 16 million (Kuroda, 1982) . In economic terms, in one year alone (1968) , 466,000 were harvested for food, fat, pharmaceutical oils and down at $12-16 per 100 birds, a total value of about $A 70,000 (Serventy et al. 1971).

The Short-tailed Shearwater was previously reported to be the more common of the two species in the Bering Sea and among the Aleutian Islands (Murie, 1959). The Sooty Shearwater, which migrates both north and south along the western seaboards of South and North America, was said to be the more common of the two species in the eastern sectors of the Gulf of Alaska. But the true status of the two species in the northwestern part of the Gulf of Alaska and the Aleutian Islands is less clear.

Shearwaters have been the subject of study by Japanese scientists for many years e.g. Kuroda (1955, 1957, 1960), and have been studied in the northwest Pacific Ocean in recent years by Wahl (1978), Tanaka and Kajihara (1979), Ogi et al. (1980) and Ogi (1981).

Shearwaters do not return to the colony until they are at least three years old and do not breed until older than this; some subadult birds may remain in the Northern Hemisphere until mature (Serventy 1956b, Serventy et al. 1971).

The OCS Draft Study Plan (page 20) referred to the seabird population of the Gulf of Alaska as an "International Resource", and this the shearwaters from southern Chile, New Zealand and Australia certainly are. Sowl and Bartonek (1974) discussed the value of seabirds, and described them as Alaska's "most neglected resource".

Finally, the carrying of influenza viruses by water birds (Webster and Laver, 1975; Webster et al. 1976, 1977), apparently includes shearwaters (Kaplan and Webster 1977), making the migrations of shearwaters a topic of concern in the field of epidemiology and international aspects of disease control.

B. SHEARWATER ECOLOGY AT SEA IN THE COASTAL DOMAIN AND THE IMPORTANCE OF THE ALASKA CONTINENTAL SHELF TO SHEARWATERS

The writings of Murie (1959), Gabrielson and Lincoln (1959), Swartz (1967), Martin and Myres (1969), Bartonek (1971, "102 statement-description of bird resources along proposed tanker route from Port of Valdez to southern terminals"), Bartonek and Gibson (1972), Isleib and Kessel (1973), Shuntov (1964, 1974) and Gill et al. (1979) on the North Pacific region, provide the background accounts of the ecology of shearwaters during the period of the year when they occur close to shore in the Bering Sea and the Gulf of Alaska.

The subject has been most recently reviewed by Strauch (1980) for the Northeastern Gulf of Alaska and Strauch et al. (1980) for the Kodiak Island region of the Northwestern Gulf of Alaska. Hunt et al. (1981b, 1982) have reported on the pelagic distribution of marine birds in the Southeastern Bering Sea. Besides our own previous reports for 1975 and 1976 (Myres and Guzman, 1976-1977), shipboard surveys in Alaskan waters during the OCSEAP program have been reported as follows: for 1975, Lensink and Bartonek (1976); for 1976, Gould et al. (1977); and for 1977, Lensink et al. (1978). Aerial surveys were reported by Harrison et al. (1977) and Harrison (1982).

The number of shearwaters observed in the center of the Gulf of Alaska, however, has not been spectacular at all (M.T. Myres, unpublished data from 1958 to 1981, for Ocean Weather Station "Papa" at 50 degrees N, 145 degrees W), so it was evident that more information was needed on the width of the coastal zone along which the shearwaters feed and migrate.

Sanger (1972, page 601) estimated that the group to which the shearwaters belong comprised 84% of the standing stocks and 89% of the biomass in the Coastal Domain of the North Pacific Ocean during the summer. Interference with the food chain on the Alaskan Outer Continental Shelf might cause a substantial reduction in the world population of these most abundant birds, since a high proportion of the total population appears to depend on the resources of the region for a large period of the year.

The role of shearwaters in rapidly recycling nutrients in the surface marine ecosystem, in redistributing them during their movements, and in thus fertilizing the waters of the Subarctic North Pacific Ocean, is clear from their preponderant numbers and position at the top of the food chain, feeding as they do on euphausiids, squids and fish and converting these to readily reabsorbed feces. Sanger (1972) warned that since the Sooty and Short-tailed Shearwaters "have populations numbering at least in the tens of millions . . . . a large reduction in their numbers could influence their ecosystems adversely".

Wiens et al. (1980) simulated the energetic of seabird populations and their sensitivity to perturbations in their food supply.

There is no evidence that shearwaters form an important food for any predator upon them, although when they die their bodies are contributed to the scavengers and decomposes in the region in which this occurs. The rapid migrations of Short-tailed and Sooty Shearwaters across the equatorial zone suggest that they export little in the way of nutrients from Alaskan waters to that zone; rather, because many shearwaters newly raised each year in Australasian and Chilean colonies must die during their stay in Alaskan waters there may be a net importation of biomass as a result of their coming there. About the importance of shearwaters to the Australasian countries there can, in any case, be little doubt.

The interactions of shearwaters with other species of seabirds are complicated by (1) the fact that the shearwaters are not tied to breeding colonies in the Northern Hemisphere, (2) their enormous numbers, (3) their mobility, and (4) their usual avoidance of nearshore waters (bays and inlets). Hoffman et al. (1981) consider shearwaters to be both catalysts (attracting other species to feeding areas) and suppressors (preventing feeding by other species) . They found that shearwaters and kittiwakes initiated most mixed-species feeding flocks in Alaska.

C. MOVEMENTS OF SHEARWATERS WITHIN THE COASTAL ZONE DURING THE SUMMER MONTHS IN RELATION TO FOOD AND WEATHER-RELATED STRESSES

Sanger (1972, page 607) wrote that "very little is known about distribution, abundance, and movements of seabirds in the region and their relationships with the pelagic environment". For a long time, the Short-tailed Shearwater has been known to sailors in Alaskan waters as the "whale bird" (Gabrielson and Lincoln, 1959), and Murie (1959) states that "it may be significant that the center of abundance of shearwaters in the Aleutians today coincides fairly well with localities where whales were once particularly abundant in the Fox Island group". A relationship exists between the distribution of baleen whales and a high marine productivity where there are water mass boundaries (Uda, 1954), and in both the Gulf of Alaska and the Bering Sea whales apparently move along the margin of the Alaskan Stream (Nemoto, 1959; Fig.16.12 in Nasu, 1974). Harrison (1979) discusses the association of shearwaters with whales in the northern Bering Sea, and it is significant that whales were seen on August 17, 1975, at the same time as several million shearwaters (Table 1).

One of the unexplained facts frequently noticed is that shearwaters "vary in numbers from day to day in any given locality" (Martin and Myres, 1969). While this is apparently most often due to feeding conditions changing with the tides or winds and currents, Manikowski (1971) obtained some evidence that some seabirds leave an oceanic region that is in the path of an advancing storm or advancing fronts associated with cyclonic conditions. Shearwaters may make cyclone-related "weather movements" from one locality to another within their overall region for the particular season, but we were not able to determine whether the directions in which flocks were observed moving during the summer months, when they are not actually migrating, were weather-related or wind-related.

The ability of shearwaters to smell (Grubb, 1972) suggested the probability that the wind could either inform them of feeding conditions upwind (Hutchison and Wenzel 1980) e.g. at upwelling areas, or of weather conditions at a distance, and produce a local movement in response.

The extent to which shearwaters feed or make organized local movements at night outside the breeding season is unknown. That shearwaters can feed on fish in darkness was established for Wedge-tailed Shearwaters (Puffinus pacificus) by Gould" (1967). So, it may not be surprising if flocks seen one day are not to be found in the same place on the next day but, because the vessels from which observations in this study were made were usually traveling at night, little information on this phenomenon was obtained during this study and it remains a major gap in our knowledge.

Because euphausiids come nearer to the surface at night (Alton and Blackburn 1972), it would be expected that shearwaters might feed at night at the lower latitudes in southern Alaska in summer, although few observers have been very specific about this. On the other hand, swarming of euphausiids takes place in the daytime (Komaki 1967). Komaki also points out that Euphausia pacifica swarms off Japan at temperatures between 7 - 16 degrees C from February - May.

Bad weather sometimes causes mortality to seabirds on a large scale at sea (e.g. Bailey and Davenport, 1972).

TABLE 1 : AGGREGATIONS OF SHEARWATERS OF MORE TNAN 10.000 BINDS SEEN IN 1975

MONTH DAY TIME	REGION AREA LOCATION DS=distance from shore(est.) D-depth estimate (fathoms)	PHYSICAL CONDITIONS SST=sea surface temp. AT-air temp. B=barometric pressure W-wind: direction(degrees) strength(knots) S=wave height (feet)+ swell height(feet)/ direction(degrees)	CENSUS DATA No. of bias, Transect type(N,E or S), and duration CA=census area (km²) MD=max. density rd km²)	DESCRIPTIVE REMARKS F=No. of flocks FSR=flock size range MFS-seen flock size
June 8 2000-2115	BERING SEA North Bristol Bay 58°10'N. , 159°44'W. DS 28 nm. D 15	SST 3.6% AT 6.0°C B 29,74 W 135°/6k S 1 + 2/100°	15,350 E -75 min. CA 28.7 km² ND 535	Short-tailed Shearwaters F 21 FSR 150-1000+ MFS 731 Molt.
June 10 1045-1100	SEWING SEA south of cape Newenham 58°02'N., 161°52'W , DS 32 m. D 23	SST 1.6°C AT 5.0°C B 29.98, rising W 2650 5k S 0+0 /-	15,000 E - 15 min. CA 35.7 km² MD 421	Short-tailed Shearwaters F 13, on the water MFS 1,154 Molt From 1115-1130 there were another 8000 birds in 8 flocks and from 1345-1442, 6000 birds in 5 flocks. The distance between these flocks wee 08. 500m.
June 10 2210-2245	BERING SEA Southwest of Cape Newenham 58°22'N. , 163°03'W. DS 34 nm. D 17	SST 1.8°C AT 3.6°C B 29.95 W 265°/5k s 0+0/-	110,000 E -35 min. CA 121 km² MD 909	Short-tailed Shearwaters F 47, on the water (70,000 birds) at 2210 F 32, on the water(40,000 birds) at 2240 FSR 200 - 2000 birds MFS 1,392 Some birds were flying among the flocks, others formed small groups of 10-50 birds. No more than 1 % were flying simultaneously. Food regurgitated under harassment from jaegers was semidigested euphausiids

Table 1 (continued) :

June 12 0430-0500	BERING SEA Outer Kusko-kwim Bay 58°47'N., 164°15'W. DS 60nm. D 17	SST 1,8% AT 2. 1°C B 29.82 ,falling W 035°/16k S 1 +2 /020°	17,500 S - 30 min. CA 36.5 km^2 MD --	Short-tailed Shearwaters F 1 (17,500 birds) MFS 17,500 A big flock that crossed the bow for 30 minutes. It was only 100 metres wide but more than 10 km long (an area of ca. 1.0 km^2). The distance between individual birds was only 2-25 metres.
July 24 1325-1440	ALEUTIANS Urilia Bay, North Unimak Island 54°57'N., 164°21'W. DS 2.5 nm. D 9	SST 6.7°C AT 15.6°C B 29.64 W 320°/2k S 0+?	42,000 (est.) E -75 min. CA 1.13 km^2 MD 37,168 (Urilia Bay)	Short-tailed Shearwaters The birds were moving from east to west (towards 270°) for 75 minutes. They were traveling in long files ca. 50 metres wide. The birds settled on the water ca. 2 miles to the west in flocks of ca. 1000 birds each.
July 24 2135-2220	ALEUTIANS North Unimak Pass, Shelf Edge. 54°33'N., 165°37'W. DS 15 nm. (exact) D 173 (exact)	SST 6.7°C AT 9.4°C B 29.64 W 290°/8k S 0+1 /220°	50,714 E -45 min. CA 9.72 km^2 MD 5,21a	Short-tailed Shearwaters
July 27 1155-1200	ALEUTIANS North Akutan Pass, Shelf Edge 54°09'N., 166°14'W, DS 5 nm. D 28	SST 7.8°C AT 8.9°C B 30.13 W 112°/9k S - + -	57,000 E -5 min. CA 1.54 km^2 MD 37,013 (N. Akutan Pass)	Short-tailed Shearwaters (plus some Sooty Shearwaters) Fog, so birds were estimated only out to 500m. from the ship during this 5 minute observation Period.

Table 1 (continued) :

5- 0915-1420	KODIAK SHELF NE Kodiak, NE of Woody & Long I slands 57°50'N., 152°17'W. DS 2 nm. D less than 30	SST 8.6% AT 12. 3°C B ? W ?/? S 2+1/?	50,000 E - 305 min. (Launch trip) CA 45 km² MD 1,701	Sooty Shearwaters (90% of total, and Short-tailed ill% of total). A mixed flock with 20,000 Black-legged Kitti - wakes. Feeding on small fish,
August 6 0920-1430	KODIAK SHELF NE Kodiak, NS of Woody & Long I slands 57°50'N., 152°17'W. DS 2nm. D less than 30	SST 8. 9°C AT 19.4°C B 29.83 W -/- S -/-	40,000 E - 310 min. (Launch trip) CA 45 km² MD 1,460	Short-tailed Shearwaters (70% of total) A mixed flock with 20,000 Black-legged Kitti-wakes. Feeding on small flab.
August 11 " 1715-1730	NWGOA Shumagin Islands 55°08'N., 160°27'W. OS 1.2 nm. (exact) D 29 (exact)	SST 10, 0°C . AT 11.5°C B 29.58, falling W 015°/12k S 1+2/110°	16,000 N - 15 min. CA 1.95 km² MD 8,210	Sooty Shearwaters
August 17 1035-2000	BERING SEA South Nunivak Island 59°03'N., 167°58'W. → 58°39'N.. 167°42'W .. (a transit distance of 25-30 miles). DS min. 63 am. max. 82 nm. D 22-29	SST 8. 9°C →8. 3°C AT 10.0°C →9.4°C B 29.69→29.64 W 060°/11k→060°/14k S 1+4/340°→2+3/320° (2) The shearwaters were broth settled on the water and flying, often in big circles. Some appeared to be feeding. Individual flocks varied greatly in size, in the distance between each flock and the next one, and in the distance from one bird to smother. FSR 100-6,000. Many flocks took off and flew only 100-200m before settling again.	6-10,000,000 (in 5 1/2 hrs) E - 325 min. CA(est.)1152 km² MD(est.)5,210 -8,680 (max. in 10 minutes: CA 12096 km² MD 15,432),	Both Short-tailed and Sooty Shearwaters were pre - sent, but accurate relative proportions of each were not established for the entire "'super-aggregation". Short-tailed Shearwaters predominated, but some individual flocks were fairily (80%) composed of Sooty Shearwaters. (1) "Flocks all over the ocean to the horizon - flocks with thousands of birds." Numbers of shear-waters between the ship and the, horizon were calculated at various times during the day as follows: 1510-1530: 40,000 (to horizon) + 100000 (near horizon) -140,000 1535 : 200,000 1615-1625: 250,000 (At least five whales were seen during this period.)

Table 1 (continued :

August 18 1615-1635	BESING SEA East of Pribilof Islands 57°22'N., , 167°35'W. 0s 77 nm. D 40	SST 10.00C AT 11.1°C B 29.52 W 040° 17k S 3+4/070°	6s,000 E - 20 min. 1615-1620 CA 4.2 km2 MD 12,619 1620-1635 CA 0.7 km^2 MD 21,733	Species unidentified, but both Short-tailed and Sooty Shearwaters believed present. From 1615-1620 a f leek estimated at about 50,000 was in flight about 3 nm. from the ship. "The birds fly in circles." Closer to the ship there was snother 3,000 birds about half of which were settled on the water. In this flock the birds "fly in circles too".
		Fog made observation cliff icult from 1620-1635, but two flocks (of 10,000 and 5,000 birds respectively) were recorded. In the smaller flock, about 75% were sitting on the water. Feeding birds dove from a height of 2-3 metres.		

Storms at sea often result in pelagic seabirds being seen in unusual numbers along the coasts of the Pacific Northwestern States, perhaps aggregated and blocked by the land mass in the course of making normal 'escape flights' away from approaching bad weather. In response to bad weather conditions and poor feeding conditions, the relative distribution of pollutant residues (e.g. DDT derivatives, dieldrin and PCB's) as between one tissue and another may change in shearwaters over quite short periods of a few days (or a week or two), and such mobilization of pollutants and exposure of more sensitive tissues and organ systems to them should induce stress and, on occasions, mass mortality. Seabird specimens taken under different conditions could exhibit different values.

D. THE THREAT OF OIL TO SEABIRDS

Because shearwaters travel along both the North American coast and the coast of Japan during their migrations across the equatorial, tropical and temperate latitudes, they are exposed to pollutants. Among these near industrial areas are polychlorinated biphenyls, which have been found in seabirds.

The fate of oil in the ocean has been reviewed by ZoBell (1964), Berridge (1968), Pilpel (1968), Anderson et al. (1974) and the Ocean Affairs Board (1975).

One of the busiest oil tanker routes in the world is that from the Persian Gulf to Japan, and Short-tailed Shearwaters migrate along part of this route in the Western Pacific Ocean. The oil threat to seabirds on the Canadian West Coast has been reviewed by Bartonek and Sowl (1972), Vermeer and Vermeer (1975), Canada (1978), and Thompson (1978), and on the Yukon coast by Vermeer and Anweiler (1975).

Of the damage that can be caused by oil, among the most important is the oiling of birds (Clark and Kennedy, 1968; Vermeer and Vermeer, 1974 and 1975; Smith, 1975). The feathers of birds once oiled lose their waterproofing and insulating quality, and consequently the birds lose their buoyancy and the capacity to control the temperature of the body (Vermeer and Vermeer, 1975). Overall effects of oil pollution of the sea on, seabirds have been documented by Clark and Kennedy (1968), Clark (1969), Bourne (1970, 1972, 1976) and Ohlendorf et al. (1978).

In 1970, at least one tanker/day was arriving in Cook Inlet to load oil from the Kenai-Cook Inlet oilfields, and it has been estimated that 0.3% of all oil handled in Cook Inlet is spilled (Kinney et al., 1969); further, tides and winds flush much of this oil out of Cook Inlet rapidly. The toxicity of the water-soluble fraction of Cook Inlet crude oil has been studied by Nunes and Benville (1978) and Whipple et al. (1979). With the movement of Prudhoe Bay crude from Valdez by tankers that started in June 1977, the problem cannot but escalate.

The history of incidents involving oil and seabirds is a long one with an extensive literature. The number of birds killed during a spill of oil depends mainly on the characteristics of the 'incident', physical conditions of the environment (currents, weather, distance offshore), season of the year, proximity to colonies and species of birds present in the area. It has been estimated that 150,000 - 400,000 seabirds are killed annually in the North Atlantic Ocean (Tanis and Morzer Bruyns, 1969).

During the winter 1969/70 the U.S. Dept. of the Interior (1970) estimated that from 10,000 - 100,000 seabirds were killed by oil (probably routine ballast discharges) in the Gulf of Alaska. Jim King ("Bird kills from oil contamination in the Gulf of Alaska, February - March 1970"; unpublished report to Regional Director, Bureau of Sport Fish and Wildlife, Portland, Oregon, March 1970) considered that they were found ashore mainly because of an unusual 6-week period of southeast winds in February-March 1970, not because the mortality level was itself abnormal; the abundance of globs of oil "formed around feathers" suggested that the birds from which they came had died and decomposed at sea some considerable time earlier and that this might be quite a common event offshore. It was stressed that it is impossible to calculate the number of seabirds that are not drifted ashore, but are instead 'trapped' in the offshore Alaskan Gyre of the Gulf of Alaska.

Differences in the effects of oil on different taxa are not well known, although species behave in varying ways in the presence of oil on the surface of the water: murres and penguins dive, and Manx shearwaters, gulls and kittiwakes fly away (Bourne, 1968; Vermeer and Vermeer, 1975). Oil Vulnerability Indices were prepared for 176 species of marine birds by King and Sanger (1979). For the Northeast Pacific Ocean, Sooty and Short-tailed Shearwaters had total scores of 51 and 53 respectively, which is in the middle range (maximum vulnerability is 100). Ford et al. (1982) attempted to estimate the long-term consequences to seabird populations of both one-time and chronic oil spills.

Unfortunately most species react only after contact with an oil slick. Under calm wind conditions and smooth-surfaced areas of down-welling, shearwaters tend to aggregate and settle; unfortunately, oil slicks tend to simulate these natural conditions under still-air conditions or very light winds and smooth the water surface. In such circumstances shearwaters could become oiled in large numbers, although we know of no recorded incidents of this, perhaps because major oil spills and large aggregations of shearwaters may not so far have coincided in the oceans of the world prior to this possibility having arisen in Alaskan waters.

Another cause of seabird mortality, indirectly due to petroleum, is likely to be caused by loss of the food species upon which seabirds depend on. Few confirmed and documented examples have been studied in detail, however.

Judging by reports of Bourne (1968), Monaghan et al. (1973), Wellman (1.973), Wong et al. (1974, 1976a), Butler (1975) and Brown and Huffman (1976), southern hemisphere shearwaters have plenty of opportunity for ingesting petroleum products. Boersma (1981) has demonstrated that storm-petrels breeding in the Barren Islands, north of Kodiak Island, do ingest fuel hydrocarbons and that these can be detected in stomach samples.

E. THE DETECTION OF OIL-DERIVED HYDROCARBONS AND THEIR EFFECTS

The degree to which oil and oil-derived hydrocarbons are harmful to water birds, and in what manner, is not well established, apart from i) acute toxicity through ingestion and ii) the loss of thermoregulatory capacity caused by oiling of the plumage (Hartung and Hunt, 1965; Hartung, 1967) .

Methods for determining the presence of petroleum-derived residues in plant and animal tissues, including zooplankton and fish had only recently begun to be developed when this study of shearwaters was first proposed. Effects of petroleum uptake on marine organisms and its transfer through the food chain have been described in: ZoBell (1964), Synder et al. (1971), Lee et al. (1972), Lee (1975, 1977), Holmes and Cronshaw [1977), Malins (1977), Stegeman (1977), Wolfe (1977, 1978), Malins (1979), Whipple et al. (1979) and Neff and Anderson (1981).

The detection and fate of oil-derived hydrocarbons in seawater have been studied by Boylan and Tripp (1971) , Payne (1976), Wong et al. (1976a, 1976b) and Cretney et al. (1977) . Bourne and Bibby (1975) showed how the temperature of the water varies the threat of oil to seabirds.

‘ Slow, chronic, harmful effects on seabirds from petroleum breakdown products and fractions were almost unknown when this study began. Clark and Kennedy (1968 pages 11-16) and Clark (1969] had reviewed what was known. Hartung and Hunt (1966) found that industrial oil caused lipid pneumonia, gut irritation, fatty livers and adrenocortical hyperplasia when fed to ducks. Crocker et al. (1975) studied the effects of oil fractions on intestinal functions in ducklings. Peaker (1971) suggested that oiling of birds could affect the activity of the salt glands. The influence of petroleum products on avian reproduction (egg formation, and embryo and chick development) has been studied by Hartung (1965), Grau et al. (1977), Albers and Szaro (1978), Miller et al. (1978), Butler and Lukasiewicz (1979), Peakall et al. (1980), and Ainley et al. (1981). McEwan and Whitehead (1978) suggested that mature gulls may be able to metabolize low levels of petroleum hydrocarbons.

F. OCEANOGRAPHY OF THE STUDY AREA (FIVE REGIONS)

The oceanography of the subarctic North Pacific Ocean has been studied extensively during the last 30 years by, among others, Fleming (1955), Dodimead et al. (1963), Uda (1963), Tully (1964), Dodimead and Pickard (1967), Royer (1975), Ingraham et al. (1976), Favorite et al. (1976), Sobey (1980a, 1980b) and Muench and Schumacher (1981).

The oceanography of the Bering Sea has been reviewed in, among others, Zenkevitch (1963), Kitano (1970), and various authors in Hood and Kelley (1974) and Hood and Calder (1981), including Gershanovitch et al. (1974), Girs (1974) and Hughes et al. (1974).

The study area is composed of five regions or geographical units, as described in this section: Central Gulf of Alaska, NEGOA, Kodiak Island Shelf, NWGOA, and Bering Sea.

The nomenclature of the oceanographic Domains and Current Systems discussed in this section follows that of Favorite et al. (1976).

They distinguished the following surface (upper 125 metres) Domains and Current Systems in the Subarctic region, as shown in Figure 1.

(1) Domains (white in Figure 1)
- E= Ridge Domain and Alaskan Gyre
- F= Transition Domain
- G= Dilute Domain
- I= Upwelling Domain
- J= Coastal Domain

(2) Current Systems (black in Figure 1).
- A= Bering Current System
- C= Subarctic Current System
- D= Alaska Current System (Alaska Stream)
- H= California Current System
- L= Okhotsk - Kuril Current System

(3) Gyres (anticlockwise) (thin arrows).
- B= Bering Sea Gyre
- E= Alaskan Gyre
- M= Okhotsk Sea Gyre
- N= Western Subarctic Gyre

(4) K= Subarctic Boundary

1. The Central Gulf of Alaska

The Northeastern Pacific Ocean above 50 degrees N (the *Central* Gulf) includes the northern boundary of the Upwelling Domain, the Coastal Domain, the Dilute Domain, the Subarctic Current, the Ridge Domain and Alaska Stream (Fig.1). When J.R.G. sailed between Seattle and Kodiak Island, on three occasions, all of these domains and currents were crossed at some point. For most of the year, shearwaters are not common over the open ocean of the

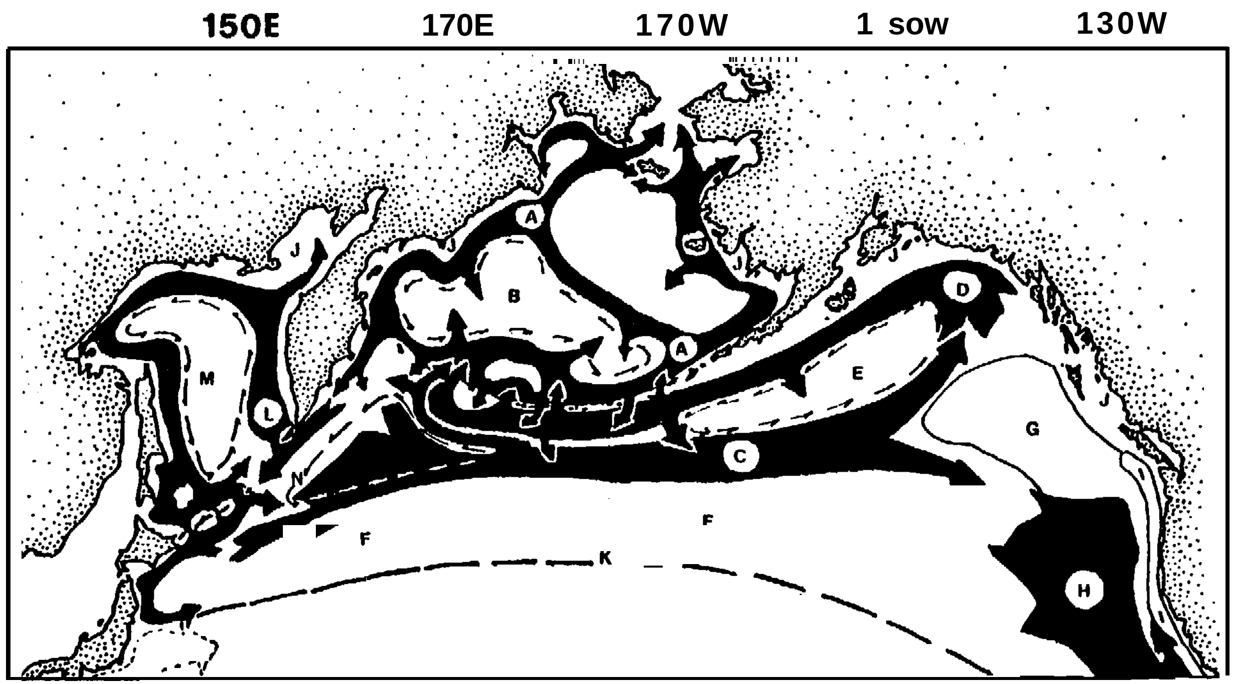


Figure 1. Subarctic Domains and Current Systems, according to Favorite et al. (1976). For interpretation of the letters (A-N) see text section III F (page 18).

Central Gulf.

Some seamounts of the Kodiak-Bowie Seamount Chain were passed on the trans-Gulf crossing. The ones considered most important, because of the number of shearwaters encountered, were the Giacomini, Surveyor and Welker Seamounts. These seamounts are located in the Ridge Domain and Dilute Domain and in the Subarctic Current System in between them. Upstream seamounts produce small scale subsurface fluctuations in dynamic topography that are manifested as baroclinic eddies at the sea surface (Royer, 1978).

Shearwaters concentrate in the Coastal Domain and the Upwelling Domain (Fig.1) and are found only in low numbers in all other domains and currents.

2. Northeastern Gulf of Alaska (NEGOA)

The Northeastern Gulf of Alaska (NEGOA) covers the area from Yakutat Bay to 147 degrees W. The study area lies mainly within the Coastal Domain and the Alaska Current System (Fig.1).

The influx of fresh water is a major driving force over the NEGOA shelf (Roden, 1967; Royer, 1979; Sobey, 1980b). Precipitation and runoff are the most important sources of low density waters nearshore. This occurs mainly during spring and early summer, from huge glaciers that almost extend down to tidewater.

Bathymetry is another factor affecting circulation. Troughs in the shelf region seem to direct flow towards the shore. Islands such as Middleton Island and Kayak Island, seem to have an important role in directing water flow shorewards or seawards.

3. The Kodiak Island Shelf

The Continental Shelf in the Gulf of Alaska is at its widest between Prince William Sound and Kodiak Island. The Kodiak Shelf is characterized by the presence of a series of troughs, which run across the shelf to the Shelf Break or act as channels for current flow between the continental slope and the inner shelf near Kodiak Island. From N-S these are Amatuli, Stevenson, Chiniak and Kiliuda Troughs. Kennedy Entrance lies between the Barren Islands and the Kenai Peninsula, and Stevenson Entrance between the Barren Islands and Afognak Island. Shallow banks are located between these troughs. From N-S these are Portlock Bank and North, Middle and South Albatross Banks (Sobey 1980a in the <u>Kodiak Interim Synthesis Report</u>, Science Applications, Inc.).

The Kodiak Shelf is located in the Coastal Domain. Along the Shelf Break, flow is dominated by the Alaska Current System {Alaska Stream) (Fig.1). The shelf is influenced by low salinity waters near the coast and denser waters along the Shelf Break. Upwellings are weak during the summer.

4. The Northwestern Gulf of Alaska (NWGOA) and Unimak Pass

The Continental Shelf becomes quite narrow west of the Shumagin Islands.

The Alaskan Stream, as it flows westward along the south side of the Aleutian Islands, penetrates into the Bering Sea through the passes along this chain and has a warming effect (Favorite, 1967; Kitano, 1970). Marked temperature and salinity fronts at the boundaries of the warm, dilute, low-salinity Alaskan Stream have been shown to exist in the spring and summer between 155-165 degrees W and south of Adak Island (Favorite et al. 1976).

There are altogether approximately 40 passes along the Aleutians, with the depth increasing towards the west. From east to west, these passes are grouped in six areas of major exchange: (i) Unimak, (ii) Amukta, (iii) Amchitka, (iv) Buldir, (v) Near and (vi) Kamchatka (Favorite et al. 1976). Flow through the passes may be either northward or southward (Reed, 1971). It is highly variable, and may be "greatly influenced by how far south of the passes the main axis of the Alaskan Stream occurs and at what longitude [westward] the main recirculation of coastal water [back] into the Gulf of Alaska takes place" (Favorite, 1974). Reed (1968) showed that at 165 degrees W the Alaskan Stream is only just over half as wide in September as in January, and concluded that the volume of flow is "correlated with the seasonal pressure systems", as had been postulated by Uda (1963).

Unimak Pass is the most important for this study. It is a shallow opening, only 60 metres deep, and is the first large communication between the Gulf of Alaska and the Bering Sea. Unimak Pass is characterized during spring and summer by the presence of thousands of shearwaters, no doubt because of the high concentration of nutrients, and hence of prey items, possibly due to a considerable degree of mixing that brings the nutrients to the euphotic zone.

5. The Bering Sea

Favorite et al. (1976) suggested a circulation pattern for the Bering Sea, which they called the Bering Current System. Water flows from the Alaska Stream north through several passes west of Unimak Island, and then is incorporated either into the Bering Current System flowing northwest along the Bering Sea Shelf Break, or into a coastal current flowing northeast along the north side of the Alaska Peninsula. There is a northward flow over the continental shelf in Bristol Bay and along the Alaskan coast towards the Bering Strait. The situation over the southeastern shelf is complicated by the effects of tidal and wind currents and fresh water runoff. Gershanovich et al. (1974) stated that tidal currents are very important on the shelf near the Pribilof Islands and on the continental slope. In the Southeastern Bering Sea, the area of interest for shearwaters is the eastern Continental Shelf and the Shelf Break Front.

Sancetta (1981) distinguished four zones, separated by three fronts: (i) the Shelf Break Front at the edge of the Bering Sea Basin at the 200 metres isobath (100 fathoms), (ii) a Middle Shelf Front at the 100 metres isobath (50 fathoms), and (iii) an Inner Shelf Front at the 50 metres isobath (25 fathoms) (Figure 2).

The Shelf Break appears to be permanent, and to separate more saline, warmer, waters of the Alaskan Stream and the Bering Basin from cooler, lower salinity, waters from the shelf. The Middle and Inner Shelf Fronts appear to be seasonal, and the thermocline is affected by wind and tidal vertical mixing. Thus, the waters between 50 - 100 metres are stirred by tidal and wind vertical mixing, which increases the concentration of nutrients available to the primary producers, resulting in a spring bloom of phytoplankton.

G. THE MARINE ENVIRONMENT

Seabird distributions must be understood in relation to the marine environments they use, such as the complex arrangements of Domains, Current Systems and Fronts that occur in the Subarctic North Pacific Ocean (Fig. 1). They maintain "a paradoxical consistency in their habitat preferences throughout the year" (Brown, 1980).

The analysis of the distribution of shearwaters in this report has mainly been based on an habitat classification derived from Kessel (1979) and Sancetta (1981). For this purpose the distance and the depth offshore at which shearwaters were found have been considered the basic environmental parameters in the analysis.

1. Marine Habitats

Kessel (1979) has classified the bird habitats of Alaska. Based on studies carried out by PROBES (Processes and Resources of the Bering Sea) , there are 4-5 major marine habitats (Waters or Zones) separated by structural fronts (Kessel) which are defined in terms of vertical mixing of the water by winds and tides (Sancetta, 1981), as follows (Fig. 2):

A= Nearshore Zone
B= Inshore Zone (<50 m = 25 fathoms)
C= Middle Shelf Zone (25 - 50 fathoms)
D= Outer Shelf Zone (50 - 100 fathoms)
E= Oceanic Zone (>100 fathoms)

The Middle Shelf Zone and Outer Shelf Zone together make up the Offshore Waters.

(1). Nearshore Waters

The Nearshore Zone includes waters that are protected by the configuration of the coast and/or by islands, and that are also generally shallow, e.g. bays and inlets.

(2). Inshore Waters

The Inshore Zone consists of exposed coastal waters

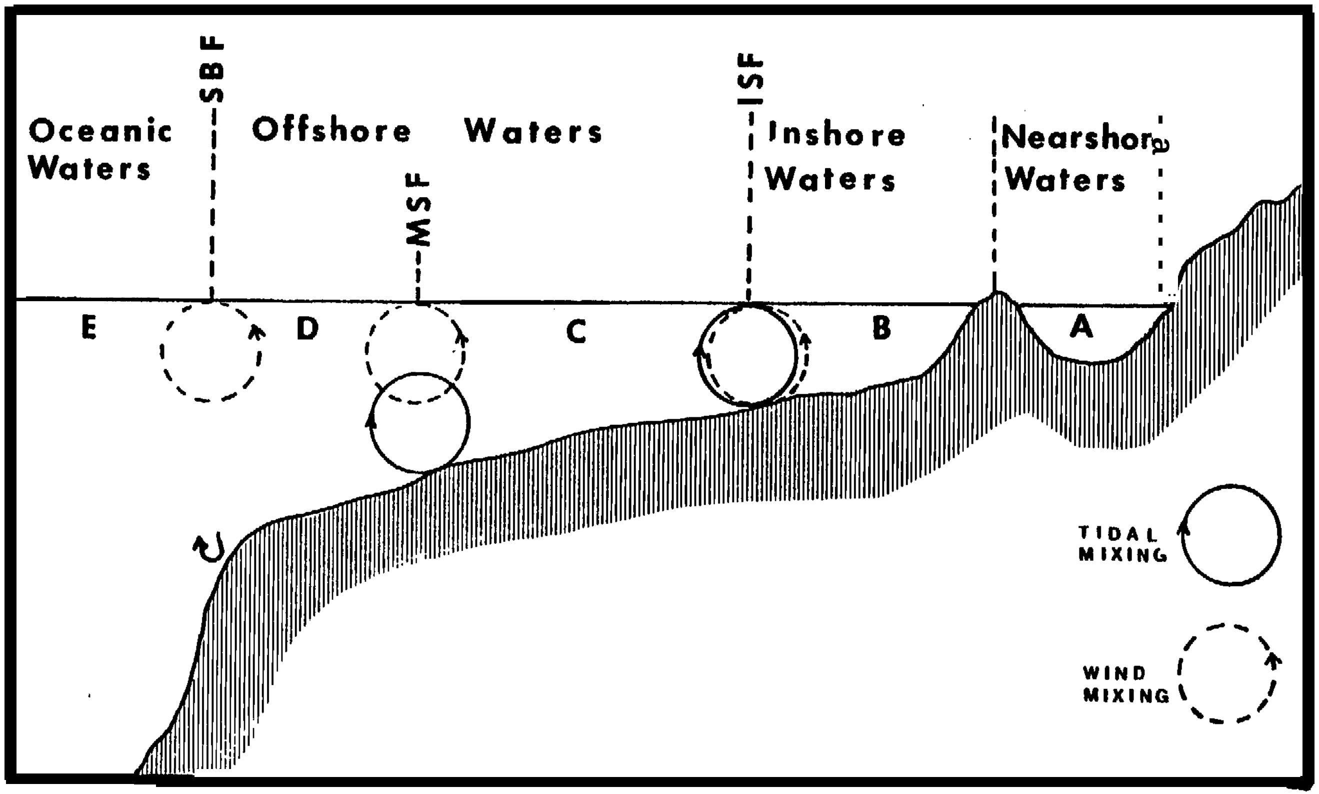


Figure 2. Schematic Cross-section Representation of the Continental Shelf to show Marine Habitats for Alaskan Waters, after Kessel (1979) and Sancetta (1981). For interpretation see text section III G (page 21).

that extend out to the Inner Shelf Front. The depth does not usually exceed 50 meters (25 fathoms) and they do not generally extend more than 6 km offshore. Both wind and tidal mixing occur at the sea surface at the Inner Shelf Front (Fig.2).

(3). Offshore Waters

Offshore waters extend seawards from the Inner Shelf Front and can be subdivided into:
(i) the Middle Shelf Zone (C in Fig.2), which extends from the Inner Front to the Middle Shelf Front, i.e. from the 25 50 fathoms isobaths, and (ii) the Outer Shelf Zone (D in Fig.2), which extends from the Middle Shelf Front to the Shelf Break Front , i.e. from the 50 - 100 fathoms isobaths.

(4). Oceanic Waters

Beyond the Shelf Break Front is the Oceanic Zone, with depths greater than 100 fathoms. Kessel considered everything beyond the Inner Shelf Front as being Offshore Waters, but use of that term will here mean only the region between the Inner Shelf Front and the Shelf Break Front, as in Sancetta (1981). Kessel's Oceanic Zone will be called Oceanic Waters.

2. Circulation of Nutrients

The circulation of nutrients in a vertical direction can be achieved by several different processes (Sverdrup et al. 3.942; King, 1975; Davis, 1977; Boje & Tomczac, 1978; Sobey, 1980 a and b).

(l). Influence of Winds

When Ekman transport pushes near-surface waters offshore away from a coastline, a divergence zone arises and water from deeper layers moves to the surface to replace the water masses moving away horizontally. This is upwelling (King, 1975; Boje & Tomczac, 1978; Sobey, 1980a). Downwelling occurs when waters of the surface layer are pushed inshore.

Upwellings are the most important factor in the supply of nutrients. An Upwelling Index (Bakun 1973, 1975) can be defined as being “numerically equal to the offshore component of the Ekman transport per 100 meters of coastline”. Positive values of the Upwelling Index indicate upwelling, and negative values refer to downwelling.

For the Northeastern Gulf of Alaska, the Upwelling Indices, averaged over 1975-1977, have been calculated by Royer (in Sobey, 1980 a and b). He found a very short upweLling season in the NEGOA, from about May to August, with only a very small positive index value. During the rest of the year strong downwelling prevails along the coastal area of NEGOA and the Kodiak shelf.

On the Kodiak Island shelf, Ingraham et al. (1976) also reported Upwelling Indices with weak positive values from June to September, and strong negative values during the winter when there is considerable downwelling in this area.

Sobey maintains that the upwelling season 'is probably too short to be biologically significant". In the Gulf of Alaska upwellings are probably not an important oceanographical factor responsible for high productivity, hence concentration of nutrients must be due to other oceanographic features.

Another mechanism by which wind can affect nutrient circulation is direct forcing. Direct forcing of the surface waters may occur when depth is small (35-50 m) compared to Ekman depth, or when wind fluctuates over short periods of time (shorter than the inertial period of about 14 hours in GOA).

(2). Turbulence and Local Currents

Along coasts there is an important supply of nutrients from runoff from the land, which are then transported along the coast by offshore currents and tidal currents. The stirring of nutrients from the bottom by wave action, and downslope transport along continental slopes and submarine canyons, are also important mechanisms increasing the amounts of nutrients available.

(3). Density Currents

Due to changes in water temperature, seasonal vertical mixing by changes in water density are particularly important in mid-latitudes, where it helps in transporting nutrients to the euphotic zone. Along the coast of NEGOA and the Kodiak Shelf there is a very strong stratification in the summer season, but during the winter there is a mixing (Sobey, 1980 a and b).

(4). Geostrophic Circulation

Favorite et al. {1976) calculated the wind driven transport of the sea surface currents "by computing geostrophic winds from the sea-level atmospheric pressure distribution". They found an area of current divergence in the Aleutian area between 50 - 55 degrees N, from-December to February and in June and September. It shifted northward to 55 - 60 degrees N from March to May, and it was absent in July and August. They suggested that, as 'this feature exists for most of the year", the vertical transport 'should be considered as an important mechanism in this area". It is probably partly responsible for high productivity,and hence for concentration of food items for secondary and tertiary consumers in the Aleutian Island passes.

3. Productivity, and the Foods taken by Shearwaters

Biological productivity and plankton have been described for the coastal areas of the Gulf of Alaska by Larrence et al. (1977), Dunn et al. (1979b) and Fucik (1980), for the Bering Sea by Motoda and Minoda (1974), and for the southeastern Bering Sea by Iverson et *al.* (1979) in relation to the Shelf Break Front. The distribution of euphausiids in the North Pacific has been described by Brinton (1962), Nemoto (1962), Ponomavera (1963) and Komaki (1967) .

The foods taken by shearwaters in the Northern Hemisphere have been reported by Lensink et al. (1976), Sanger and Baird (1977), Sanger et al. (1978), Krasnow et al. (1979), Ogi et al. (1980), Brown et al. (1981) and Ogi (1981) .

The diving behavior of shearwaters for food has been described by Brown et al. (1981), and Dunn (1973) and Birkhead (1976) described how the fishing ability of terns and guillemots is affected by windspeed and the condition of the sea surface - shearwaters may be similarly affected. Slater (1976) discovered a tidal rhythm in guillemots feeding on sandlance some distance offshore.

The trophic relationships of seabirds in the North Pacific Ocean and Bering Sea have been described by Lensink et al. (1976), Sanger and Baird (1977), Sanger et al. (1978) and Ainley and Sanger (1979).

Seabirds sometimes occur in interspecific feeding assemblages (Scaly, 1973, Hoffman et al. 1981). The community structure and interrelationships of marine birds, including shearwaters, in the North Pacific Ocean have been analyzed by Wiens et al. (1978).

IV. STUDY AREAS

The areas studied were at sea in the North Pacific Ocean and the Bering Sea, between 50 - 60 degrees North and 140 - 180 degrees West (10 degree x 10 degree Marsden Squares 195, 196, 197 and 198). This huge area includes parts of the following oceanographic regions: Coastal Domain, Alaskan Stream Domain, Transitional Domain, Central Subarctic Domain and Western Subarctic Domain (Figure 1) (Favorite et al. 1976) in the Gulf of Alaska and the Bering Sea.

Where to draw the boundary line between NEGOA and NWGOA has been a constant problem. In 1975 the NEGOA Continental Shelf, east of 150 degrees W, was not visited and Kodiak Island was included in the NWGOA. Greater activity just northeast of Kodiak Island early in 1976 necessitated treating that area also as part of the NEGOA. In this Final Report, NWGOA is limited to the region west of Chirikof Island to Akutan Pass (ea. 156 - 167 degrees W), and an intermediate area, the Kodiak Island Shelf, has been distinguished as occupying the area from Chirikof Island east to Amatuli Trough (148 - 155 degrees W.).

The area covered, as well as the cruises and periods of observations, were mainly pre-determined by the schedules of vessels used for other research ('ships of convenience') .

A. PERIODS OF OBSERVATION

All observations for R.U. 239 were made by J.R. Guzman. The first ones were made on June 3, 1975, north of Adak Island, and the last ones were made on August 19, 1976.

Observations were made during 1975-1976 for a total of

142 days (1975-58 days; 1976-84 days) spread over seven months (ranging from May through August) .

During 1975, one cruise was made on board the NOAA R/V DISCOVERER and two cruises on board the NOAA R/V SURVEYOR. In 1976, three cruises were made on board the R/V DISCOVERER and two cruises on board the R/V SURVEYOR. This was a combined total of eight cruises aboard the NOAA vessels. Small boats (launchers) were lowered from the vessel, when weather and time allowed, for collection and direct observations of shearwaters.

SUMMARY OF SHIP TIME

MAIN LOCATION	DATES	No. OF DAYS	VESSEL	FILE I.D.
	1975			
Bering Sea	June 2-19	18	Discoverer	01UC75
Bering Sea	July 11-Aug. 1	21	Surveyor	02UC75
Kodiak I.	Aug. 3-6	4	Launch	03UC75
Bering Sea	Aug. 7-22	15	Surveyor	03UC75
Total		58		
	1976			
NEGOA	May 3-22	20	Discoverer	01UC76
NEGOA	May 24-30	7	Discoverer	02UC76
Bering Sea	June 5-25	21	Surveyor	03UC76
NEGOA	July 16-31	16	Discoverer	04UC76
Bering Sea	Aug. 1-20	20	Surveyor	05UC76
Total		84		

The above listing shows only the main location visited during each cruise. In more detail, the time was spent as follows: the Northeastern Gulf of Alaska (40 days), the Northwestern Gulf of Alaska, including Kodiak Island (13 days), the Bering Sea (77 days), and in transit across the Gulf between Seattle and Kodiak (12 days).

B. TRACKS OF NOAA VESSELS

For location of the places named here refer to the Kodiak Interim Synthesis Report (Science Applications, Inc., March 1980, pages 4-7) and the Northeast Gulf of Alaska Interim Synthesis Report (Science Applications, Inc. , July 1980, pages 4-7).

The approximate tracks of the vessels appeared on maps in Myres and Guzman (1976 - 1977), and in Guzman (1981). The actual Transect and Station counts of all shearwaters recorded were also plotted on these maps. On those maps each plot represented one single observation, or a group of observations if these were so close together that it was impossible to represent them separately on the map. The maps showed daylight observation linked together in daily sequences. The lines linked the order in which the observations were taken rather than the actual tracklines of the vessels. Numbers against each plot referred to the day of the month, and were placed in front of the first observation of each day. The symbols represented absolute numbers of birds seen at each particular spot. They showed presence or absence of shearwaters, and the relative sizes of the aggregations.

1. 1975.

(l). June

The areas covered during this month were all west of 150 degrees West, and the observations were almost entirely confined within the Eastern Bering Sea. J.R.G. joined R/V DISCOVERER at Adak Island.

Observations were made during (i) a transit cruise from Adak Island in the central Aleutians to the Pribilof Islands near the edge of the Continental Shelf in the central Southeastern Bering Sea, and southeast of the Pribilof Islands, (ii) a cruise along the north side of the Alaska Peninsula as far east as inner Bristol Bay, (iii) a cruise in the northern part of outer Bristol Bay past Cape Newenham, (iv) a cruise close to Nunivak Island and as far west as the edge of the continental shelf west of the Pribilof Islands, (v) a cruise in the central Southeastern Bering Sea east of the Pribilof Islands, and (vi) during a transit voyage through Unimak Pass to Seward on the Kenai Peninsula of the Gulf of Alaska.

In the Bering Sea in June 1975 there was a lack of shearwaters to the northwest and towards the edge of the shelf in the west. Highest numbers were found off Kuskokwim Bay, Cape Newenham and inner Bristol Bay. On the one-way transit of the NWGOA to Kodiak at the end of the cruise only low numbers of shearwaters were recorded beyond the 1000 fathoms isobath.

(2). July

There were transit voyages (i) from Seattle to Kodiak across the Gulf of Alaska and (ii) from Kodiak to Unimak Pass. Formal observations were made (iii) in the Bering Sea along the north side of the inner Aleutian Islands and outermost Alaska Peninsula, and north as far as Cape Newenham. These were followed by (iv) a return transit voyage from Unimak Pass back to Kodiak.

Altogether, about 2,700 shearwaters were recorded when passing southwest of the Welker and Surveyor Seamounts in the Gulf of Alaska during the transit from Seattle to Kodiak on R/V SURVEYOR. The inside passage, along the south side of the Alaska Peninsula was very poor in shearwaters. Shearwaters were abundant around Unimak Pass and Amak Island. None was seen around Cape Newenham. On the return trip along the continental shelf break of the NWGOA they were seen only between Chirikof Island and Kodiak Island.

(3). August

As in June, the bulk of the information was obtained within the Bering Sea. Observations were first made in the Northwestern Gulf of Alaska (i) off Kodiak Harbor (Chiniak Bay), (ii) between Kodiak and the Barren Islands, (iii) in Shelikof Strait, and (iv) near the Trinity Islands and Chirikof Island. Finally, observations were made (v) in the Eastern Bering Sea.

Between 6 - 10 million shearwaters were seen, over a 30 nm distance, during 6 hours of observation, starting about 50 nm southwest of Nunivak Island on August 17, 1975 (see Figure 10). This was the largest aggregation of shearwaters seen.

2. 1976

(l). May

Observations were made in the NEGOA during (i) a transit voyage from Juneau to Kodiak along approx. 58 degrees N latitude across the deep waters of the northern Gulf of Alaska, (ii) a transit cruise from Kodiak to Cook Inlet and back, (iii) a transit cruise from Kodiak to Icy Bay, (iv) surveys in the Icy Bay - Kayak Island area, and (v) a return transit cruise to Kodiak. Finally, there was (vi) a second cruise into Cook Inlet and then on to Prince William Sound.

Shearwaters were well distributed, and very abundant over, and along the edge of, the continental shelf of the NEGOA between Icy Bay and Kayak Island, along the edges of Amatuli Trough, in Kennedy Entrance and over Stevenson Trough.

Shearwaters were found over Oceanic Waters along latitude 58 degrees N, in the Central Gulf of Alaska, on May 4, 1976, seen flying during all record periods towards the W (270 degrees) in sparse flocks (long files), which was the only time during five transit voyages across the Gulf of Alaska that a definite directional migratory movement was observed. The wind was from the ESE - SSE at 15 - 25 knots.' The largest flock seen was of 300 birds, and most flocks were only 1 - 44 birds. Some small groups stopped to dive and then continued flying.

(2). June

Observations were made during (i.) a transit voyage from Kodiak to Unimak Pass, (ii) a transit cruise from Unimak Pass to the Pribilof Islands, followed by nearly five days near the islands and a return transit to Dutch Harbor on Unalaska Island, (iii) along the north side of the inner Aleutian Islands and outermost Alaska Peninsula. Following this, there were transit voyages (iv) from Unimak Pass back to Kodiak, and (v) from Kodiak to Seattle across the Gulf of Alaska.

Unlike 1975, the inner continental shelf of the Bering Sea and Bristol Bay were, unfortunately, not visited.

Shearwaters were again absent from the Pribilof area, but were abundant between Unimak and Amak Islands, and in the NWGOA between Chirikof Island and the Trinity Islands, and over Kiliuda Trough off Sitkalidak Island.

Two relatively large flocks of 1,200 and 4,000 shearwaters were seen near Giacomini Seamount in the Gulf of Alaska on June 21, 1976, during the transit from Kodiak to Seattle.

'(3). July

Observations were made during (i) a transit voyage across the Gulf of Alaska (from Seattle to Kodiak,) (ii) a transit cruise across the deep waters of the northern Gulf of Alaska and (from Kodiak to Icy Bay) , and (iii) a cruise 'along the continental shelf back to Kodiak.

The numbers of shearwaters were quite low over the continental shelf of the NEGOA, except off Kodiak Island. About 3,100 shearwaters were seen near Surveyor Seamount on July. 18, in five groupings averaging just over 600 birds each. Very small numbers of shearwaters were also seen over Oceanic Waters along latitude 58 degrees N, in the Central Gulf of Alaska beyond the shelf edge, on July 20 - 21.

(4). August

Observations were made during (i) a rapid transit voyage from Kodiak across the Northwestern Gulf of Alaska and Bering Sea to Nome on the south shore of the Seward Peninsula, (ii) surveys in Norton Sound , and (iii) a rapid return transit voyage from Nome across the Bering Sea and Northwestern Gulf of Alaska to Kodiak.

During both crossings of the Southeastern Bering Sea and between Unimak Pass and Kodiak along the 100 fathoms line, shearwaters were seen regularly, but flocks never exceeded medium size levels.

In conclusion, to determine the locations of particular shearwater observations, the reader should refer to the maps already published in Myres and Guzman (1976-1977), or in Guzman (1981). In the remainder of this final report, these observations are analysed by latilong blocks, by distance from shore and by water depth, as described in Section V.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

A. COUNTING SHEARWATERS

The problems of counting birds at sea have been widely discussed. Dixon (1977) showed that the distances at which birds sitting on the sea are first seen varies with the species. Bailey and Bourne (1972) and Wahl (1978) presented guidelines. Heinemann (1981) developed a range finder for use when censusing pelagic birds at sea. King (1970, 1974) refined a number of observational methods developed earlier by Kuroda (1960). Recent modifications in methodology have been made by Nettleship and Tull (1970), and Brown et al. (1975). In Alaskan waters, Bartonek and Gibson (1972) prepared maps for each species recorded in Bristol Bay that showed the number of birds per 20 miles of transect. Sanger (1970) also used the indices of Kuroda (1960), and later Sanger (1972, pages 596-597) devised an equation for the standing stock of 'ecologically similar groups of species' by season and oceanographic domain. This was converted to biomass by inclusion of average weights of 'representative birds'.

In this study, observations were made with 7x binoculars. Hand counters were used to tally the birds. The numbers of birds seen, and comments on their behavior, were recorded on a tape recorder, and later transcribed onto the forms. The recording methods developed by the U.S. Fish and Wildlife Service in Anchorage, specifically for the Alaska OCSEAP (NOAA) surveys, were employed. The census method involved data forms (i) for ship transects (Form OBS-2-75 for Pelagic Bird Observations: Transect Records), and (ii) for station records (Form OBS-3-75 for Pelagic Bird Observations: Station Records).

Normal Transect Counts were made mainly from atop the pilot house (flying bridge), in a 90 degree quadrant out to a distance of 300 m forward from the ship on one side only, in three zones, each 100 m wide.

In 1975 counts were made during a standard 15 minutes of observation <u>once</u> in every hour, but in 1976 this was changed to a standard 10 minutes record period every 30 minutes. Thus, in 1976 more of the available time was utilized for recording compared with 1975 (30 minutes instead of 15 minutes in every hour sampled).

In addition, e.g. whenever visibility was limited by fog, so-called Experimental Transect Counts were made. They were recorded on the same forms as the Normal Transects, but an "E" was placed before the number to show that the information was collected using other censusing procedures than those for Normal Transect Counts. Whenever time permitted, all the shearwaters that it was possible to see from the ship were counted, and if these observations did not qualify as Normal Transect Counts they were recorded as "E" Transects.

The observations were generally carried out towards the side with least glare, i.e. away from the sun. But when shearwaters were encountered the side considered was that where shearwaters were present or from which they were approaching the vessel.

All the transects carried out from May 3 - 20, 1976, were treated as Experimental Transects ("E") because both sides of the ship were surveyed, and the time periods varied from 10 - 30 minutes. This method (including birds on both sides of the ship during a transect) proved to be impractical, because it is very difficult to observe and count all species of seabirds over the entire area simultaneously.

Furthermore, because most birds normally cross the bow from one side to the other, there is a risk of counting birds twice and the disadvantage of assigning birds to an area twice as large as necessary. Counting off one side *only* usually results in almost as many being counted as off both sides.

After May 24, 1976, transects of 10 minutes duration were employed because this proved to be more practical and valuable than the one 15 minutes period each hour employed in 1975. Fewer counts were forfeited because of interruptions, and it allowed for a higher number of 'record periods' during a single hour. It was easier to work three transects of 10 minutes into 'block periods' of 30 minutes per hour. Any information besides counting was recorded under remarks.

At fixed Ship Stations all the birds up to 600 m all around the ship were counted.

Eventually all the data collected was transcribed onto coded forms developed by the USF&WS in Anchorage, for use by the U.S. National Oceanographic Data Center (NODC), for all OCSEAP projects in Alaskan waters.

B. SPECIMENS

Whenever possible, specimens were collected with a 20-gauge shotgun under USF&WS sub-permit (No. 7-SC-25) of the federal permit to Dr. C.Lensink, and USF&WS sub-permits of State of Alaska permit No. 76-148. Only 38 specimens were collected in 1975-1976. They were distributed as follows:

	Short-tailed Shearwater	Sooty Shearwater
1975.	12,June 10, off Cape Newenham (Bering Sea)	None
	12,August 19, off Kodiak	None
1976	13,June 15, off Amak Is. (Bering Sea)	1,August 20, Chiniak Bay (Kodiak)
Totals:	37	1

A technique for capturing shearwaters alive at sea has been described by Gill et al. (1970), and this could be used to band them or to attach radio transmitters in Alaskan waters. Unfortunately, sexing of shearwaters by cloacal examination is only possible during the breeding season (Serventy 1956a).

C. PLANKTON, SQUIDS AND FISH

As soon as birds were collected, they were weighed. Formaldehyde was forced into the esophagus to stop digestion. Stomachs were removed for analysis by

Mr. G.A. Sanger of the USF&WS, Anchorage, Alaska. The analyses of the foods taken by shearwaters in 1976 in the Gulf of Alaska and southern Bering Sea were published by Sanger and Baird (1977).

Unfortunately very little data on the occurrence and distribution of plankton, squids or fish were collected by other Research Units in the OCSEAP program on cruises of R/V DISCOVERER or R/V SURVEYOR during which J.R.G. collected simultaneous shearwater observations. Therefore, it was not possible to make direct correlations of the food taken by birds with what was available to them.

VI. RESULTS

A. METHODS OF PRESENTATION

For the year 1975, maps of the densities of shearwaters (birds/km2) were prepared for the Annual Report, but for the year 1976, actual numbers of birds seen at each observation point were plotted on maps for the Annual Report (Myres and Guzman, 1976-1977). Similar maps of actual numbers of birds counted in 1975 appeared in the Quarterly Report at the end of the 1975 season. Both methods of presentation (actual counts and densities) have drawbacks. Actual counts vary over a huge range of numbers and are not tempered by any averaging procedure, but they do identify precisely where local aggregations occurred. Density calculations obscure the strong gradient that exists from the vast area of ocean with no shearwaters at all, or very small numbers, to highly concentrated local aggregations.

Seabirds are highly mobile organisms and very patchy in distribution. It is difficult to submit count data obtained during infrequent, widely-spaced and non-parallel track-lines by ships-of-convenience to standard statistical analysis. Marine ornithologists now favor the standardization of counts into 10-minute units of equal effort.

1. "Latilong" Blocks

The study areas were each divided into regular latitude-longitude ('latilong') blocks. The latilong block sizes used were either 30'N X 30'W or 1 degree N X 1 degree W. Each 1 degree N x 1 degree W latilong has a surface area that is 60 nautical miles (111 km) tall from South-North and 30 - 35 nautical miles (56 - 64 km) wide from East-West, depending on the latitude, at 55 - 60 degrees N.

For each block visited we have plotted vertically: (i) at the top, the Effort (expressed as the number of 10-minute periods of observation), (ii) and (iii) the average number of birds of each species seen per unit-effort, and (iv) at the bottom, the average number of all shearwaters (including unidentified shearwaters) seen per unit effort. See the Key to Symbols on Maps at the start of the Portfolio of figures.

2. Unit-effort (10-minute counts)

The shearwater counts have been presented as the number of birds seen per 10 minutes of observation. Because the USF&WS switched from a 15-minute standard for Normal Transects in 1975 to 10-minute Normal Transects in 1976, we had to switch as well. As the data were collected in a very opportunistic way, not all the observations were made during standard 10-minute periods; sometimes observations were carried out for much longer periods of time.

To convert non-standard counts into 10-minute unit-efforts, the number of birds seen per 10 minutes was calculated from the total time of the particular non-standard observation. The total number of minutes of original observation was divided by 10, to determine the number of unit-efforts (periods of 10 minutes); any surplus value bigger than 0.5 was counted as an extra unit-effort. All Normal Transects, E-Transects and Station counts, described earlier, have been converted into unit-efforts.

3. The Shearwater Distribution Maps

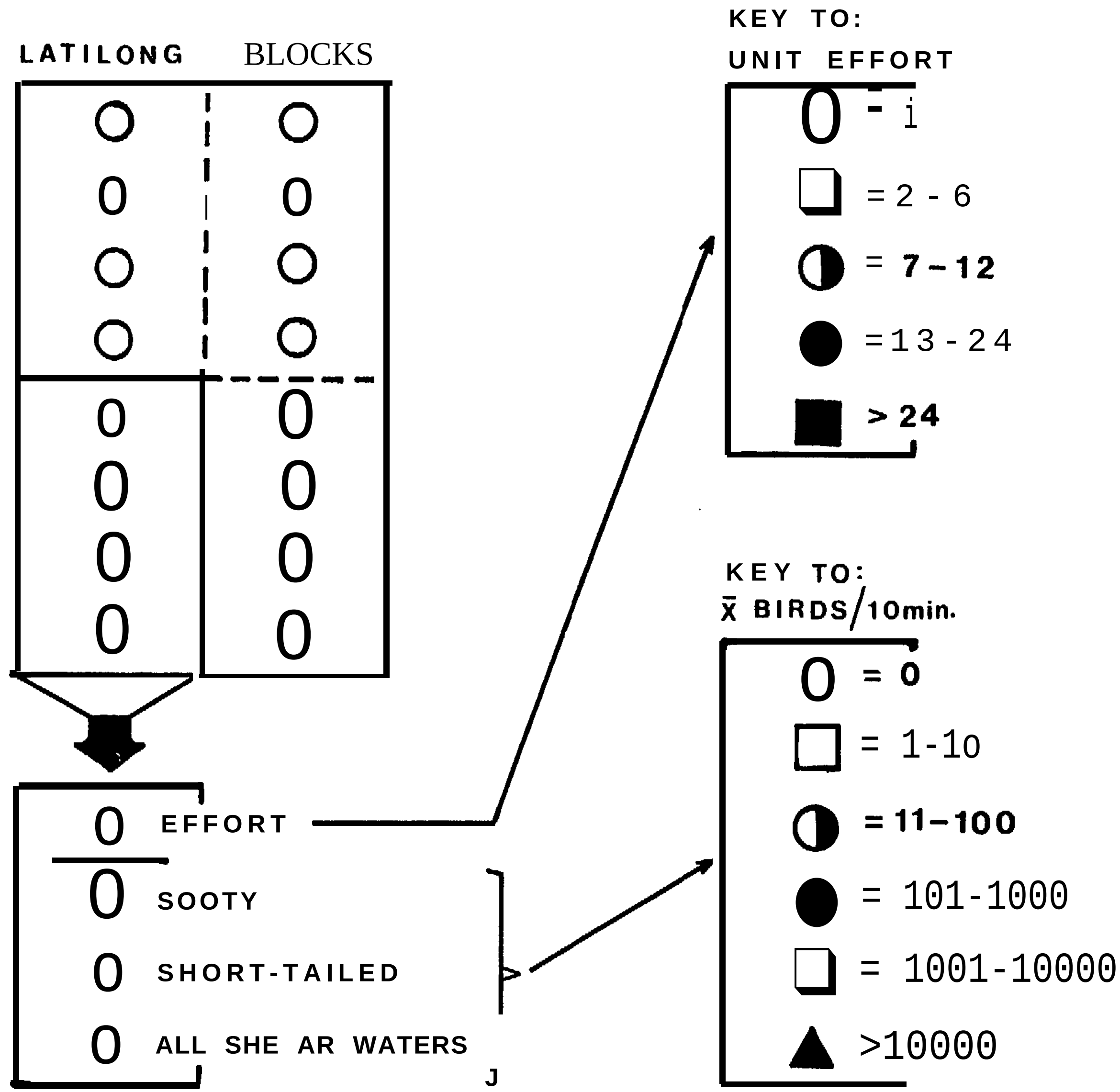
The total number of birds seen in each latilong block was divided by the number of unit-efforts in that block, so as to obtain the mean number of birds seen per unit-effort per block.

The mean number of birds per 10-minute unit-effort in each block visited, is presented for all cruises, month by month, in Figures 3-13. The topmost symbol in each 4-symbol group is the total number of unit efforts in that block upon which the analysis is based (see the Key to Symbols on Maps at the start of the portfolio of figures). The three lower symbols in each block represent (in-sequence downwards) , first the Sooty Shearwater, then the Short-tailed Shearwater and finally all shearwaters together (Sooty + Short-tailed + unidentified Shearwaters) . Thus, to determine the mean total number of shearwaters in each latilong block, scan only the lowest symbol in each group. To determine the mean number of Sooty Shearwaters scan across the line containing the second symbol down, and for the Short-tailed Shearwaters scan across the line containing the third symbol down in each group.

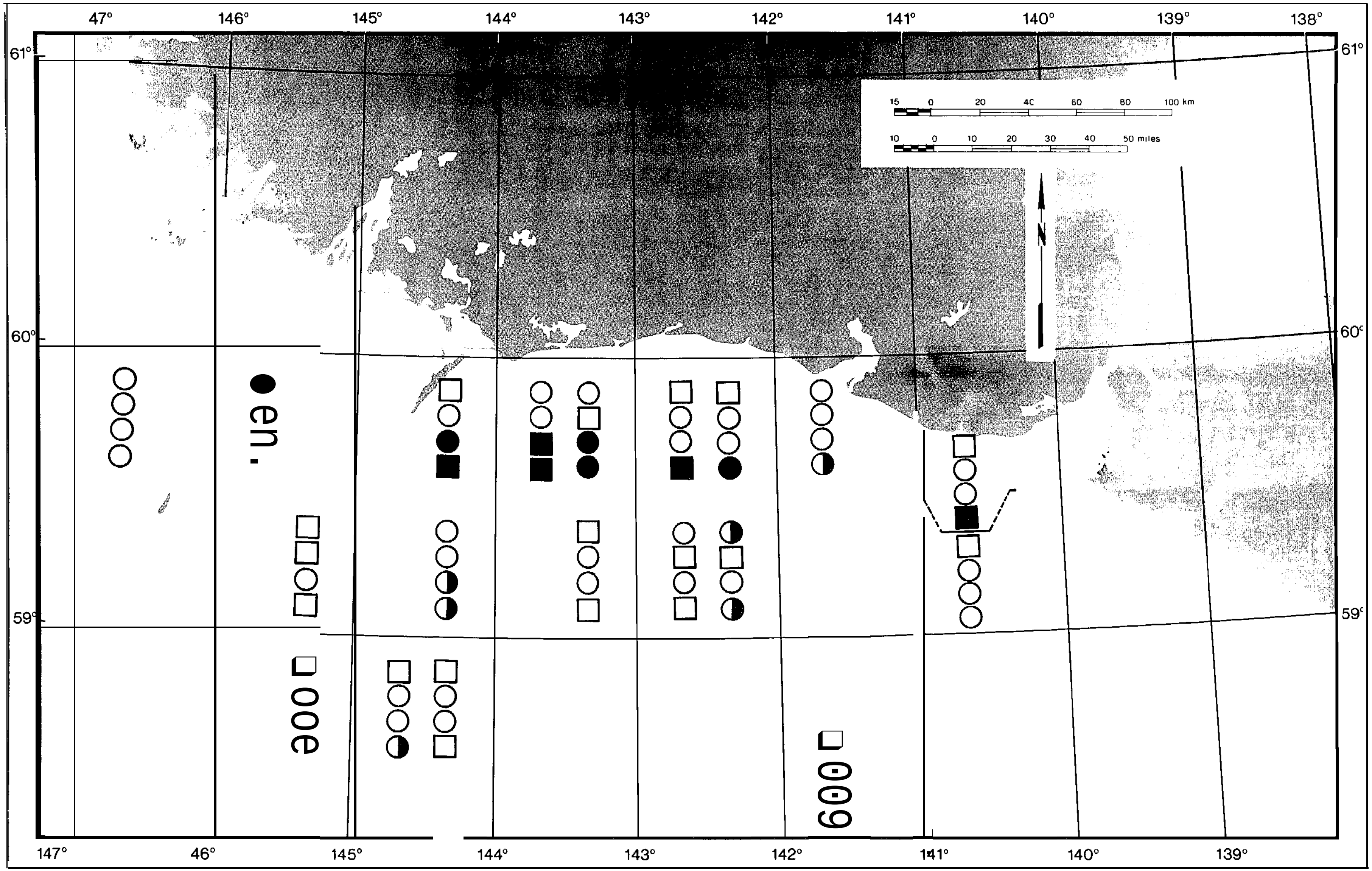
No attempt has been made to calculate density of birds per km square, as was done by the USF&WS, Anchorage, because the vessels could not be relied upon to maintain a uniform speed from which a fixed length of distance travelled in a standard time would allow the calculation of the area of observation. Furthermore, the distribution of shearwaters is so patchy that a figure for density of birds per square km calculated from sample counts in a small area misrepresents the average density in a large unit area, although calculations of this kind might be useful when dealing with assemblages of bird species.

4. Distance and Depth Analyses

The data have been analysed in two ways:

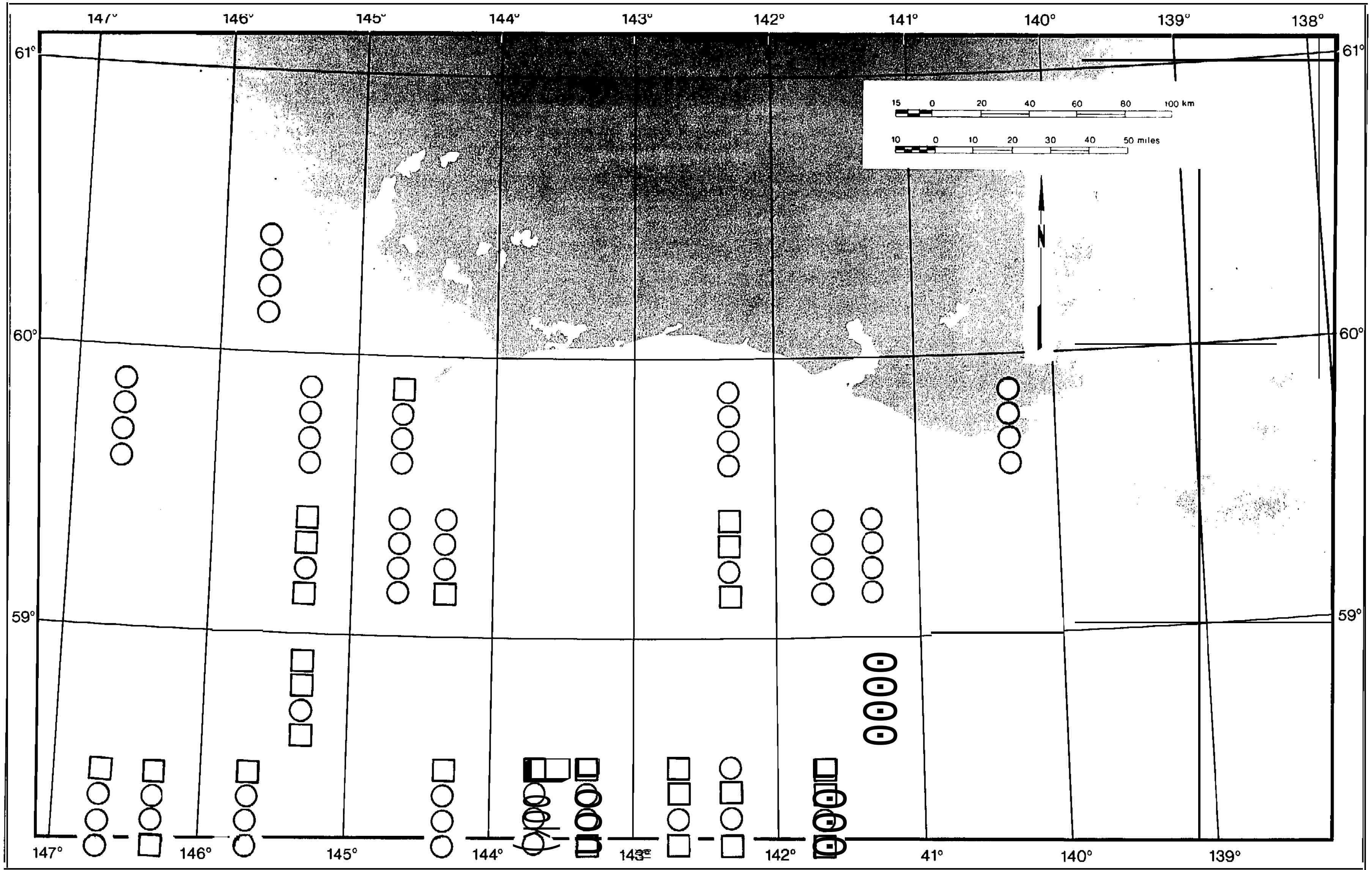


KEYS TO SYMBOLS ON MAPS



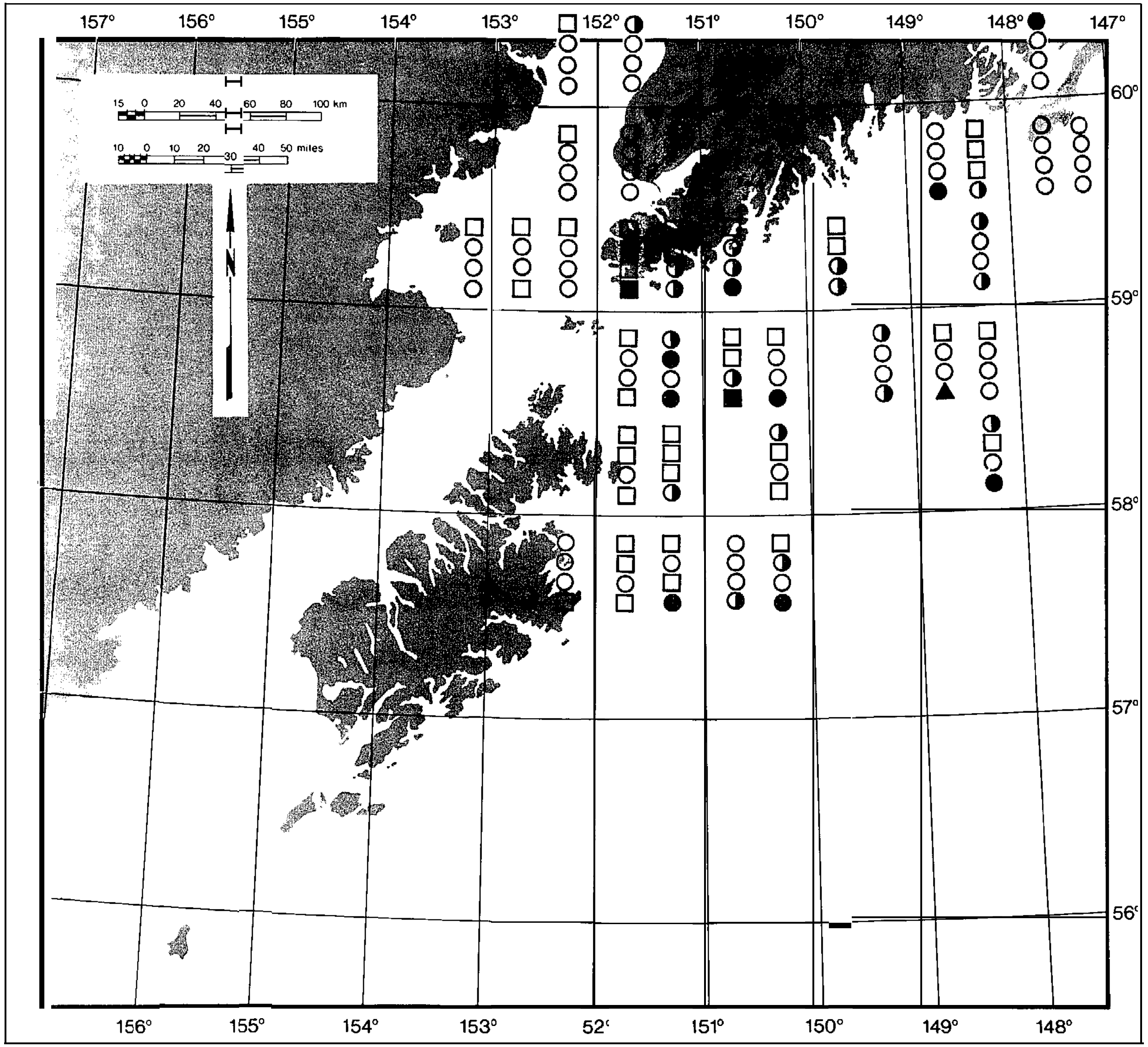
M A Y 1 9 7 6

Figure 3. Shearwater Distributions in NEGOA, May (1976).



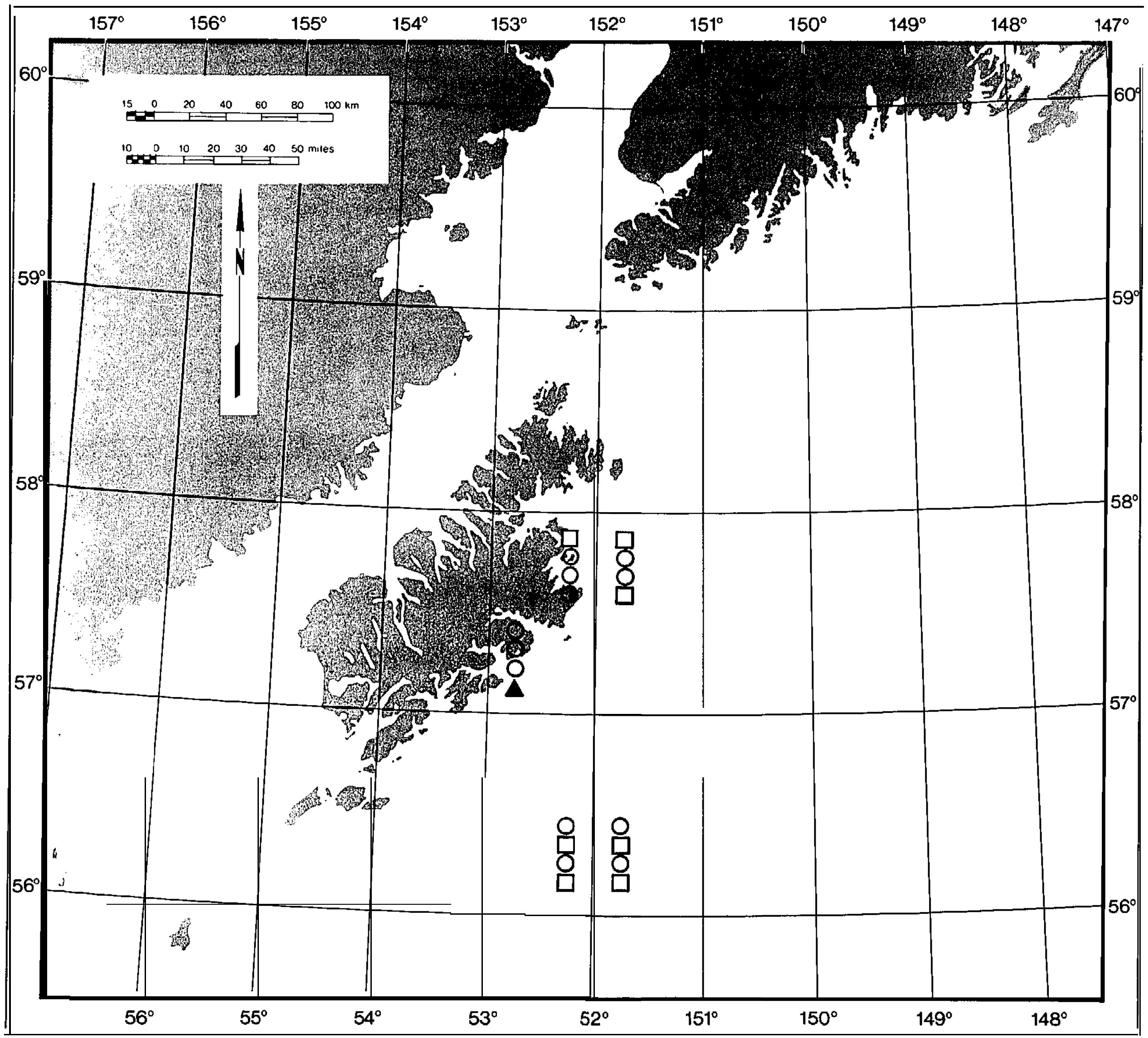
JULY 1976

Figure 4. Shearwater Distributions in NEGOA, July (1976).



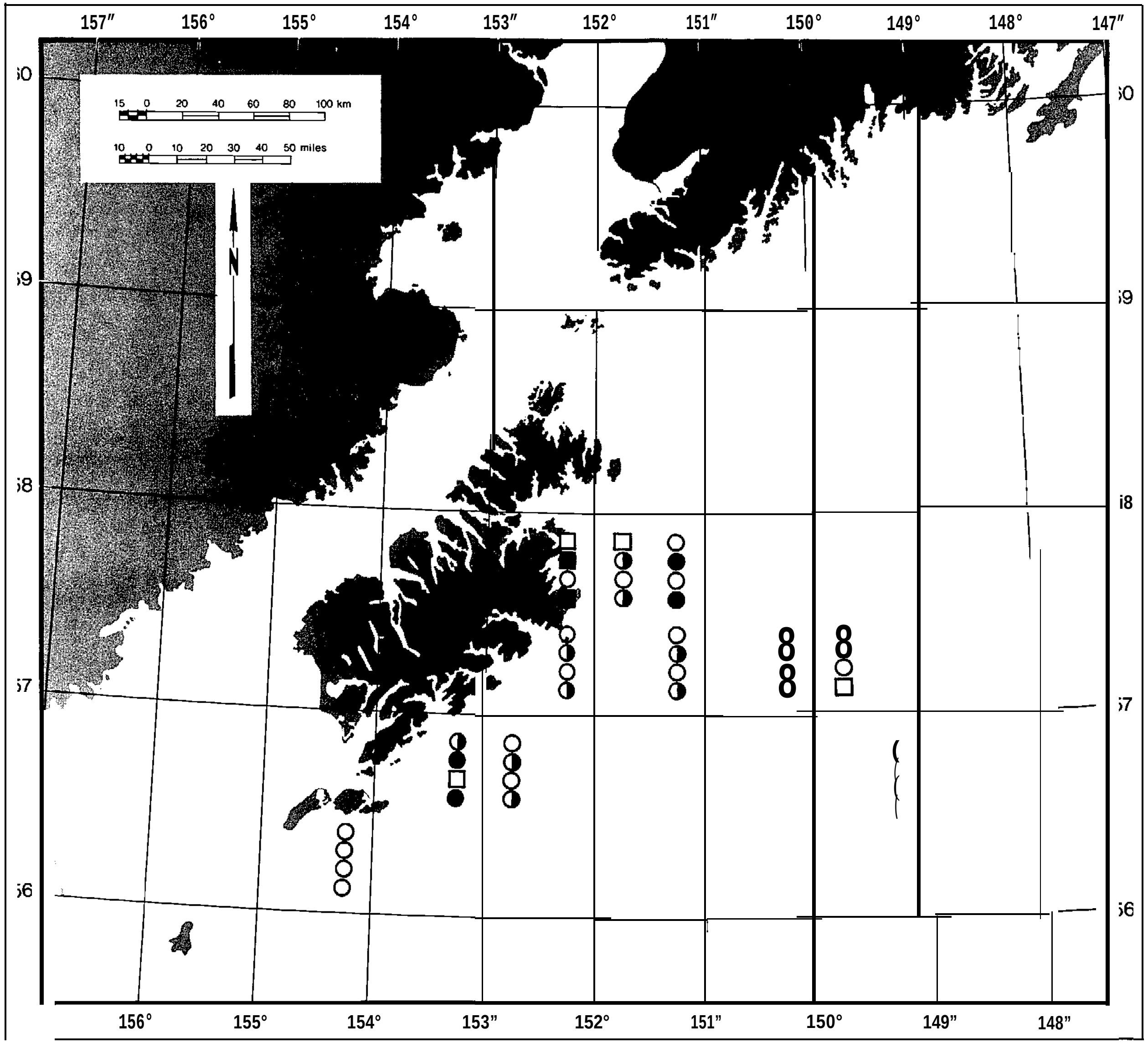
MAY 1976

Figure 5. Shearwater Distributions on Kodiak Island Shelf, May (1976).



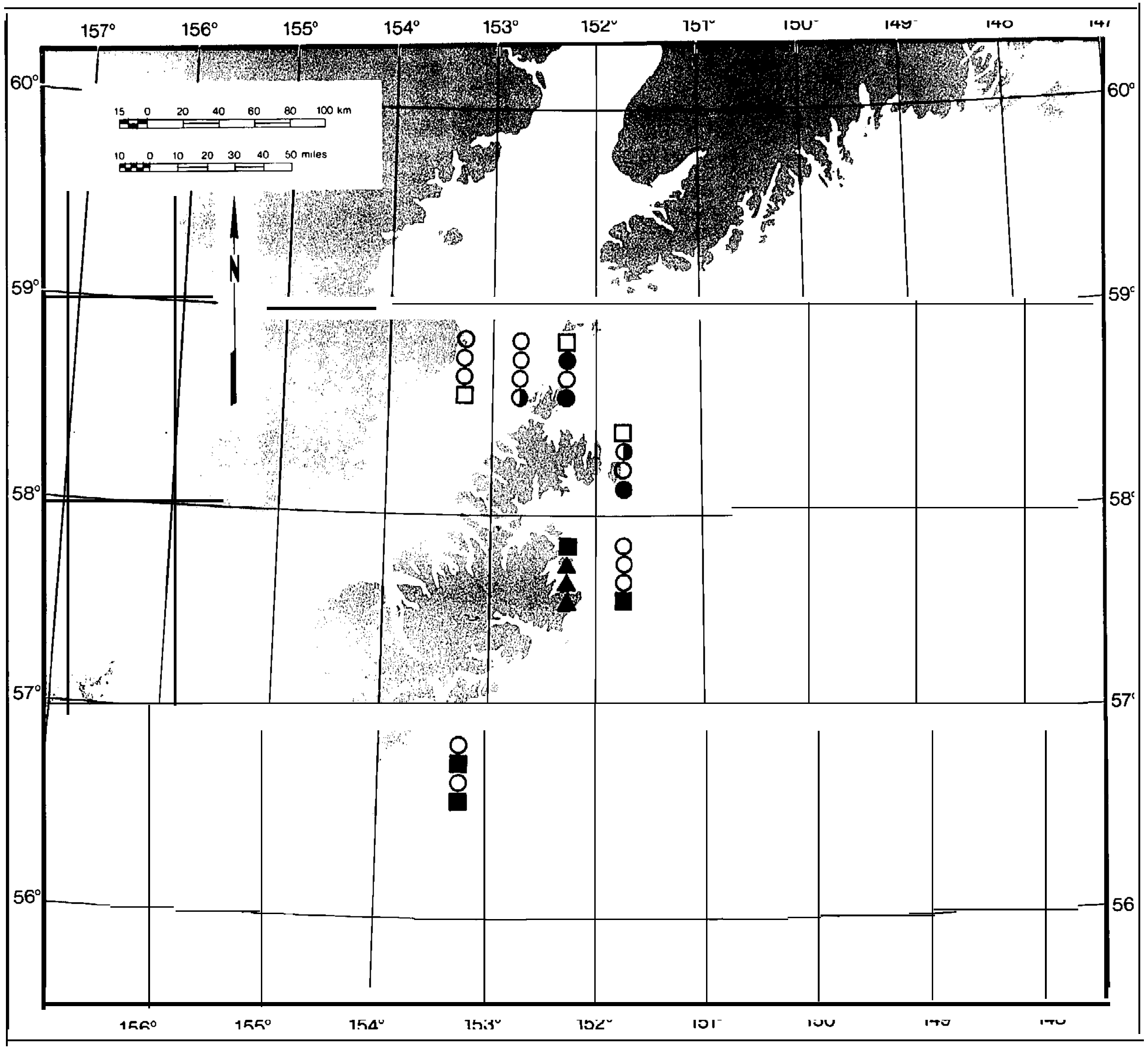
J U N E 1 9 7 5 – 7 6

Figure 6. Shearwater Distributions on Kodiak Island Shelf, June (1975-1976).



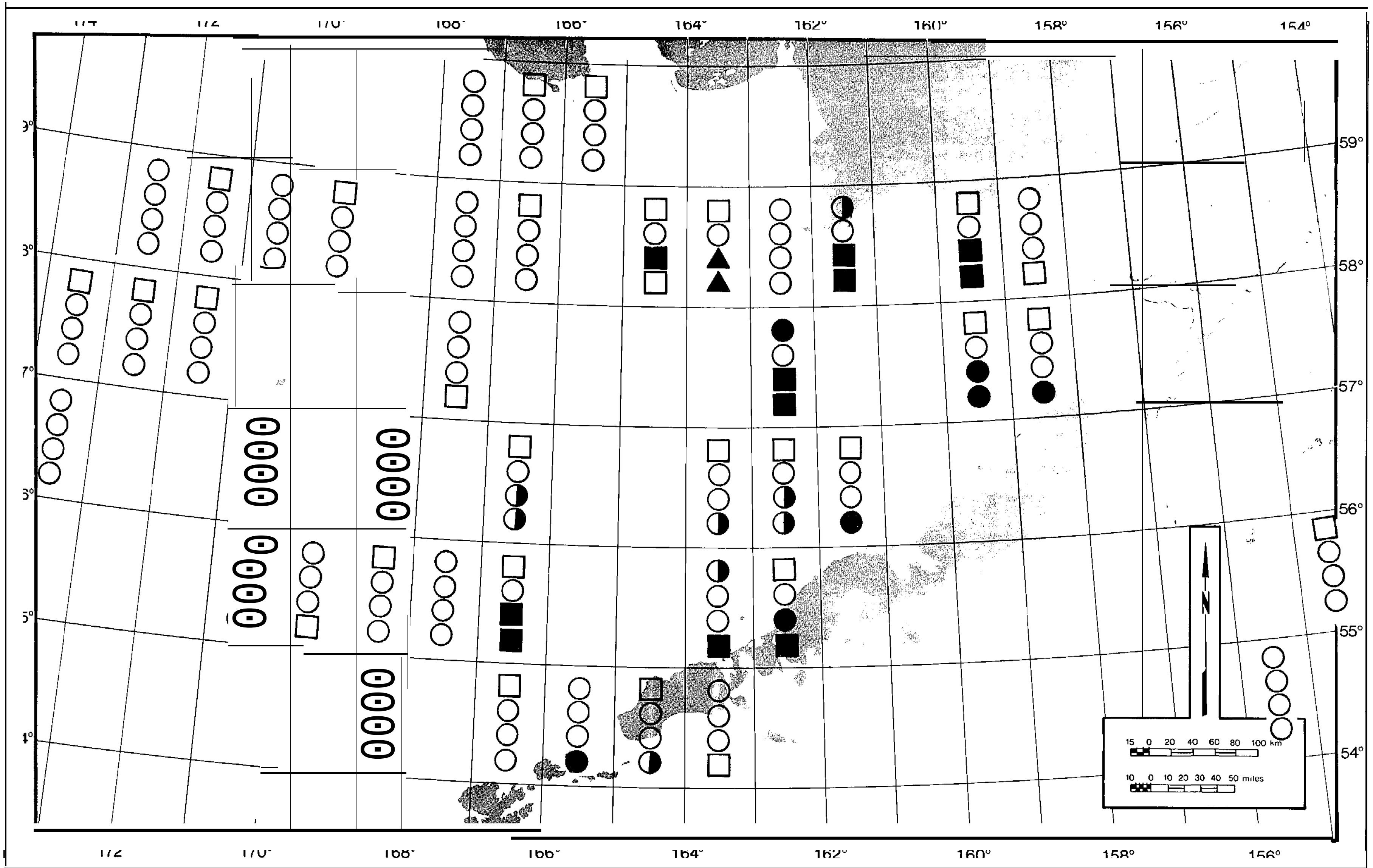
J U L Y   1 9 7 5 - 7 6

Figure 7. Shearwater **Distributions on Kod.iak Island Shelf, July** (1975-1976).



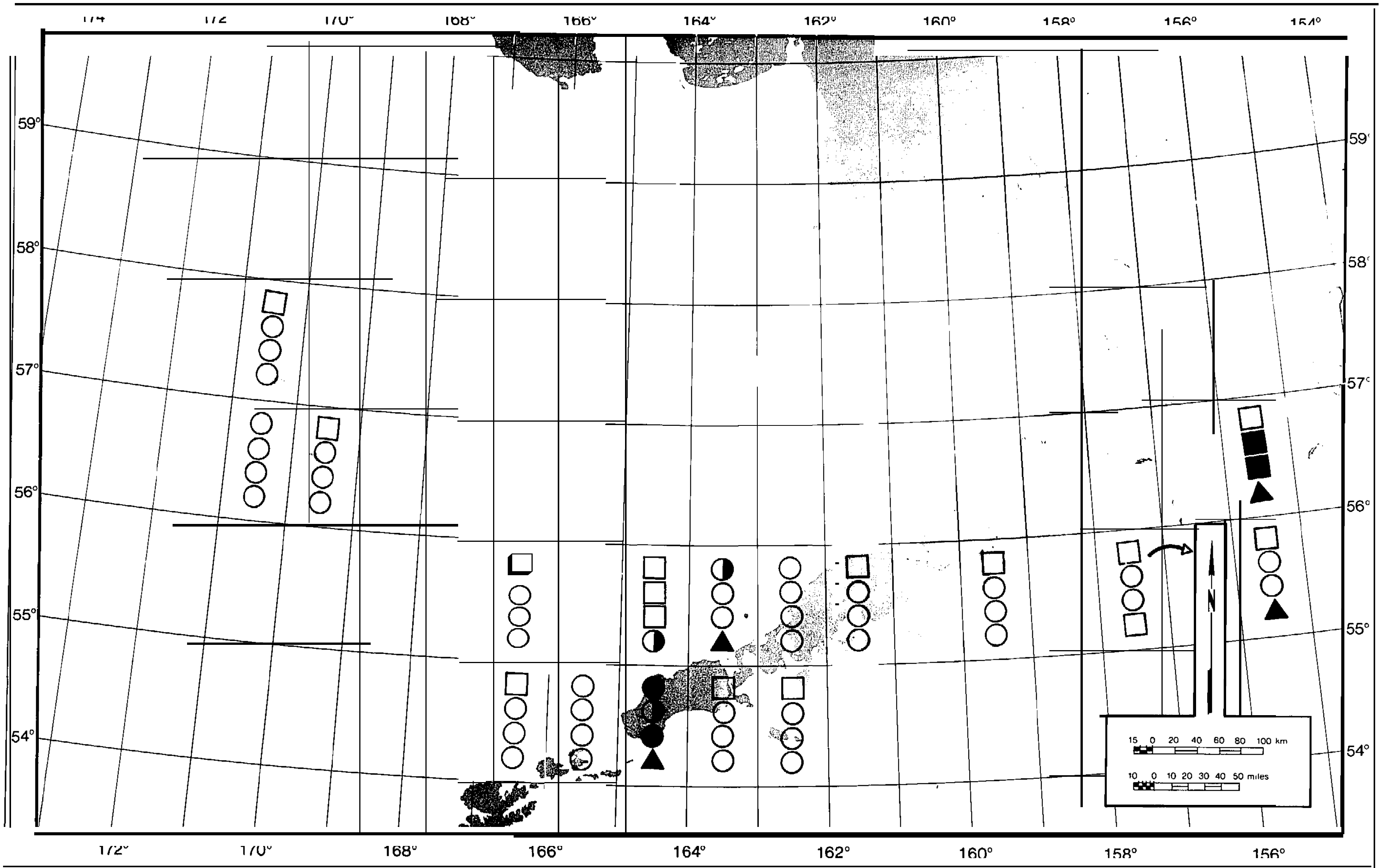
AUGUST 1975

Figure 8. Shearwater Distributions on Kodiak Island Shelf, August (1975).



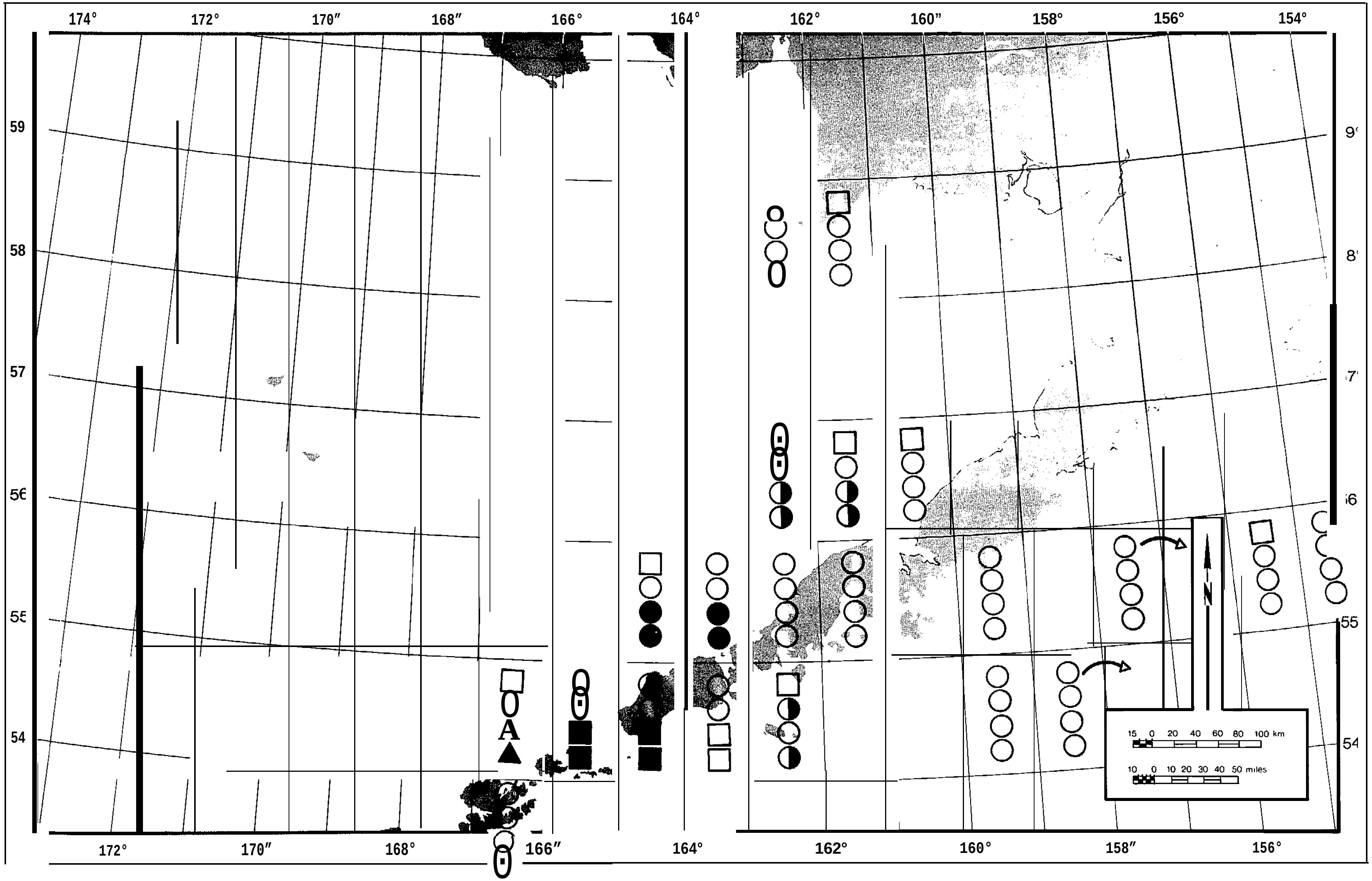
JUNE 1975

Figure 9. Shearwater Distributions in NWGOA and the Bering Sea, June (1975).



JUNE 1976

Figure 10. Shearwater Distributions in NWGOA and the Bering Sea, June (1976).



JULY 1975

Figure 11. Shearwater **Distributions** in NWGOA **and. the Bering Sea, July** (1975).

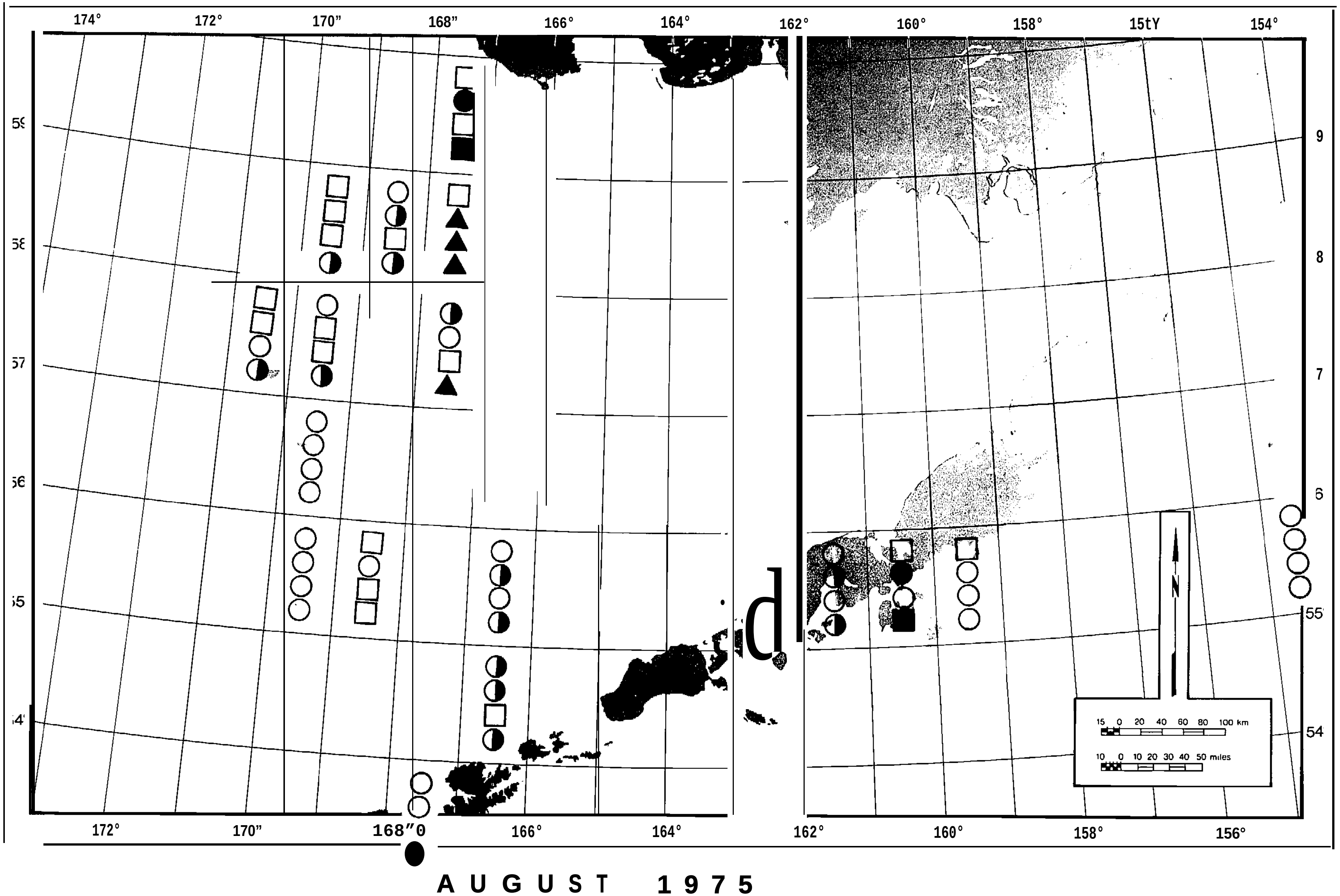
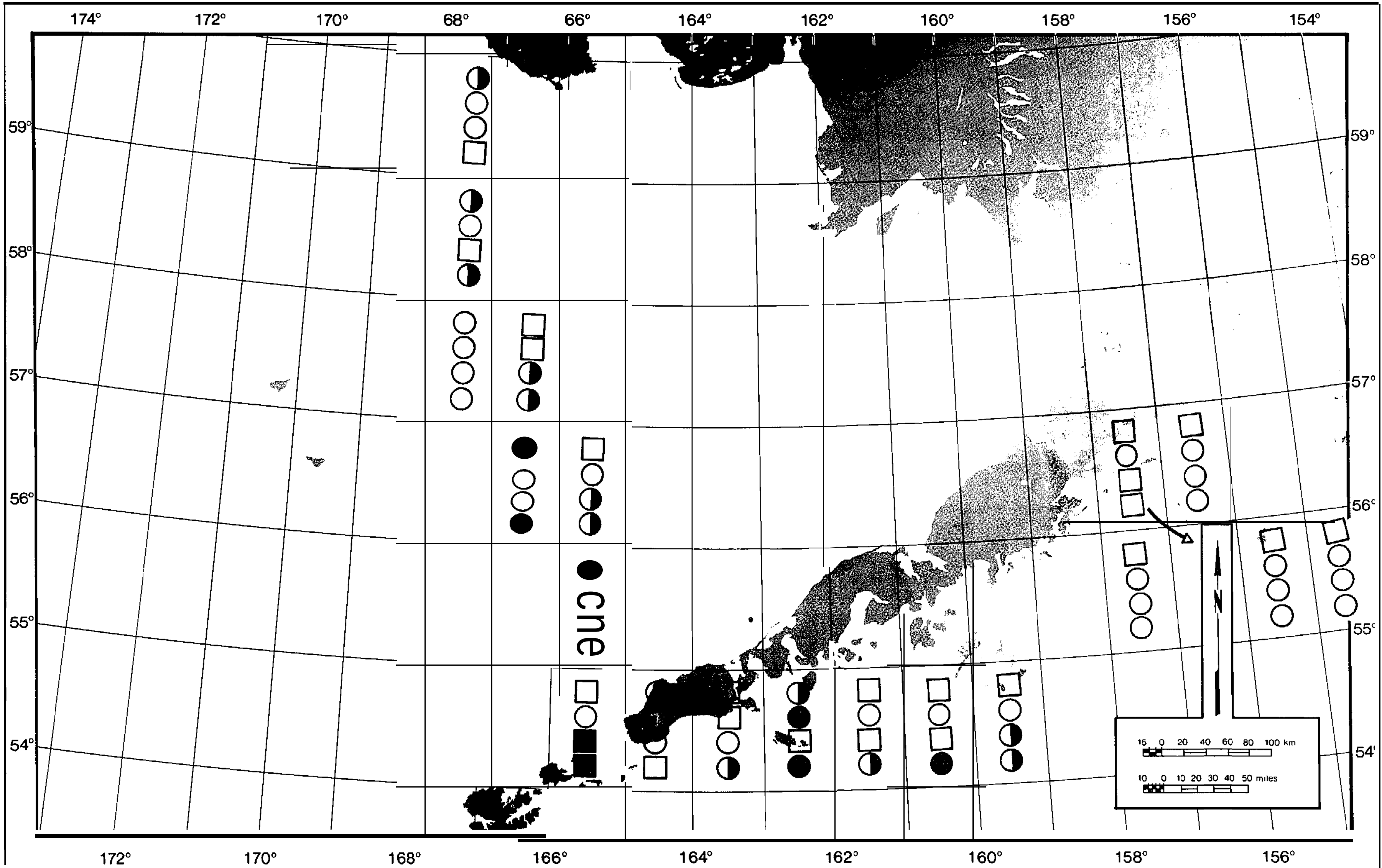


Figure 12, Shearwater Distributions in NWGOA and, the Bering Sea, August (1975).



AUGUST 1976

Figure 13. Shearwater Distributions in NWGOA and the Bering Sea, August (1976).

(1). Distribution of birds in relation to the distance offshore (Figs 14-17). This does not discriminate the different habitats over the continental shelf, but does shed information on the response of shearwaters to coastlines, the Continental Shelf edge, seamounts, and possibly on their movements over the wintering grounds.

(2). Distribution of birds in relation to depth of the water, as a measure of habitat selection (Figs 18-20). One of the best indicators of the degree of tidal and wind mixing over the continental shelf is the depth of the water; so, habitats are basically defined in terms of the isobaths along the continental shelf.

Since the perimeter of the Gulf of Alaska is mountainous, most of the study area presents a very rugged shelf, characterized by the presence of troughs, canyons and sounds. Waters in these features can be quite deep and, indeed,the 100 m isobath (50 fathoms), comes in some places very close to the shore line. However, the 200 m (100 fathoms) isobath is not affected and is found about 60 nm offshore. The eastern shore of the Bering Sea, in contrast, is not as mountainous and the continental shelf offshore has less relief, is shallower and has the shelf edge much farther offshore.

5. Aggregations

Shearwaters were seen in groupings of varying sizes: (i) loose groups of 2-12 birds traveling together, (ii) small flocks of up to a few hundred birds, (iii) large flocks of a few thousand, and (iv) very large grouping of more than 10,000 birds, here referred to as aggregations. These are themselves composed of separated clusters of up to a few hundred birds each.

The large aggregations of shearwaters that were seen in 1975-1976 (10,000 birds or more) are presented in Tables 1-2. Highlights are discussed in the following sections.

6. Sea-Surface Temperatures

The sea surface temperatures associated with aggregations are presented in Table 3.

7. Disposition of Contract Data

The data were coded, keypunched and transfered to magnetic tape. This was sent to the Juneau Project Office in April 1977, although an amended tape was not submitted by the Juneau Project office to the National Oceanographic Data Center (NODC) in Washington, D.C. until 1978.

Also submitted in 1977 were 389 pages of computer-printed data that presented all of our observations on all the species of seabirds seen during the study, by 1 degree N X 1 degree W latilongs on a month-by-month basis.

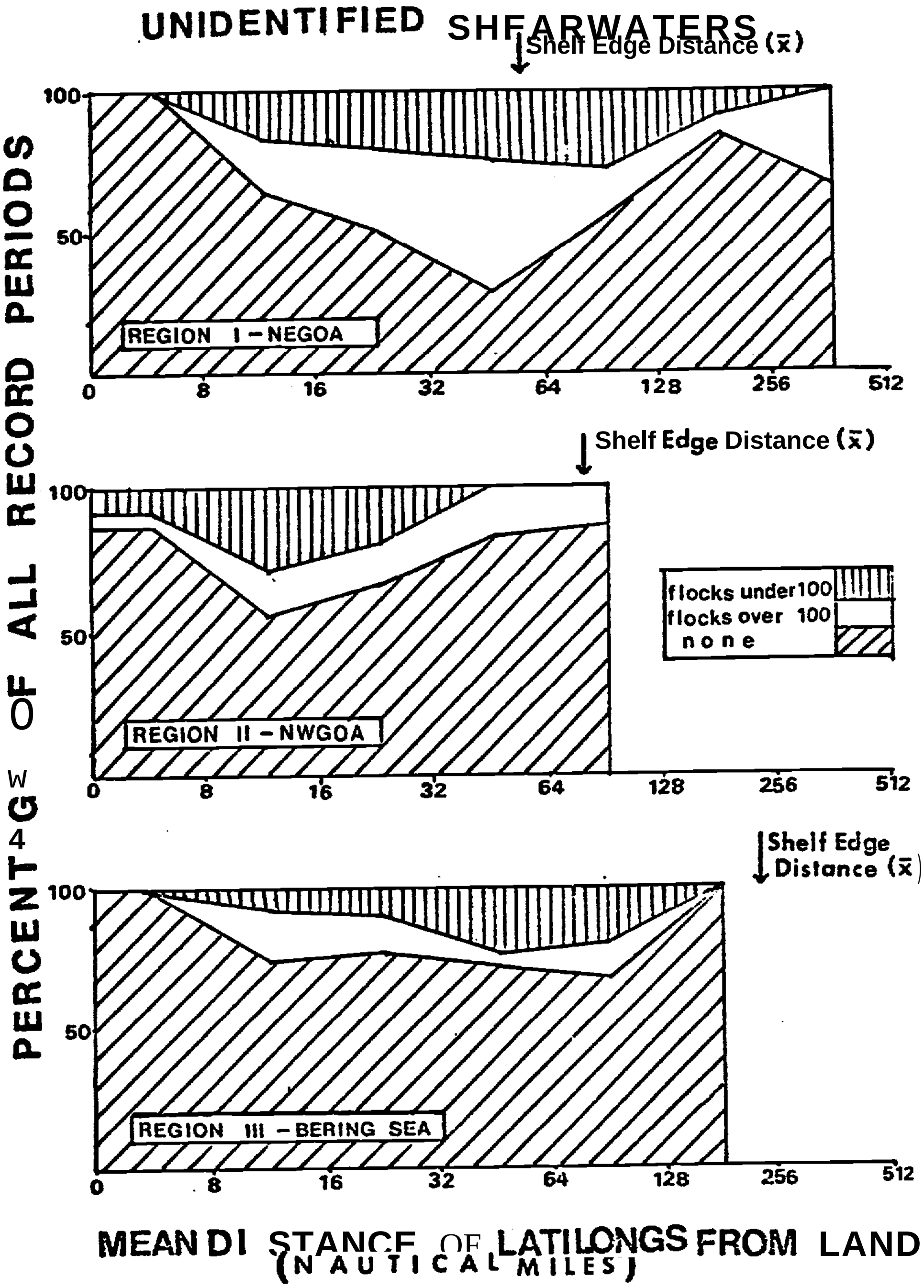


Figure 14. Proportions of 10-minute observation periods in which (a) no shearwaters, (b) flocks of under 100 birds, and (c) flocks of over 100 birds, were seen at different distances from lend, 1975-1976.

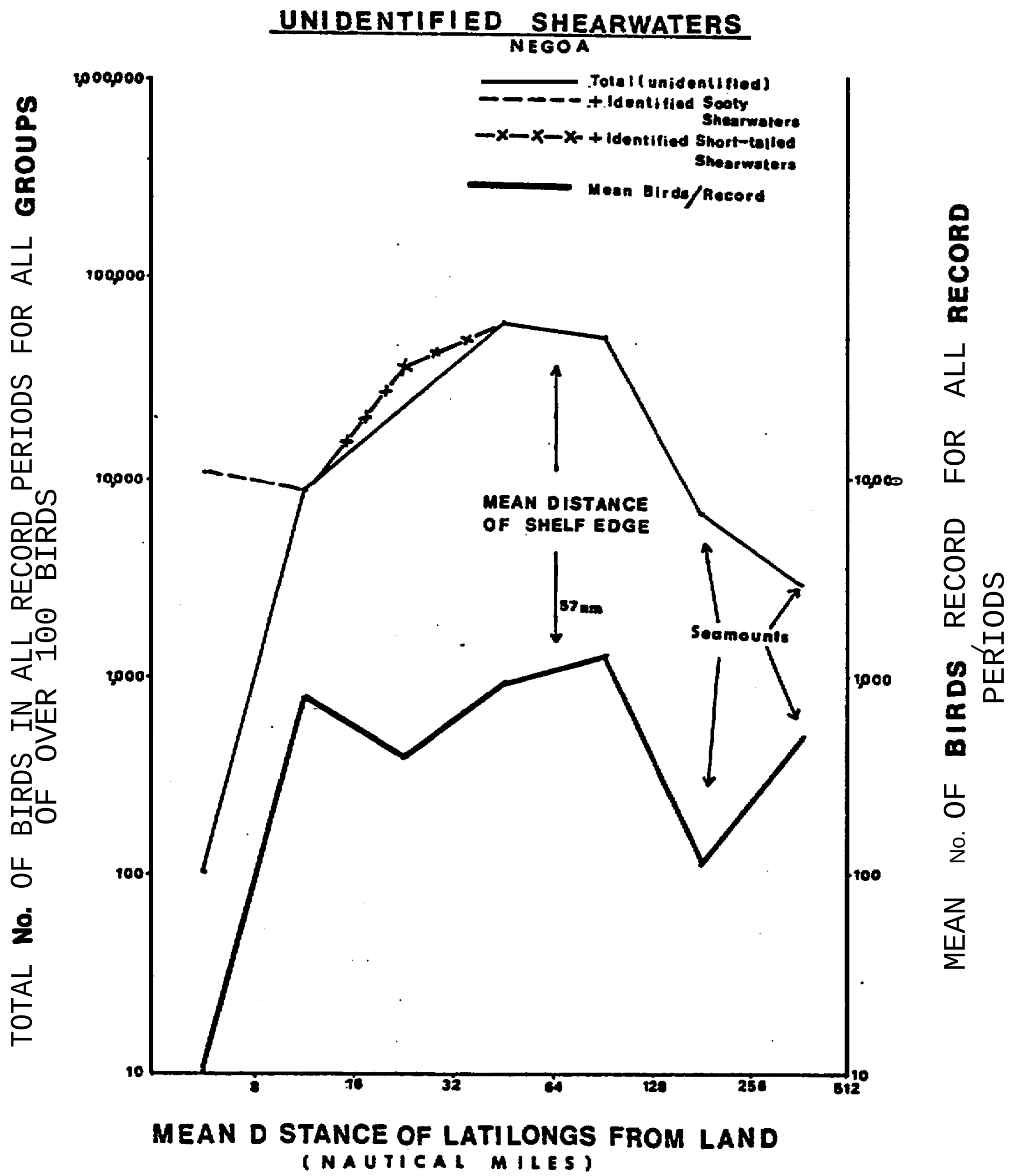


Figure 15. Distribution of shearwaters in the NEGOA in 1975-1976 by Distance Zones from the nearest land (section V1 C).

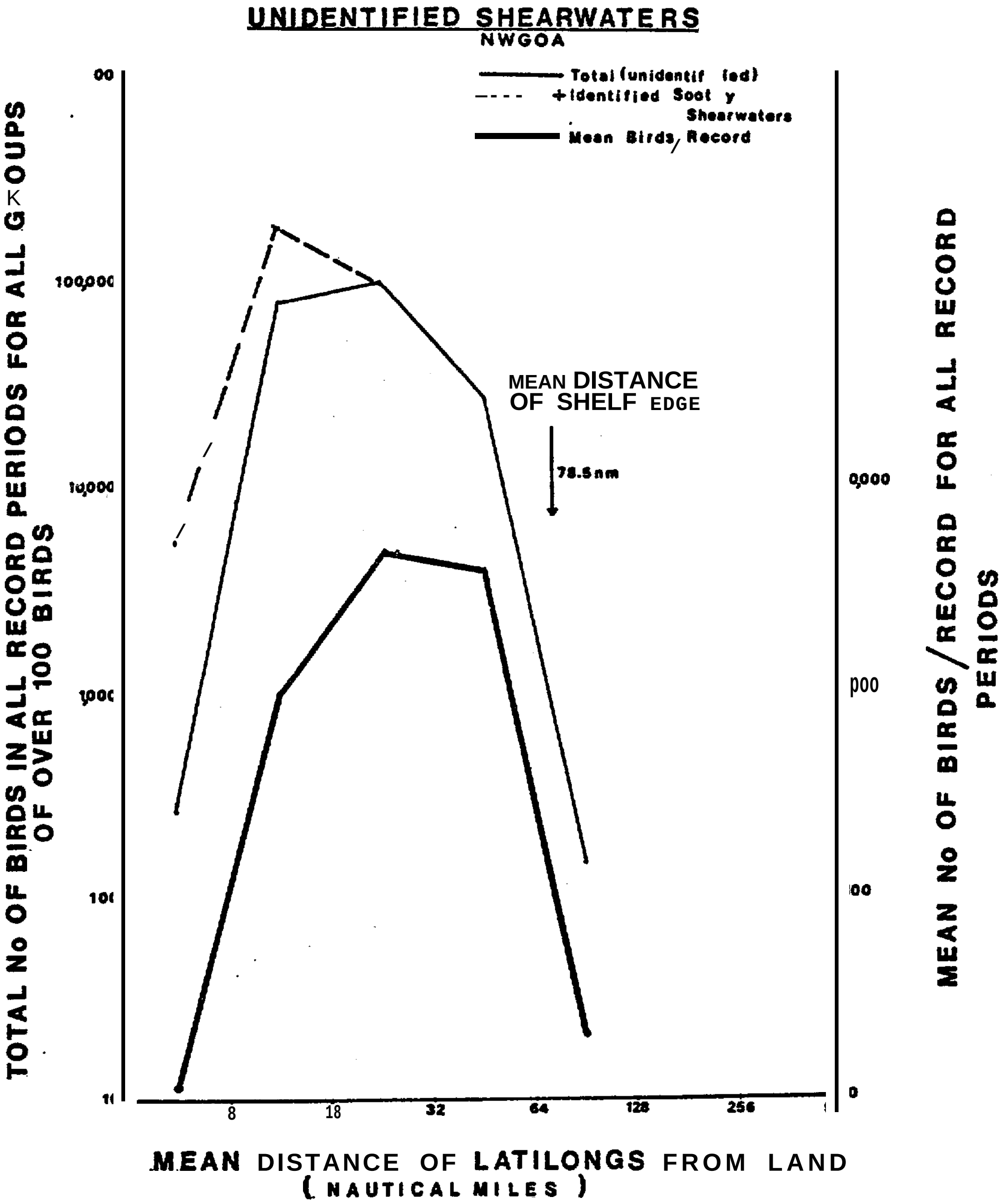


Figure 16. Distribution of shearwaters in the NWGOA in 1975-1976 by Distance Zones from the nearest land. In this presentation NWGOA includes Kodiak Island and adjacent waters.

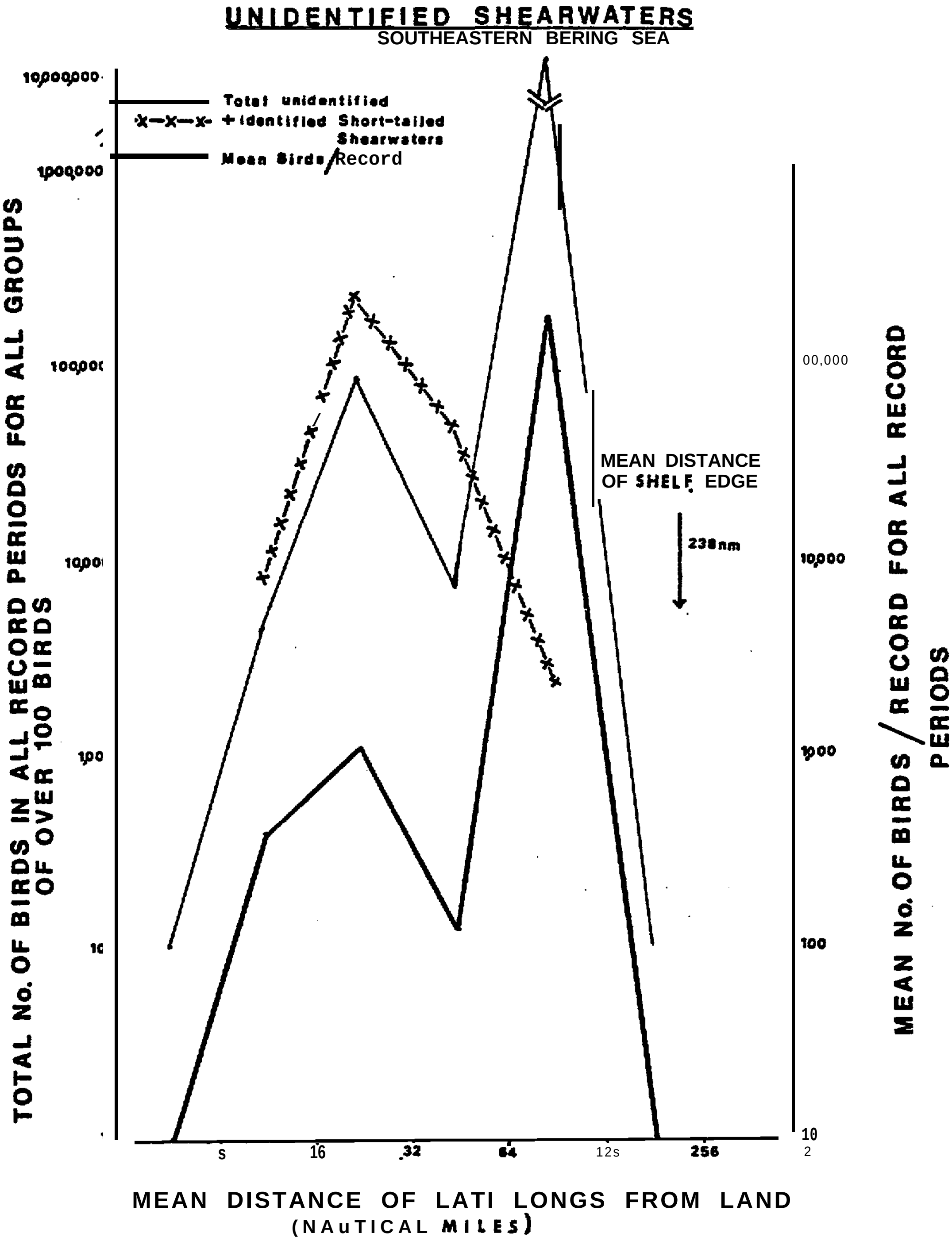


Figure 17. Distribution of shearwaters in the Bering Sea in 1975-1976 by Distance Zones from the nearest land.

TABLE 2 , AGGREGATIONS OF SHEARWATERS OF MORE THAN 10,000 BIRDS SEEN IN 1976

MONTH DAY TIME	REGION ANSA LOCATION LE.-distance from shore(est.) D-depth estimate (fathoms)	PHYSICAL CONDITIONS SST=sea surface temp. AT=air temp. B=barometric pressure W=wind; direction (degrees) strength (knots) S=wave height(feet)+ swell height (feet)/ direction(degrees)	CENSUS DATA No, of birds, Transect type(N ,E or S), snd duration CA=census area (km^2) MD=max, density(birds/km^2)	DESCRIPTIVE REMARKS F=No, of flocks FSR=flock size range MFS=mean flock size
May 8" 1130-1200	KODIAK SHEIF Amatuli Trough Shelf Edge 58°33'N., , 149°00'W. DS 65 no. D 59	SST 5. 3°C AT 5. 2°C B 29.82 ,f ailing W 080° 24k S 3+2/145°	17,500 E - 30 min. CA 10.5 km^2 MD 1,905	Species unidentified.
May 8 1925-2010	KODIAK SHEIF Amatuli Trough Shelf Edge 58°35'N., 148°55'W. DS 65 mm, D 59	SST 5.4°C AT 4. O°C B 29.63, falling W 070°/33k S 4+3/140°	50,020 E -45 min. CA 11.85 km^2 MD 2,532	Both Sooty and Short-tailed Shearwaters. From 1925-1930 20,000 birds were distributed as follows; F 20 MFS 1000 From 1940-2010 another 30, 020 were estimated. Some flocks were composed mainly of one species and come flocks mainly of the other.
May 16 1300-1310	NEGOA Shelf Edge (Bering Glacier) 59°43'N., 142°52'W . DS 22 nm. D 100-120	SST 5.8°C AT 6. 1°C B 29. 9, falling H 295 14k S 2+3/195°	15,000 E - 10 min. CA ? MD ?	Species unidentif led. This flock of 15,000 birds was recorded during only a 10 minute period.

Table 2 (continued):

May 19 1045-1300	NE Shelf (SE Hinchin- brook Island) 59°50'N., 145°41'W. DS 28 sm. D 42	SST 5.8°C AT 5.0% B 29. ?, falling W 100° 40k S 9+7/110°, then 12+6/150°	16,500 s -70 min. + E - 60 min. CA 2.26 km² MO 5,974	Species unidentified. From 1045-1155 Shearwaters were passing at a rate of 150-200/minute, for a total of about 13,500. From 1200-1300 they were still passing at a rate of about 45 birds/minute for a total of about 3,000.
May 27 1350-1400	KODIAK SHELF Inner Kennedy Entrance. 59°02'N., 151°38'W. DS 4 nm. D 40-70 (?)	SST 5.0°C AT 4.8°C B 29.60, falling W 290°/38k S 7+?/275°	10,600 N - 10 min. CA ? MD ?	Sooty Shearwaters Feeding flocks of 5,000 + 5,300 + 300 were passed during only a 10 minute transect. F 3 FSR 300-5,300
May 30 1000-1010	KODIAK SHELF Inner Kennedy Entrance. 58°48'N., 150°48'W. 0s 25 nm. D 70-100	SST 6. 0°C AT 6. 0°C B 29. 73, rising W 285° 34k S 3+?/290°	20,000 N - 10 min. CA ? MD ?	Species unidentified. Some 20,000 shearwaters that were feeding at the surface were passed during only a 10 minute transect.
June 6 1030-1040	NWGOA Chirikof/ Trinity Islands 56°02′ N., 155°04'W. DS 18 nm. D 20-40	SST 6. 1°C AT 6. 0°C B 30.22, rising H 240° 12k S 1+2/190°	30,000 E - 10 min. CA 2.6 km² MD 11,615	Mainly Sooty Shearwaters. F 20 FSR 1000-2000
June 8 0720-0730	ALEUTIANS South Unimak Pass 54°26'N., 164°52'W. DS ? rim.(?) D 26+	SST 4.4°C AT 4.5°C B 30.25 W 290°/4k S 1+1/270°	46 ,000 E -10 min. (Helicopter) CA ? MD ?	Species unidentified. The concentration was divided in to three aggregations of birds, separated from each other by ca. 1000m., sc f ollows: (i) 16,000 F 4 FSR 2,000-5,000 MFS 4,000 (ii) 10,000-15,000 (iii) 15,000-20,000 Reaction to the he] i copter, f lying at ca. 400m., was to fly in different directions end to dive,

Table 2 (continued) :

June 15 0830-0900	**ALEUTIANS** NE Unimak Pass 54°54'N., 164°42'W . DS 5 nm. D 30 (?)	SST 5.6°C* AT ?, 5°C B 29.76 H 350° 8k* S 0+1/040° *From 0830 -0S40, SST was 6.2°C, W was 052°/10k	18,550 " N - 30 min. (3 x 10 min.) CA - MD -	Mainly Short-tailed Shearwaters but aoae f locks mostly $oot y Shearwaters. During the three 10 minute Normal Transects combined here, shearwaters were seen as follows: (i)4,700 within 10Dw + 2,500 at 800m. that were f eeding by dive-plunging. (11) F 7, FSR 250-3000, NFS 1180. (ii) F 3, FSR 100-2000, MFS 1033.
June 15 1230-1235	BERING SEA West Amak Island. 55°15'N., 163°38'W. DS 13 nm. D 25-30	SST 4.4°C AT 7.0°C B 29.74 W 050° 9k S 1+0 /-	10,000 E - 5 min. CA 2.0 km^2 MD 5,000	Species unidentif led. During this 5 minute period a flock of about 10,000 was passed sitting on the water, feeding sad flying in circles.
June 16 1140-1420	BESING SEA Alaska Peninsula * 55°13'N., 163°01'W. DS 1 nm. (exact) D 10-15 (*Amak Island, then Cape Glazenap - opposite Amak Is.)	SST 4.4°C AT 5.8°C→5. 5°C B 29,51, rising to 29.56 W 330° 15k S 1+0/-	50,000 (minimum) S -55 min. (in 3 periods) CA 0.57 km^2(1140-1145 only) MD 17,544(max.)	Species not identified. (i) 1140-1145. A concentration of 10,000 only 3,000m from the shore of Amak Island(see CA and MD), at 55°23'N.. 163°10'W. (ii) 1220-1230. A flock of 30-40,000 feeding in a very big circle. (111) 1330-1410. A concentration of 10,000 grouped in three flocks. Feeding by plunging from ca. 50 cm stove the water.
		When they start diving they concentrated in small areas in compact groups. After f ceding and flying in circles for 5-6 minutes, two flocks settled on the water. Later they flew in circles, feeding, again. The third flock turned SE and d isappeared . (iv) 1410-1420. Flocks totalling about 5,000 birds appeared from the horizon and joined the two circling, feeding flocks. Finally all the birds flew HE.		
June 17 2300-2310	**ALEUTIANS** NE Unimak Pass. 54°42'N., 164°56'S4 . DS 5 nm. D 30	SST 5. 6°C AT 5.0°C B 29.92, rising W 225° /12k S 2+6/280°	55,000 E - 10 min. CA 7.8 km^2 MD 6,410	Species not identified. All birds sitting on the water. F 21 (counted) MFS ca. 1000 There was also a long file of about 25,000 birds that was 50m wide and 3, 000m. long.

Table 2 (continued):

June 19 1035-1045	NWGOA Chirikof Island Shelf Edge 55°59'N., 155°34'W. DS 5 nm. D 14	SST 7.8°C AT 7.5°C B 29.93 W 305°/6k S 0+2/240°	ca. 30,000 S - 10 min. CA 56.6 km² MD 533	Species unidentified.
June 19 1215-1245	NWGOA Chirikof/ Trinity Islands 56°01'N., 155°00'W. DS 20 nm. D 20-40	SST 5.6°C AT 10.3°C→7.9°C B 29.94, rising W 310° 9k S 1+2/190°	50,000 E - 30 min. CA 2.6s km² MD 9,259 (max.)	Aggregations of several thousands of Short-tailed Shearwaters apparently predominated, although smaller groups may have been Sooty Shearwaters. (i) 1215-1230, 25,000 in three big flocks, and flocks of 100-500, were feeding by plunging. Wing molt was observed. (ii) 1230-1245. 20,000-30,000 FSR 100-1000. 2,000 flew NW.
June 19 2225-2235	KODIAK SHELF SE Kodiak Shelf 57°08' N., 152°38'W. DS 8 nm. D approx. 35 (?)	SST 5.6°C AT 9.5°C B 29.96, rising W 090°/6k S 1+2/220°	50,000 E - 10 min. CA 6.3 km² MD 7,937	Many were Sooty Shearwaters. F 33 (sitting on water) FSR 1000-2000 Birds flew off ENE.
July 31 1037-1050	KODIAK SHELF Kodiak approx. 57°50' N., 152°00'W. DS 8 nm. D 20-30	SST 8.3°C AT 10.6°C B 30.26 W 190° 8k S 0+2/180°	17,000 E - 13 min. CA ? MD ?	Species unidentified. F 12 FBR 350-1,500 MFS 1,500

TABLE 3 : RANGES OF WATER TEMPERATURES AT SHEARWATER AGGREGATIONS

YEAR	DATE	SEA SURFACE TEMP. (°C)	SPECIES	LOCATION
A. BERING SEA				
1975	June 8	3.6°	ST	North Bristol Bay
1975	June 10	1.6° - 1.8°	ST	S and SW of Cape Newenham
1975	June 12	1.8°	ST	Outer Kuskokwim Bay
1976	June 15	5.6°	ST/S	NE Unimak Pass
1976	June 15	4.4°	?	West Amak Island
1976	June 16	4.4°	?	Alaska Peninsula
1976	June 17	5.6°	?	NE Unimak Pass
1975	July 24	6.7°	ST	North Unimak Island
1975	July 24	6.7°	ST	North Unimak Pass
1975	July 27	7.8°	ST"	North Akutan Pass
1975	August 17	8.9° - 8.3°	ST/S	S Nunivak Island
1975	August 18	10.0°	?ST/S	E Pribilof Islands
B. NWGOA				
1976	June 6	6.1°	S	Chirikof/Trinity Islands
1976	June 8	4.4°	?	South Unimak Pass
1976	June 19	7.8° - 5.6°	ST	Chirikof/Trinity Islands
1975	August 11	10.0°	ST/S	Shumagin Islands

Table 3 (continued):

C. KODIAK SHELF (and Inshore Waters)

1976	May 8	5.3°-5.4°	ST/S	Amatuli Trough
1976	May 27	5.0°	S	Kennedy Entrance
1976	May 30	600°	?	Kennedy Entrance
1976	June 19	5,6°	ST/S	Kiliuda Trough
1976	July 31	8.3°	?	Kodiak
1975	August 5	8.6°	ST/S	NE Kodiak
1975	August 6	8.9°	ST/S	NE Kodiak

D. NEGOA

1976	May 16	5,8°	?	Bering Glacier
1976	May 19	5,8°	?	SE Hinchinbrook Island

ST = Short-tailed Shearwaters

S = Sooty Shearwaters

B. REGIONAL AND SEASONAL DISTRIBUTIONS OF SHEARWATERS

The literature available on the distribution of Sooty and Short-tailed Shearwaters in Alaskan waters has been summarized by Guzman (1981).

The previous records of Short-tailed Shearwaters show that they have been reported in really high numbers only in Unimak Pass (up to 1 million birds). In neither the Bering Sea nor the Gulf of Alaska have they been reported in really large numbers.

Sooty Shearwaters presented a different situation. They have been previously reported in the "millions" in the NEGOA, but only in very small numbers in the Aleutian Islands and the Bering Sea.

It seems that, due to the difficulties in telling these two species apart (which was explained in Section II.A.), (but incorrect) idea that Short-tailed Shearwaters move only into the Bering Sea (see the emphasis in Gabrielson and Lincoln, 1959) and Sooty Shearwaters into the Gulf of Alaska, observers have been inclined to 'decide' that the birds seen in the "Bering Sea are Short-tailed and those seen in the Gulf of Alaska are Sooty Shearwaters. There probably is a great deal of misidentification; many Short-tailed Shearwaters visiting the Gulf of Alaska may have been identified as Sooty Shearwaters, and a reverse kind of misidentification of Sooty Shearwaters as Short-tailed may also have taken place in the Bering Sea.

We will deal with the distribution of shearwaters (i) region by region, and (ii) within each region month by month. The text will be mainly concerned with all records that are outstanding, either by being positive and significant or by being negative and displaying the areas not visited by shearwaters.

1. NORTHEASTERN GULF OF ALASKA (NEGOA) (Figures 3-4).

This region was visited only twice, first in May 1976 and a second time in July, 1976.

(l). May 1976.

In May 1976 the Northeastern Gulf of Alaska (NEGOA) (Fig. 3) was given extensive and fairly even observational coverage. Unit efforts were well distributed and provided good samplings of the distribution of shearwaters in the region during the early part of the residency of shearwaters in the North Pacific.

Shearwaters were well distributed, and very abundant over and along the edge of the Continental Shelf (Shelf Break) of the NEGOA between Icy Bay and 146 degrees W in May 1976. Most could not be identified to species. Shearwaters were also found over Oceanic Waters beyond the Shelf Break Front on May 4 (see Section IV.B). On May 12 also, when on transit from Kodiak to Icy Bay, shearwaters were seen in all record periods when over Oceanic Waters beyond the Shelf Break Front, although in low numbers below 100 birds per record period.

No shearwaters were seen inside Cook Inlet on May 6-7 and only two birds were seen there on May 25-26. No shearwaters at all were seen inside Prince William Sound on May 28-29.

Near the Barren Islands a flock of 6,500 shearwaters was seen on May 8. On May 27 an aggregation of 10,600 and on May 30 two aggregations of 5,000 and 20,000 birds were seen in Inner Kennedy Entrance, near the Chugach Islands between the Barren Islands and the Kenai Peninsula. Further out, at the edge of Portlock Bank and Amatuli Trough, three large aggregations were found on May 8: 17,500, 20,000 and 30,000 birds containing both Sooty and Short-tailed Shearwaters (Table 2). Each aggregation was distributed over 10-12 square Km so that the density was only about 2,000-2,500 birds/square Km.

West of Kayak Island and southeast of Hinchinbrook Island, over 16,500 shearwaters were counted on May 19 flying SSW over the Continental Shelf between 0930-1600 hours (peak 1045-1300). The wind was from the ESE at 35-40 knots. The number of birds passing" the ship ranged from 2.5-400/minute, but at the peak passage it was 150-200/minute for a total of 13,500 in 70 minutes.

East of Kayak Island, 15,000 shearwaters were seen on May 16 at the Shelf Break Front off the Bering Glacier and south and southeast of Kayak Island groups of 7,500 and 2,500 were also seen at the Shelf Break Front on the same day. Off Icy Cape on May 15 another 8,000 birds were seen in fog and rough seas.

Short-tailed Shearwaters were quite abundant at the Shelf Break Front east of Kayak Island on May 16; the identification of Short-tailed Shearwaters SE of Kayak I. led to the conclusion that many of the unidentified shearwaters there then were probably Short-tailed Shearwaters. If this is correct it was an unanticipated finding. Many Short-tailed Shearwaters may move first of all into the NEGOA right after arrival in early May from the breeding grounds in Australia. They probably do this to exploit the spring peak of zooplankton.

Sooty Shearwaters seemed to be still moving into the NEGOA from lower latitudes along the American and Canadian coastlines during May.

(2). July 1976

The second time that the NEGOA area was visited was in July, 1976. Effort in the NEGOA in July 1976 was not high, but covered a wide area including Oceanic Waters and the Shelf Break. Observations over the continental shelf were actually in a minority.

Unlike May, the number of shearwaters seen in July was very low (Fig. 4) . Most of the continental shelf in the eastern NEGOA was devoid of shearwaters, but small parties of Sooty Shearwaters were present at the Shelf Break. The maximum number recorded at any one time was only 350. They were also seen over Oceanic Waters (see Section IV.B) of the northern Gulf of Alaska (Fig. 4} .

The Sooty Shearwater was the only species identified. Perhaps Sooty Shearwaters were already moving out of this sector of the continental shelf. The Short-tailed Shearwaters seen in May 1976 were not encountered again; they had, no doubt, moved into the Bering Sea.

2. KODIAK ISLAND SHELF (Figures 5-8)

Most of the cruises to NEGOA, NWGOA and the Bering Sea in 1975 and the 1976 started and/or finished at Kodiak, which resulted in many observations on shearwaters off Kodiak Island.

(l). May 1976

Cook Inlet was practically devoid of shearwaters, except for a few unidentified ones. Prince William Sound was not visited by shearwaters at all during this month. There was only one block with an average number of over 10,000 shearwaters per 10 minutes. This was over Amatuli Trough toward the edge of the Continental Shelf, and was due to over 60,000 birds which were seen on May 8 (Table 2). The Kodiak Shelf offshore from Chiniak Bay was well surveyed (Fig. 5), but the numbers of shearwaters seen were generally very low. However, large aggregations were encountered over Kennedy Entrance, Stevenson Trough and along the edges of Amatuli Trough.

Sooty Shearwaters were mainly restricted to Kennedy Entrance. Short-tailed Shearwaters were abundant not only at Kennedy Entrance but also at Amatuli Trough in smaller numbers.

Four aggregations of 10,000 or more birds each, were seen on May 8 (two), 27 and 30 (Table 2). In one of them (May 27) all the birds identified were Sooty Shearwaters. On May 8, at the edge of Amatuli Trough, an aggregation of 50,000 shearwaters was encountered and in this case both species of shearwaters were present. In the other two aggregations the shearwaters were not identified to the species level.

(2). June 1975-1976

In 1975, after a cruise in the Bering Sea, the vessel cruised from Unimak Pass to Seward over Oceanic Waters beyond the Chirikof Island - Kodiak Island Shelf Break Front on June 18. Very few shearwaters were seen (Fig.6), and none were seen during most record periods. The only identified birds were Sooty Shearwaters.

In 1976, about 30,000 mainly Sooty Shearwaters were seen east of Chirikof Island on June 6. On June 19, during the return journey, three aggregations (totalling 80,000 birds) were found north and northeast of Chirikof Island,

and these were predominantly Short-tailed Shearwaters (Table 2; latilongs between 155-156 degrees in Figure 10). Another 50,000 Short-tailed Shearwaters (in 33 flocks) were seen later on the same day over Kiliuda Trough on the Kodiak Shelf (Table 2; Fig. 6).

(3). July 1975-1976

During July 1975, the Kodiak Shelf was crossed while arriving from Seattle on July 15, and then when traveling between Unimak Pass and Kodiak on July 31 (Fig.7). A flock of about 2,600 Sooty Shearwaters was recorded over Kiliuda Trough and another of about 5,000 birds over Chiniak Trough on July 31. There were few Short-tailed Shearwaters.

In July 1976, the shelf off Chiniak Bay was crossed during a voyage from Seattle to Kodiak and when sailing towards and returning from NEGOA (Fig. 7). An aggregation of 17,000 shearwaters was found off Long Island on July 31 (Table 2) when J.R.G. was ending a cruise in the NEGOA; though mostly unidentified, some were Sooty Shearwaters.

(4). August 1975

When R/V SURVEYOR was docked in Kodiak Harbor on August 5 and 6, 1975, J.R.G. went by launch to the south part of Marmot Bay (just north of Long Island), and during both days large aggregations of 50,000 and 40,000 birds respectively were seen (Table 1; Fig. 8). On August 5 the 50,000 birds were mainly (90%) identified as Sooty Shearwaters and the following day the 40,000 birds were believed to be 70% Short-tailed Shearwaters. The difference between the two days could be due to problems of identification, since only a few birds were identified on each day and the percentages of each species were estimated on the basis of those identifications. The shearwaters on both days were in mixed feeding flocks with 20,000 Black-legged Kittiwakes (Rissa tridactyla), feeding on small fish. On August 7, only 5,000 shearwaters were seen in Chiniak Bay from the R/V SURVEYOR.

On August 7-9, 1975, R/V SURVEYOR cruised around Afognak Island"and through Shelikof Strait to the Trinity Islands. About 3,000 shearwaters were seen in the Barren Islands, but in Shelikof Strait the largest number seen during a single record period was 225. In the Trinity Islands the largest number seen during a single record period was 1900, and on August 10 no shearwaters were seen near Chirikof Island. Only Sooty Shearwaters were identified (Fig. 8).

During August 1976, sailing out of (or into) Kodiak Harbor took place during night time, and no data were obtained in that month. A small boat was launched east of Long Island, Chiniak Bay, on August 19, but only four shearwaters were seen.

3. NORTHWESTERN GULF OF ALASKA (NWGOA) (Figures 9-13)

Unfortunately, there were no visits to this region in the month of May.

(l). June 1975-1976

In June 1975, the NWGOA region between Unimak Pass and the Trinity Islands was crossed only once and mainly during the night. Some observations were made south of Unimak Pass on June 17 and beyond the 1,000 fathoms isobath south of Kodiak Island on June 18, but as was noted earlier recorded only low numbers of shearwaters (Fig. 9). No identifications to species could be made.

In 1976, the NWGOA was crossed twice, on June 7 and 19, but no shearwaters were seen along the Inside Passage between Cold Bay and the Shumagin Islands (but see the Kodiak Island Shelf Section). On June 8, about 46,000 shearwaters were seen from the ship's helicopter during a 30-minutes flight in the southern sector of Unimak Pass. The birds were in three aggregations (16,000; 10-15,000; 15-20,000 birds) separated from each other by about 1000m (Table 2; Fig. 10).

(2). July 1975

In 1975, the NWGOA was crossed twice: (i) entirely along the Shelf Break (100 fathom line) on the outward journey to the Bering Sea on July 16, and (ii) on the return trip, from Unimak Pass to the Shumagin Islands through the inner passage on July 28-30, and then over the Kodiak Shelf on July 31. Along the NWGOA Shelf Break west of 155 degrees W and in the inside passage behind the Shumagin Islands no shearwaters were seen. Small flocks of Sooty Shearwaters were seen over Davidson Bank (east of Unimak Pass) and Sanak Bank (Fig. 11).

(3). August 1975-1976

In 1975, during a cruise from Kodiak to Unimak Pass, one aggregation of 16,000 shearwaters only 1.2 nautical miles off the coast of the Shumagin Islands was seen on August 11 (Table 1) of which some were identified as Sooty Shearwaters, but otherwise only small flocks were sighted in the NWGOA during the month of August (Fig. 12).

In August 1976, en route to the Bering Sea, the vessel followed the 100 fathoms isobath west from Chirikof Island on August 1. There were fewer than 10 birds per sighting. After leaving the Bering Sea, R/V SURVEYOR followed along the Shelf Break at about the 100 fathoms isobath to Kodiak Island. Shearwaters numbers were again low. Seven flocks of 1,000 - 4,000 shearwaters (mainly Short-tailed) were found between the Sanak Islands and a point south of the Shumagin Islands on August 18 (Fig. 13). Besides them, only small flocks were recorded. Very few Sooty Shearwaters were encountered except on Sanak Bank.

4. BERING SEA (Figures 9-13)

There were no visits to the Bering Sea in the month of May.

(l). June 1975-1976

During June 1975, the southeastern Bering Sea, right up to the Shelf Break, was widely covered. A few observations were also made, only on this cruise, over the deep Bering Sea Basin beyond the 1,000 fathom contour.

Between Adak and the Pribilof Islands, around the Pribilof Islands, over Pribilof Canyon and on the outer (western) portion of the shelf south of Nunivak Island, west of 165 degrees W and north of 57 degrees N, no shearwaters were seen. Over St. George's Basin on June 5, four shearwaters were seen. On June 16, east of the Pribilof Islands, no more than 83 shearwaters were recorded during any record period. Short-tailed Shearwaters were, however, present farther east in the Bering Sea. Four aggregations that varied from 15,000 - 70,000 birds (for a total of over 200,000) were located from June 8-12, all of them along the north side of Bristol Bay: off Kuskokwim Bay, Cape Newenham and in inner Bristol Bay (Table 1, Fig. 9). Flock sizes ranged from 150 - 17,500 with a mean between 1000 - 1500 birds per flock (Table 1).

Almost no Sooty Shearwaters were found during June 1975, except for a few birds in the Southern Bering Sea off the Alaska Peninsula.

During June 1976, the waters along the north side of the Alaska Peninsula were surveyed from Unimak Pass to Amak Island, and the area near the Pribilof Islands was visited. TJnfortunately, Bristol Bay and Cape Newenham were not visited in June 1976. The Pribilof Islands area was totally lacking in shearwaters from June 9-13. Two birds were seen over deep water 30nm N of Unalaska Island on June 14. Shearwaters were abundant, however, from Unimak Pass to Amak Island, and six aggregations that varied in size from 10,000 to 55,000 shearwaters were seen on June 15-17 (Table 2, Fig. 10), for a total of about 135,000 birds. Flock sizes within and composing these aggregations ranged from 100 - 250 birds up to feeding flocks of several thousands circling and plunging together. Estimated maximum densities ranged up to 17,500 birds/square Km only 2000 - 3000 meters from the shore of Amak Island on June 16 (Table 2). In the northeastern sector of Unimak Pass there was a long line of about 25,000 shearwaters sitting on an area of water 3,000 m long and 50 m wide on June 17 (Table 2).

(2). July 1975

In July 1975, only Bering Sea waters along the north sides of the outermost portion of the Alaska Peninsula and eastern Aleutian Islands, and off Cape Newenham, were visited. No observations were made in the shelf edge area near the Pribilof Islands. Off Cape Newenham, observations were carried out along the 10 fathoms isobath, and no shearwaters were seen there. An aggregation of 42,000 shearwaters was found in Urilia Bay (Unimak Island) , another of 51,000 on the northern sector of Unimak Pass on July 24. A third aggregation of 57,000 was seen in fog on July 27 in the northern sector of Akutan Pass (Table 1, Fig. 11) . Densities were the highest ever recorded by J.R.G., 37,000 birds/square Km at the most concentrated locations (Table 1) on these two days. The shearwaters were all identified as Short-tailed Shearwaters, except for some Sooty Shearwaters seen in Akutan Pass.

(3). August 1975-1976

There was a quick foray over the western sector of the continental shelf of the Southeastern Bering Sea, from Unalaska Island to the Pribilof Islands and Nunivak Island from August 13-19, 1975.

The largest concentration of shearwaters seen, during the whole period of this study, was found on August 17, 1975, over the continental shelf between Nunivak Island and the Pribilof Islands. R/V SURVEYOR was traveling south from Nunivak Island towards Dutch Harbor. It had travelled NE from the Pribilof Islands towards Nunivak Island on the previous day, during which no more than 200 birds were seen during a single record period. On August 17, east of the previous day's track, the vessel passed through a "super-aggregation" for five and one-half hours between 59 degrees 03 minutes N, 167 degrees 58 minutes W and 58 degrees 39 minutes N, 167 degrees 42 minutes W. Birds extended to beyond the horizon. Individual flocks varied greatly in size, from 100 - 6,000 birds and in their distances apart from each other. This concentration contained 6-10 million shearwaters over a 30 nm distance and both species under study were present [Table 1; Fig. 12) . Short-tailed Shearwaters predominated, and probably made up 70-80% of the total seen. There were however, estimated to be well over 100,000 Sooty Shearwaters in this concentration. Although the total number was quite exceptional, the estimated area covered was large (1150 square Km) and the estimated maximum density was less than half of that recorded in Urilia Bay or North Akutan Pass (over a smaller area) in July.

A second aggregation of 68,000 birds, also believed to consist of both species, was found due south of the first one, east of the Pribilof Islands, on August 18 (Table 1; Fig. 12) . Unfortunately, Bristol Bay was not visited in August in either 1975 or 1976.

During August 1976, all the observations were made while in transit to Norton Sound and back to Kodiak. Just north of Unimak Pass, 5,000 birds crossed the bow on August 2, but otherwise the largest number seen during a single record period on the voyage to Nome was only 100 birds. The only bird seen in Norton Sound from August 5-15, 1976 was one Short-tailed Shearwater. The same western shelf region between 165 - 170 degrees W and 55 - 60 degrees N, as in August 1975, was crossed briefly. Although shearwaters were seen during almost every transect record, their numbers were low in August 1976 (Fig. 13) and flocks ranged from 130 - 2000 (mean: 564 birds).

The same general area where the 1975 aggregation of millions was seen was traversed exactly a year later on the night of August 16/17, but this time only a very few birds were seen. Actually, it would be fairly easy to miss them if they are congregated in a relatively small area; a vessel might pass only a few miles away from them and see nothing. They may congregate in the same general region year after year, but in different patches depending on where food is available. Food distribution could easily change in space and/or time from one year to the next one, depending on the predominant oceanographical and meteorological conditions. The point is that in 1976 the chances of seeing them again were probably no higher than they were of missing them.

North of Nunivak Island only a very few birds were seen (no more than 10, with only one bird seen in Norton Sound). Only a very few Sooty Shearwaters were identified in the Bering Sea.

5. SUMMARY OF FIGURES 3-13

Wherever a latilong contains no cluster of symbols, no observational effort at all was made there. Further, where an open circle occurs at the top of a cluster of symbols, only a single 10-minute record period of observation was. made in that latilong.

There are relatively few latilongs on the maps in which black squares or triangles (average of over 1000 birds/10 minute record period) occur at the bottom of a cluster of symbols (representing all shearwaters counted). Generally, when these occur, they are the result of one-time aggregations having been seen there. Although coverage was quite extensive in other latilongs, more often the average number of shearwaters seen in 10 minutes was fewer than 10 or less than 100 birds, i.e. shearwaters are usually not seen in more than very small numbers at sea off Alaska, despite their aggregate preponderance over other Alaskan seabirds during the summer months. In many latilongs the average was recorded as zero, perhaps through lack of enough repeated efforts (as in the case of open circles for both top and bottom symbols in a series).

The places where shearwaters have been seen in large numbers, and months in which they were there seen, can be summarized from our previous reports, as follows:

(1) NEGOA	Off Icy Cape and SE and S of Kayak Island.	May (1 year)
(2) Kodiak I.	Off Chugach Island	May (1 year)

Shelf		
(3) Kodiak I. Shelf	Inner Kennedy Entrance and Amatuli Trough	May (1 year)
(4) Kodiak I. Shelf	Kiliuda Trough	June (2 years) and August (1 year)
(5) Kodiak I. Shelf	Marmot Bay, Kodiak Island	July (2 years) and August (1 year)
(6) NWGOA	Chirikof Island	June (1 year)
(7) NWGOA	Semidi Islands	August (1 year)
(8) Aleutian Islands	Unimak Pass	June (1 year) and July (1 year) and August (1 year)
(9) Aleutian Is.	Akutan Pass	July (1 year)
(10) Bering Sea	N. Bristol Bay·	June (1 year)
(11) Bering Sea	Amak Island	June (2 years)
(12) Bering Sea	SW of Cape Newenham	June (1 year)
(13) Bering Sea	S. of Nunivak Island	August (1 year)

Unfortunately, in only three locations (Marmot Bay, Kiliuda Trough and Amak Island) were large numbers of shearwaters seen in the same month in both years of this study. This was because of the "ship-of-convenience" logistics available to us. However, we believe that shearwaters probably occur in several widely separated locations (e.g. Unimak Pass in the Aleutian Islands and off Kodiak Island) in large numbers fairly regularly. During an independent study in 1977-1978 (Guzman 1981), off Kodiak Island, shearwaters were found in large numbers over Stevenson Entrance and Chiniak Trough and off the Barren Islands and Ugak Island, in addition to Marmot Bay and Kiliuda Trough.

The NEGOA is apparently not a favored location for shearwaters after May and/or June. Dated aggregations have been reported only occasionally (Isleib and Kessel 1973).

There are several places (Inner Kennedy Entrance and Amatuli Trough) south of the Kenai Peninsula (NE of Afognak Island) where aggregations of shearwaters can be found fairly regularly at least in May, and off the NE, SE and SW coasts of Kodiak Island where aggregations can be found from June-August (Marmot and Chiniak Bays, Kiliuda Trough and N and NE of Chirikof Island). But west of Chirikof Island shearwaters are scarce along the south side of the Alaska Peninsula until Unimak Pass is reached. Unimak Pass exceeds the Kodiak Shelf area as a place for shearwaters to congregate from June-August (and perhaps in May, though we have no data for that month).

Our sampling of the huge and wide expanse of the Continental Shelf in the Southeastern Bering Sea was inadequate to establish locations in which shearwaters regularly aggregate, apart from near Amak Island where birds were found in June of both 1975 and 1976. North Bristol Bay, which produced aggregations in June 1975, was not revisited in June 1976, and although the area south of Nunivak Island, that produced a "super-aggregation" on August 17, 1975, was revisited on the anniversary date in 1976, such aggregations could have been missed if they had been a few miles farther east or west of the transit line.

Often when the bottom symbol of a cluster is a blackened circle (100-1000 birds/10 min.) the latilong in which this occurs is often next to one with an aggregation. It is ironic that this is a fairly widespread rate of bird observation, but that equally (if not more) common are the open circles and squares indicating less than 10 birds/10 minutes, i.e. very sparse shearwaters.

Analysis of the symbols by region in Figures 3-13 shows that, combining all months for each region and excluding all occasions when there is only one record period in any latilong in any month, the mean number of birds is less than 10 birds/10 minutes in the following proportions and percentages of latilongs by region:

NEGOA	16/26	(61.5%)
Kodiak Shelf	14/34	(41%)
NWGOA	13/22	(59%)
Bering Sea	19/47	(40%)

These rise to the following proportions when the mean number of birds is not more than 100 birds/10 minutes:

NEGOA	19/26	(73%)
Kodiak Shelf	22/34	(64.7%)
NWGOA	17/22	(77.3%)
Bering Sea	31/47	(65.9%)

Finally, a mean of over 1000 birds/10 minutes occurs in only the following proportions of the latilongs:

NEGOA	3/26	(11.5%)
Kodiak Shelf	4/34	(11.7%)
NWGOA	3/22	(13.6%)
Unimak Pass	4/4	(100%)
Bering Sea	12/47	(25%)

c. DISTRIBUTION OF SHEARWATERS IN RELATION TO DISTANCE FROM THE COAST AND WATER DEPTH

1. Distance from the coast

In the analysis of shearwater observations in terms of their distance from the shore the Kodiak Island Shelf area is combined with the NWGOA. The vast majority of shearwaters counted *were* not identified, hence Figures 14 - 17 are headed "unidentified shearwaters".

What Figure 14 shows is that, despite the huge numbers of shearwaters present in Alaskan waters each summer, the frequency with which shearwaters are seen during a 10-minute watch at sea is very low, from almost never within 8 miles of the coast (except in NWGOA) to only 30-65 percent of occasions at *various* distances over the continental shelf. Flocks of over 100 birds are seldom seen during more than one count in every four (25%). So, shearwaters are by no means ubiquitous, and to many observers might appear to be quite scarce on many days.

In Figures 15 - 17, the total numbers of unidentified shearwaters (from all groups of over 100 birds) and the mean numbers of all birds seen per record (including negative periods) are plotted. Each one of these records has been identified with the 1 degree x 1 degree Latilong in which it took place. The distance of each latilong from land has been taken as the mean of the maximum and minimum distances from land of the farthest and nearest points within the latilong.

The Distance Zones (O-8, 8-16, 16-32, 32-64, 64-128 nautical miles, etc.) have been given decreasing relative space as distance from land increases because tha purpose was to determine whether the birds were attracted to, or avoided, the coast. SO, the separation of the waters in the first 8, 16 or 32 nautical miles from land is exaggerated.

The mean distance to the edge of the Continental Shelf is indicated, as well as the distances of seamounts in the Central Gulf of Alaska, which had the effect of attracting shearwaters at distances from land beyond the Continental Shelf at which the birds would not usually otherwise be found (Fig. 15).

Two months of observations in 1976 (May and July) were mainly devoted to NEGOA, and some data was collected during three transits across the Gulf of Alaska from Seattle to Kodiak.

The distribution of total numbers of all shearwaters seen in relation to distance from land in NEGOA (east of, and not including, Kodiak Island) shows a peak in the number of shearwaters seen between 32 and 128 nm offshore, spanning the mean distance to the Shelf Edge (57 nm) (Fig. 15). The mean number of birds per record (Fig. 15) shows low numbers in waters close to shore, then no great variation from 8 nm to 128 nm. Since this kind of analysis does not discriminate for habitat selection in relation to depth, the zone from 8 to 128 nm, is a mixture of Offshore Waters with some Inshore and Oceanic Waters, which when analyzed together would not show too much change. At about 128 nm, there is a dropping in the number of birds because of Oceanic Waters. Nevertheless, numbers do not drop off completely "because of the presence of shearwaters over the Gulf of Alaska seamounts. In the NEGOA in 1976 most shearwaters were not identified. Some Sooty Shearwaters were identified in the first 8 nm from the coast line (Fig. 15). Some Short-tailed Shearwaters were identified around the 16 nm interval from shore (Fig. 15), which is due to the aggregation of that species seen in May 1976, east of Kayak Island at the Shelf Break Front (Fig. 3).

The distribution of total numbers of all shearwaters seen in relation to distance from land in NWGOA (including the Kodiak Island Shelf (Fig. 16) shows that shearwaters are mostly found over the rather narrow continental shelf along the south side of the Alaska Peninsula, and that beyond the NWGOA Shelf Edge (at a mean distance of 78.5 nm) the numbers decrease sharply. This allows one to compare shelf and oceanic waters.

In Figure 17 which was drawn soon after the field work, most of the birds were considered as unidentified, and only those positively identified in the field as Short-tailed Shearwaters were treated separately.

Eight aggregations of shearwaters were encountered fairly close to the coastline between Akutan Pass and Amak Island (including Unimak Pass), in 1975 and 1976 (Tables 1 and 2), and these explain the peaks at 8-32 nm in Fig. 17. This area seems to be one of the most heavily visited by shearwaters in Alaskan waters during the northern summer.

The analysis of observations in terms of their distance from shore was complicated by the great width of the Continental Shelf in the Southeastern Bering Sea. The mean distance of the Shelf Edge is 238 nm, 3-5 times greater than in the Gulf of Alaska. Shearwaters are rare that far out, however. The peak distance for shearwaters was only 16-32 nm, if the August 1975 aggregation of millions at 64-128 nm is excluded.

2. Water Depth.

The objective of the depth analysis is (i) to determine the zonal preferences of each species under study, and (ii) at the same time to find out what habitats they prefer as a group, considering that both species together constitute more than 80% of the seabird population in Alaskan waters during the summer months.

In Figures 18 - 20 the distribution of shearwaters each month has been analysed according to the depth of the water, in order to determine their zonal preference. Zones B,C,D, and E were described in Figure 2. As shearwaters did not visit the Nearshore Zone, the analysis has been done for the Inshore (Zone B), Offshore (Zones C and D) and Oceanic (Zone E) Zones. Zone C is the Middle Shelf Zone, and Zone D is the Outer Shelf Zone.

Zone B goes up to 50 metres (25 fathoms) of depth, Zone C from 51 to 100 metres of depth, Zone D from 101 to 200 metres of depth and Zone E covers all waters over 200 metres of depth. The mean depth of each latilong “block” was used.

Figures 18 - 20 have been divided into three sections as follows:

A. Sooty Shearwater
B. Short-tailed Shearwater
C. All shearwaters, which includes Sooty, Short-tailed and also unidentified Shearwaters.

(1) Northeastern Gulf of Alaska (NEGOA) and Kodiak Island Shelf

For the purpose of relating shearwater observations to water depth in NEGOA, some data collected on the Kodiak Island Shelf in 1978, as part of an independent project, have been combined with the NEGOA data from 1976.

An analysis of the numbers of shearwaters per unit-effort in relation to depth, for all shearwaters in the NEGOA and off Kodiak Island taken together, is presented in Figure 18C. The occurrence of shearwaters in the Outer Shelf Zone may depend on the influence of oceanic waters from the Alaska Current, bringing nutrients to the surface along the shelf break and at the edges of troughs.

Dunn et al. (1979) studied the food web and seasonal composition of marine organisms over the Kodiak Shelf. They found that the euphausiid crustaceans *Thysanoessa inermis* and *Th. spinifera* occurred at more stations in spring than fall, but the density per catch was about the same. Both species were particularly abundant near the edge of the shelf over Kiliuda Trough. *Euphausia pacifica* was found in low densities in the spring along the Shelf Break Front, but was very abundant over the shelf during the fall (mainly on Northern Albatross Bank and over Stevenson Trough). Finally, *Thysanoessa longipes* was found to be more abundant during the fall and in waters deeper than 100 fathoms.

Sooty Shearwaters seemed to prefer the Middle Shelf Zone waters (C) in May, but to extend their range to the Outer Shelf Zone (D) in June.

In contrast, the Short-tailed Shearwater was most abundant in the Outer Shelf Zone (D) in May 1976. It is evident that large aggregations were associated with the edges of troughs. In May 1976, Short-tailed Shearwaters were found almost exclusively associated with the Shelf Break Front east of Kayak Island (Fig. 3). This concentration must be associated with sources of food, available to them as a consequence of a high spring productivity (Fucik, 1980). The causes responsible for a high productivity here could be either (i) the start of a weak summer upwelling, stirring of nutrients by changes in the longshore currents, and inshore movement of deep waters along the troughs, or (ii) fresh water runoff from nearby glaciers. A change of direction of the Alaska Stream caused by the geographical presence of Kayak Island also produces eddies and possible stirring of bottom waters along the Shelf Break.

There are no June data from NEGOA proper. In July 1976 the NEGOA region east of Kodiak was almost devoid of

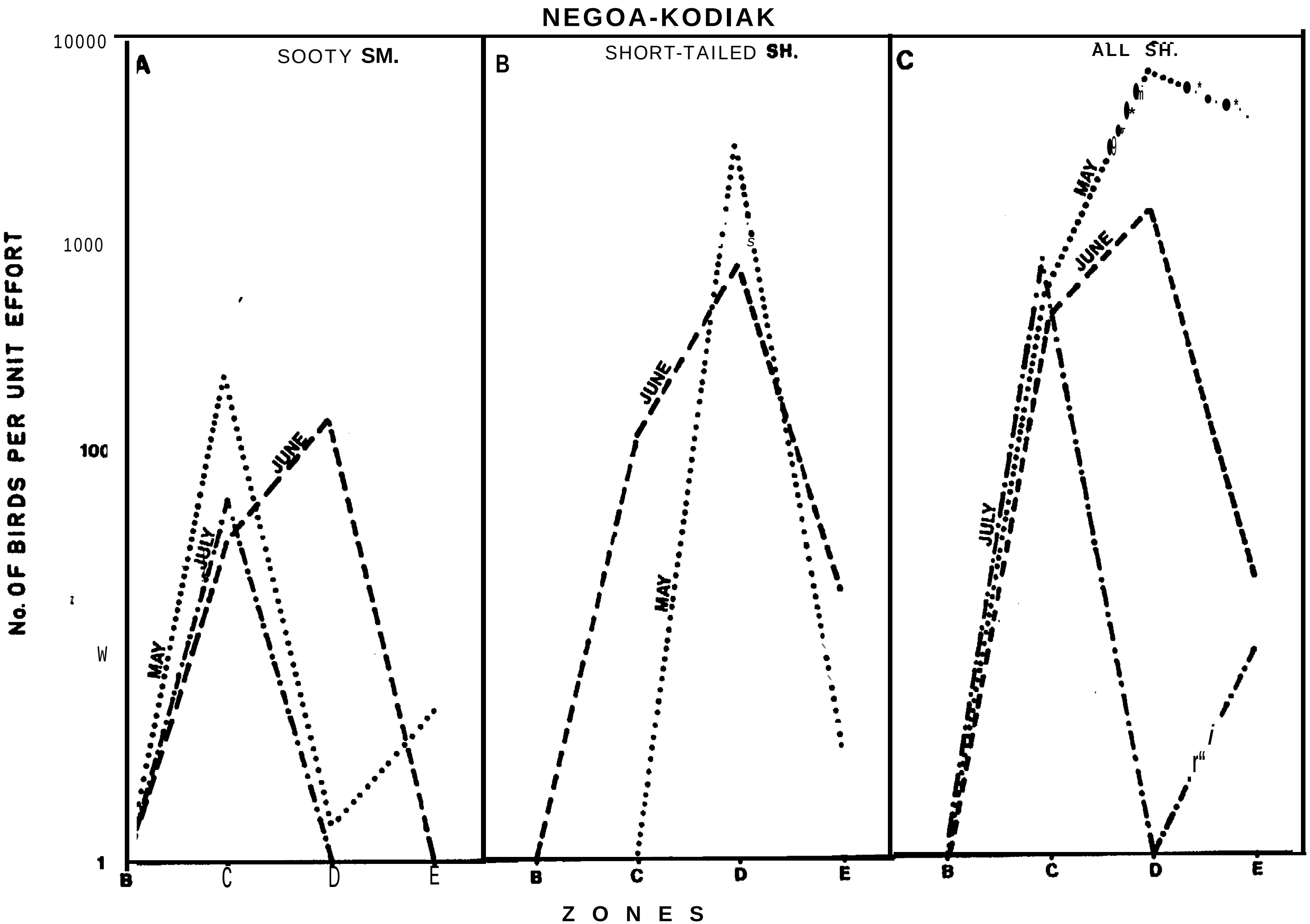


Figure 18. Monthly distribution of shearwaters in the NEGOA and Kodiak Shelf in relation to Depth Zones, during May-July 1976 (ad also 1978). All shearwaters (C) includes unidentified shearwaters.

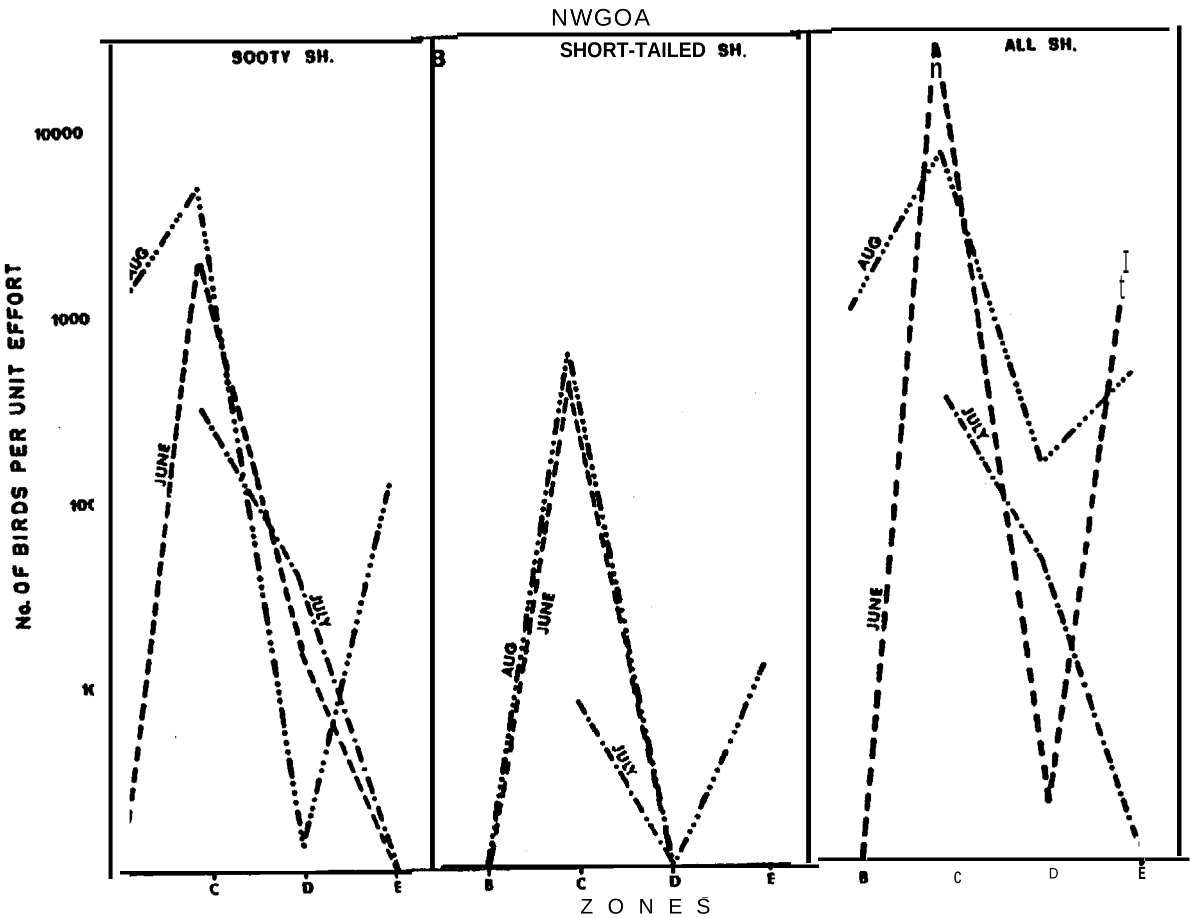


Figure 19. Monthly distribution of shearwaters in the NWGOA, in relation to Depth Zones during June-August 1975-1976.

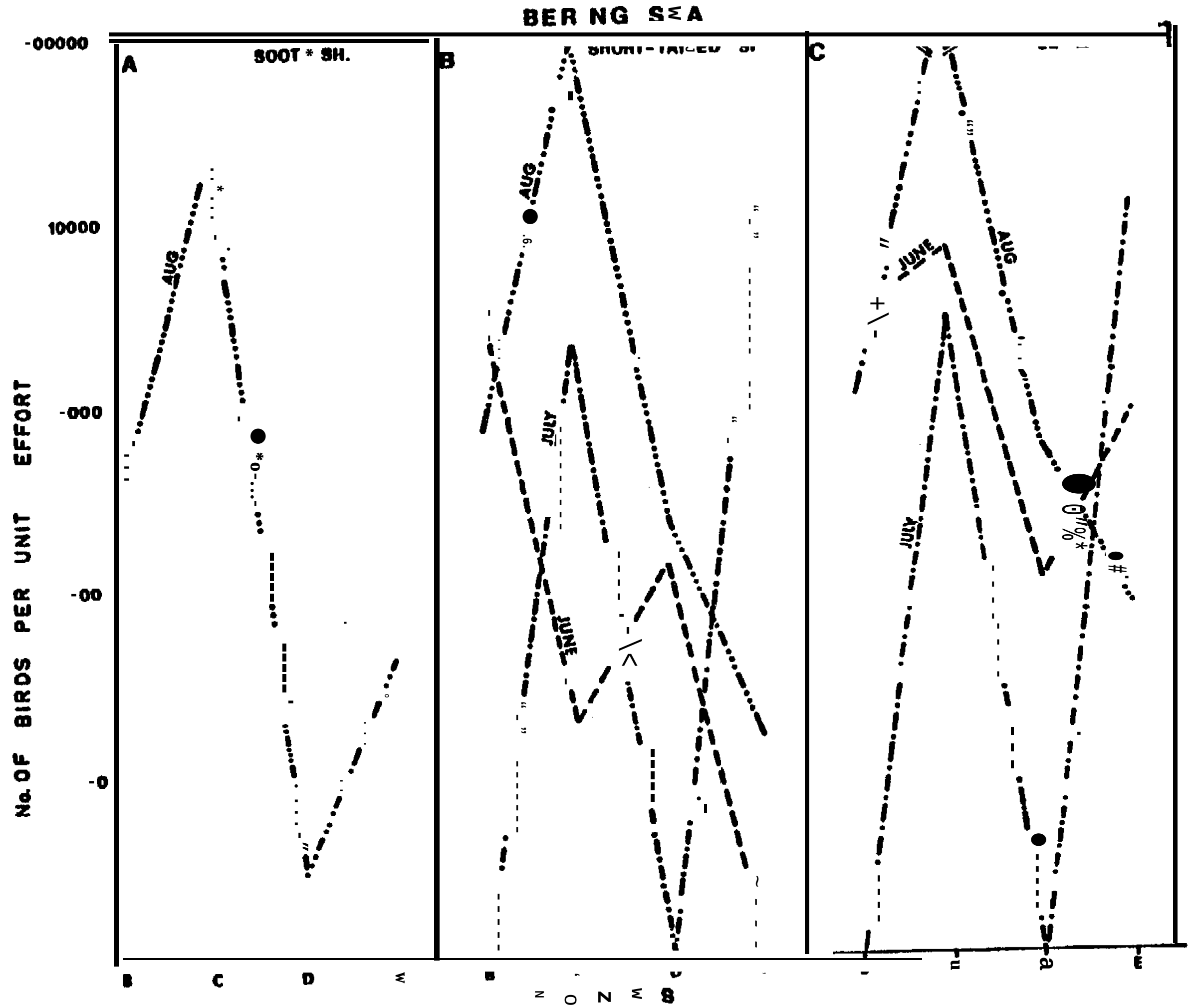


Figure 20. Monthly distribution of shearwaters in the Bering Sea, in relation to Depth Zones, during June-August 1975-1976.

Short-tailed Shearwaters. It is possible that after the spring bloom of plankton in NEGOA both species of shearwaters move to more productive waters off Kodiak Island and in NWGOA, during the mid- and late summer. Damkaer (in Fucik,1980) stated that the zooplankton in NEGOA appear to reach maximum numbers from late May through mid-June.

In contrast, Dunn et al. (1979) and Dunn et al. (in Strauch et al., 1980) found that zooplankton were more abundant on the Kodiak shelf during the fall than during the spring.

(2) Northwestern Gulf of Alaska

The Northwestern Gulf of Alaska, west of Kodiak Island, was visited only while in transit between Kodiak Island and the Bering Sea. The analysis of all shearwaters together,. whether identified or not (Fig. 19), shows that there was a considerable number of birds in the Middle Shelf Zone (C), because of several aggregations west of the Trinity Islands in June 1976 (Fig. 10). They were also seen over Oceanic waters (E) just beyond the Shelf Break Front, during August 1976 (Fig. 13) east of Unimak Pass.

It seems that the habitat selection of shearwaters in NWGOA follows a very similar pattern to that observed in NEGOA, with big aggregations at the 50 fathoms or 100 fathoms isobaths, mainly related to troughs or canyons across the shelf.

Shearwaters were found over inshore waters during August 1975 (Fig. 19A) because of their occurrence in the Shumagin Islands on August 11, 1975.

Short-tailed Shearwater numbers were lower than those of Sooty Shearwaters in NWGOA.

(3) Southeastern Bering Sea

The only month that the Southeastern Bering Sea was well covered by surveys was June, 1975 (Fig. 9) .

For the calculations in Figure 20, we have assumed that six million shearwaters were seen on August 17, 1975, of which 80% were Short-tailed Shearwaters (4.8 million) and 20% were Sooty Shearwaters (1.2 million).

Because most of the shearwaters seen in the Bering Sea were Short-tailed Shearwaters, the three month depth distribution patterns shown are basically similar in Figures 20C and 20B.

In general, Short-tailed Shearwaters prefer Middle Shelf waters (Zone C) in the southeastern Bering Sea, but they are also found in considerable numbers in Inshore and Shelf Break Front waters. Their numbers are definitely lower over the Outer Shelf Zone than in any other Bering Sea zone.

This habitat selection by shearwaters seems to be very similar to that of the distribution of phytoplankton in the southeastern Bering Sea (Sancetta,1981). PROBES workers have shown that in the Middle Shelf Zone "the thermocline is occasionally disturbed by wind and tidal vertical mixing in spring", which "results in higher nutrient concentrations, leading to a spring bloom of phytoplankton" (Sancetta, 1981), and that the concentration of chlorophyll persists below the surface until fall. This probably results in spring and summer concentrations of zooplankton in the Middle Shelf Zone.

Oceanic Waters just beyond the Shelf Break Front west of Unimak Pass seem to be frequently visited by shearwaters. In contrast, Oceanic waters and the Shelf Break near the Pribilof Islands were practically devoid of shearwaters. West of Unimak Pass, high productivity may well be caused by nutrients brought up to the euphotic zone by turbulence produced by the impact of the Bering Current System against the steep Shelf Break, and/or the input of water from the Alaska Stream in the North Pacific through the Aleutian Islands passes.

In the Outer Shelf Zone of the Bering Sea, shearwaters were never found to be very abundant, in contrast to the situation observed in the Gulf of Alaska where the Continental Shelf is so much narrower. This suggests that the coastline of the Bering Sea does have some undefined general influence on shearwater distributions.

The Oceanic Waters of the Bering Sea were surveyed beyond the Shelf Break only briefly. The Short-tailed Shearwaters shown over Oceanic Waters in Figure 20B are mainly shearwaters seen near the Shelf Break Front just west of Unimak Pass.

D. SEA-SURFACE TEMPERATURES AT SHEARWATER AGGREGATIONS

1. Reports in the Literature

There are few previously published measurements of the sea surface temperatures with which Sooty and Short-tailed Shearwaters have been precisely associated in the Northern Hemisphere. However, water temperatures for the same month may vary greatly from year to year in the eastern Bering Sea (Straty and Haight 1979) which is a shearwater wintering area so, unless high latitude shearwaters wander widely seeking a specific narrow range of temperature, it seems probable that they are adapted to living off waters that may be quite variable in their temperature range.

In the North Pacific the Short-tailed Shearwater goes farther north than the Sooty Shearwater, in both the Sea of Okhotsk and the Bering and Chukchi Seas. Kuroda (1957) saw Short-tailed Shearwaters in pack ice in the Sea of Okhotsk in late April 1950.

Tanaka and Kajihara (1979) described the presence of Short-tailed Shearwaters, from 10-25 July 1977, off the Sea of Okhotsk coast of Hokkaido in what they described as a 'cold upwelling zone", but the water temperatures ranged from 9.5-17.5 degrees C, and the largest flocks of these birds (5,000-20,000) occurred at 11.0-12.0 degrees C., which might not be considered “cold” in Alaskan waters. The Continental Shelf there was narrow and the shearwaters were mainly close to, or outside, the 100 m (50 fathom) isobath in what we have called the Outer Shelf Zone. As will be seen shortly, these temperatures are warmer than any which we recorded as associated with large aggregations of Short-tailed Shearwaters in Alaska.

For Sooty Shearwaters there are a few previously published temperature records. Kuroda (19S7) stated that Sooty Shearwaters “remain off Japan over the warm current sea surface (Kuroda 1956)”. Off Northern Honshu, Japan, on 4 June and 14 July, 1954, Kuroda (1955) saw Sooty Shearwaters when the water was at 12.0 and 12.5 degrees C, respectively, and at various distances off Kushiro, Hokkaido, from 10-13 July, 1954, he saw a few birds only in waters ranging from 8.2-12.0 degrees C. In the Aleutian Islands, Sooty Shearwaters were reported on July 12 and August 6, 1966, in waters that were at 8.2 and 9.8 degrees C, respectively (Miscellaneous Reports of the Yamashina Institute of Ornithology and Zoology, 1967). The reported range for wintering Sooty Shearwaters has, therefore, spanned 8.2-12.5 degrees C. in the literature and, as will be seen below, the upper end of this range matches what we found. We recorded aggregations of Sooty Shearwaters at lower temperatures than 8.2 degrees C, but no Short-tailed Shearwater aggregations above 10.0 degrees C.

We know of no water temperature measurements having been made from southern Japan or from Washington, Oregon or California, but these are not strictly wintering areas.

2. Alaska 1975-1976

From Tables 1 and 2, we have extracted the sea surface temperatures, when known, that were recorded at aggregations of 10,000 or more shearwaters during the field seasons 1975-1976, and these are listed in Table 3.

The ranges of temperature at which aggregations were seen for each of the major regions are:

NEGOA	5.0 - 6.0 degrees C (May 1976)
Kodiak Island	5.6 degrees C (June 1976; Kiliuda Trough) 8.3 degrees C (July 1976)
NWGOA	5.6 - 7.8 degrees C (June 1976) 4.4 degrees C (June 1976; S Unimak Pass) 10.0 degrees C (August 1975)
Bering Sea	4.4 - 5.6 degrees C (June 1976; NE Unimak Pass to Alaska Peninsula) 1.6 - 3.6 degrees C (June 1975; Bristol Bay to Kuskokwim Bay) 6.7 - 7.8 degrees C (July 1975; North Unimak and Akutan Passes)

8.3 - 10.0 degrees C (August 1975;
Pribilof Islands to Nunivak Island)

What this shows is that:

(1) We recorded aggregations in waters ranging from 1.6 - 10.0 degrees C, in Alaska a fairly wide range, which suggests

(2) that the birds were not always voluntarily selecting these temperature but had to pass through these temperature zones at one time or another (e.g., even in the huge aggregation of millions in the Bering Sea on August 17-18, 1975); and

(3) favoured feeding locations, such as off Kodiak Island, experienced temperature variations: (i) from year to year, or (ii) in very different places (10.0 degrees C off the Shumagin Islands in August 1975 but 4.4 degrees C in Unimak Pass in June 1976 and 1.6 degrees C near Cape Newenham in June 1975).

These findings are rather unexpected, but fairly convincing. We had assumed that the optimal range of temperature for wintering shearwaters might be fairly narrow (perhaps as little as 3-4 degrees at most), but it appears that the sea surface temperature, as such, at which wintering shearwaters may commonly be found can vary over at least 8 degrees C (e.g. 2.0 C - 10.0 degrees C).

One is inclined, therefore, to conclude that various types of high secondary or tertiary food production (zooplankton and fish) can occur over a wide range of temperatures in the complex oceanographic conditions on either side of the Aleutian Islands Archipelago and Alaska Peninsula regions.

The actual partitioning of the marine environment by the two species of shearwaters is probably less related to water temperature than to a complex of environmental choices" associated with differences in food preferences between them.

E. SHEARWATER DENSITIES IN AGGREGATIONS.

For aggregations of shearwaters that achieved an observed accumulated total of over 10,000 birds (those listed in Tables 1 and 2), there appear to be four broadly different levels of shearwater density, as follows:

	Max Density (birds/km2)	Census Area (km2)	Total No.of Birds
(1) L. D. spread out	421-1,701	28.7-121.0	(15,000-110,000)
(2) I.D.- more con- centrated	1,905-15,432	1.95-12.96	(10,000-55,000)
(3) I.D.-			

spread out	5,210-8,680	1152.0	(6-10 million)
(4) V.H.D.- very concentrated	17,544-37,168	0.57-1.54	(10,00 0.57,000)

[L.D. = Low density
I.D. = Intermediate density
V.H.D. = Very high density]

The recorded maximum density of birds, in aggregations of over 10,000 altogether, can thus, for example, range from
(1) as few as 421 birds/km2 for 15,000 birds spread over 35.7 km2, through
(2) an overall 5,210 - 8,680 birds/km2 for the 6-10 million birds spread over 25-30 linear nautical miles on August 17, 1975, in the Bering Sea, to
(3) an absolute maximum of 37,013 birds/km2 for a flock of 57.,000 birds-in fog during a 5-minute observation of a dense concentration covering only 1.54 km2 of the north side of Akutan Pass on July 27, 1975, or
(4) 37,168 birds/km2 for 42,000 birds counted moving westward in a restricted location, 1.13 km2 of Urilia Bay, on the north side of Unimak Island, during a 75-minute period on July 24, 1975.

It is evident from the tabulated summary (above) that large total numbers, for example 10,000 - 110,000 birds, can be found both (1) in very concentrated aggregations within very small areas of less than 2 km2 each, and (2) at very much lower densities spread *over* areas ranging up to 120 km2. The most exceptionally large aggregation of all in terms of absolute numbers of birds, recorded on August 17, 1975 in the Bering Sea, was dispersed over so large an area as not to have a particularly high density per unit area, although the total area was over 1000 km2.

The highest densities per unit area were recorded either (1) in a very small and localized patch, e.g. in a favorable feeding site in a pass in the Aleutian Islands chain, or (2) when flocks are on the move from one location to another past a particular point, resulting in a much larger total count per unit time than when the birds are settled on the water. In fact the highest counts of shearwaters that occur anywhere are probably those made during the pre-breeding migration of Short-tailed Shearwaters southwards along the coast of New South Wales in September (Australian Seabird Group Newsletters; Guzman 1981)..

It is evident from Tables 1 and 2 that most usual "maximum density" figures recorded were less than 10,000 birds/km2, spread over a census area of no more than 2 - 12 square kilometers. Thus 55,000 birds spread over 7.8 km2 had *a* maximum density of 6,410 birds/km2, and 50,000 birds spread over 11.85 km2 had a maximum density of 2,532 birds/km2, neither of which are high figures. There were only three occasions when the estimated total aggregation size exceeded 55,000 birds.

F. FLOCK SIZES IN AGGREGATIONS

Each aggregation is composed of more or less separate flocks, which have been brought together in one place as an aggregation. From Tables 1 and 2 it is possible to examine the size ((and size ranges) of the flocks that constitute these aggregations.

In the 6.10 million bird aggregation on August 17, 1975, flock sizes varied greatly, from 100 - 6,000 birds, and there was great variation also in the distance between each flock and the next one.

For aggregations of altogether 15,000 - 20,000 birds, the number of flocks ranged from 4 - 21 per aggregation, and for aggregations of altogether 30,000 - 70,000 birds the number of flocks ranged from 3 - 47 per aggregation. Regardless of the total number of birds in aggregations, flock sizes ranges from 100 - 5,000 birds, and mean flock sizes in aggregations were most commonly 1,000 - 1,500 birds. There was no apparent difference in either characteristic between smaller and larger aggregations.

An aggregation of shearwaters therefore apprears to be composed of fairly discrete groupings of several hundreds, or a few thousands, of birds. This is apparent not only in aggregations resting on the water on feeding but also in migrating birds or aggregations making single unidirectional shifts of location.

G. REPRODUCTIVE CONDITION.

In shearwaters mature females lay only one egg every breeding season, and for this reason only the largest ovarian follicle has been recorded. The mean sizes of the largest ovarian follicle and largest testis for all specimens each month are shown in Figure 21. In general, the gonads are larger in the Sooty Shearwater (Fig. 21), which is the bigger species.

Short-tailed Shearwater males showed a slight increase in the size of the testes from June to August (Fig. 21). Females showed a constant size of the largest ovarian follicle from June to August. In both sexes, the sizes decreased in September in the samples (Fig. 21), and this is interpreted as being due to mature birds having left on the return migration, so that the sample largely consists of subadults in September.

For Sooty Shearwaters gonad size seems to be biased by the small sample size (n=67). There was a decrease in size of both largest testis and largest ovarian follicle from May to June (Fig. 21), which could be attributed to the arrival of juvenile birds. The size increased from June to July and then decreased in August for both sexes, but the drastic drop in the female is due to a small sample size of one bird

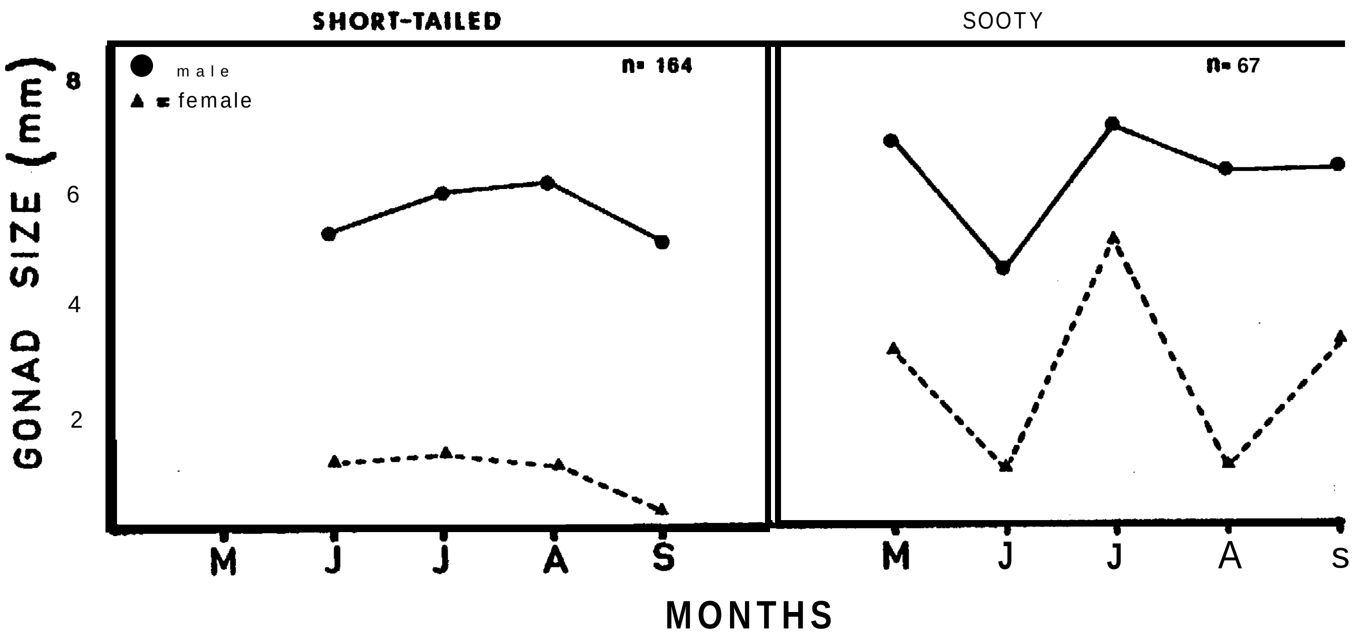


Figure 21. Mean sizes of the largest ovarian follicle and largest testis from all specimens each month.

only in that month.

Brood patches were found in only two females and a single male, all of them Sooty Shearwaters collected in August and September. Their gonads were developed and molt was already complete.

H. SHIPBOARD OBSERVATIONS OF MOLTING BY SHEARWATERS AT SEA

Molt (mainly of primaries and secondaries and sometimes upper coverts) was recorded at sea (i) by direct observation of the flight feathers being molted, in birds seen at close range, and (ii) indirectly by recording feathers seen floating in localities where shearwaters were present (or close by) at the time of the observation. A summary of these observations is presented in Table 4.

Floating feathers and molt of the flight feathers in live birds of both species were observed in both areas of study in 1975-1976: the Gulf of Alaska and the Southeastern Bering Sea. These shearwater molting records extended all through the summer from May to early August, with the number of separate occasions (locations) distributed as follows: May (8), June (4), July (5), August {3) and September (0) (Table 4).

Floating feathers provide information on the areas of the ocean where molting takes place. Since molt is a period of stress for birds, it is important that molting should not be taking place in areas where they may be exposed to oil spills. In fact, it appears that molt occurs gradually and over a very wide area (not in restricted areas) so this may not be a particularly serious problem in Alaskan waters.

VII. DISCUSSION

A. THE CIRCULATION OF SHEARWATERS IN THE WINTERING AREAS

Aside from seasonal shifts in the overall distribution of each of the two species of shearwaters in the North Pacific Ocean, and in and out of the Bering Sea, from month to month from April-September, the reasons for the discontinuous distribution of shearwaters, both in space and time, and the explanation for the "here today, gone tomorrow" phenomenon have not been elucidated. --

As Figure 14 shows, the majority of record periods do not result in shearwaters being seen, so there are many empty sea areas at any one time. Also, major aggregations are found relatively infrequently (Tables 1 and 2) except in a few limited locations, and over most of the Continental Shelf sightings are as often of fewer than 100 birds as of more than that (Figure 14).

What determines the shifts or circulation of flocks or sub-populations within a region remains unresolved. It may be determined by feeding conditions or by weather patterns, as discussed in Section IIIC.

We had hoped to be able to correlate the distribution of shearwaters with currents (or tidal currents) at the

TAME 4 : MOLT IN SHEARWATERS IN ALASNAN WATERS

Year	Region and Area	Date	Location	Description	Species Present in Area At Time (or Presumed Species Origin of the Feathers)
1975.					
	GULF OF ALASKA. Kodiak-Bowie sea-mount chain	July 13	(i) 55°21 *N, ,144°03'W.	" Feathers floating. Possibly of shearwaters."	Sooty Shearwaters
			(ii) 55°30'N. ,144°27'W.	"Many feathers of shearwaters floating on the water."	Sooty Shearwaters
	NEGOA. No Data				
	NWGOA. No molting noted, June 17-18, July 16-18, 28-31, or August 5-11.				
	BERING SEA. Inner Bristol Bay	June 8	58°10'N. ,159°44'W .	'Today saw many feathers of shearwaters. The Mrds are mo lting."	Short-tailed Shearwaters
	South of Cape Newenham	Juns 10	(i) 57°50'N. , 162°11'W .	"All the observations show that the birds are molting."	Short-tailed Shearwaters
			(ii) 58°02'N, ,161°52'11.	"Many feathers on the water."	Short-tailed Shearwaters
	North of Amak Island	July 19	56°05'N ., 162°43'W .	"Many, many f eathers f loating."	Short-tailed Shearwaters
	Beyond Continental Shelf, South of St. George*s Basin	August 14	(i) 55°09'N., 168°30'W.	"Many feathers of shsarwatere or f ulmars on the water."	Northern Fulmar ?
			(ii) 55°27'N. , 168°42'W .	"Many feathers floating; probably fulmars."	Northern Fulmars ?
1976.					
	GULF OF ALASKA. Kodiak-Bowie sea-mount chain	July 18	55°23'N. ,142°51'W.	"Brown feathers floating On the water... ,wing and/or tail feathers ; from their color and size, they are shearwater f eathers)", although no shear-waters were seen until 3 1/2 hours later at 55°57' N.. 144° [illegible]	Sooty Shearwaters ?

Table 4 (continued):

1976 (continued):

KODIAK SHELF.	Amatuli Trough	May 8	58°24'N., 148°13'W.	Molt seen in two birds seen within 100m.	Species unidentified
NEGOA.	NEGOA Shelf Edge (Bering Glacier)	May 16	(i) 59°40'N., 143°27'W. (ii) 59°39'N., 143°53'W.	"Molt". "Molt".	Short-tailed Shearwaters Short-tailed Shearwaters
NEGOA.	NEGOA Shelf Edge (Southwest of Kayak Island)	May 17	59°47'N., 145°40'W.	"Molting".	Short-tailed and Sooty Shearwaters
KODIAK SHELF.	Northeast of Afognak Island	May 20 May 24	58°26'N., 150°06'W. (i) 58°22'N., 151°37'W. (ii) 58°27'N., 151°42'W.	"Molting." "Feathers floating on the water, some of them white (gulls or murres), most of them shearwater-colored body feathers." "Molting."	Species unidentified Species unidentified Species unidentified
KODIAK SHELF.	Inner Kennedy Entrance	May 27	59°01'N., 150°56'W.	"Molting."	Short-tailed and Sooty Shearwaters
NWGOA.	Chirikof /Trinity Islands	June 19	56°01'N., 155°05'W.	"Molting; wings."	Short-tailed Shearwaters
KODIAK SHELF.	Outside Kodiak Harbor	July 19	58°43'N., 152°14'W.	"They show wing and body molting."	Sooty Shearwaters
ALEUTIANS.	Unimak Pass (North Unimak Pass)	August 2	54°09N., 165°10"W.	"W 1sss molting".	Short-tailed Shearwaters
** ********************* ***** ***** ******	****** ***** ***** *****	***** ****	****** ********	********************	******************** ******* *********
BERING SEA.	South of Nunivak Island	August 3	(i) 58°20'N., 167°26'W. (ii) 59°18'N., 167°56'W.	"Many shearwater feathers floating in the water." "Feathers of shearwaters floating."	Short-tailed Shearwaters Short-tailed Shearwaters

regional level, but the data contemporary with our shearwater observations were not adequate for this.

We conclude that biotelemetry provides the best hope of elucidating the extent and pattern of local and regional movements of shearwaters in Alaskan coastal areas.

B. THE FEEDING ECOLOGY OF SHEARWATERS IN THE WINTERING AREAS

As noted in section V.C., the foods eaten by the specimens collected in 1975 and 1976 during this Research Unit were studied by G.A. Sanger (Lensink et al. (1976), Sanger and Baird (1977)). Foods taken by shearwaters in the eastern Bering Sea have also been discussed by Hunt et al. (1981a), and foods taken in the Kodiak Island area of the Gulf of Alaska by Sanger et al. (1978) and Krasnow et al. (1979). Ogi et al. (1980) analysed 439 Short-tailed Shearwater stomachs and reported that "the diet . . . ..varied according to sea area. ..demonstrates high adaptability in prey and pelagic environment".

On the basis of a rather small sampling in 1975 and 1976, Sanger and Baird (1977) found that Sooty Shearwaters were feeding mainly on squids and fish, while Short-tailed Shearwaters were feeding mainly on euphausiids. But, with fewer than 50 stomachs altogether, from two species taken in both the Gulf of Alaska and the Bering Sea, it is clear that no breakdown reflecting differences in local feeding areas at different times was yet possible. In 1977 and 1978 over 300 more specimens were collected in the Kodiak Island area, yielding about 250 usable stomach samples (Sanger et al. 1978, Krasnow et al. 1979). Seasonal changes were found from June to September (1) from almost 50/50 squid and fish in June to 95% fish in Sooty Shearwaters, and (2) from 80% *Thysanoessa* euphausiids in June to 92% fish in September in Short-tailed Shearwaters (Sanger et al. 1978). Capelin (*Mallotus villosus*) was the predominant fish in 1977 (much more so in Sooty Shearwaters), but in 1978 Sooty Shearwaters taken in nearshore waters in Kiliuda Bay took few squids and switched from capelin to sandlance (*Ammodytes hexapterus*) between June and September (Krasnow et al. 1979). One can conclude that the separation between the feeding preferences of the two species of shearwaters is rather wide in early summer, but narrows rapidly in August. Therefore, their relative distributions must be reviewed in terms of the availability of their preferred invertebrate versus vertebrate foods, 'especially in May, June and July.

C. THE SIGNIFICANCE OF SHEARWATERS MOLTING IN ALASKAN WATERS

Flight may be affected by molt. Flight in shearwaters has been discussed by Warham (1977). Molt in shearwaters has been discussed by Watson (1971) and Guzman (1981).

1. Timing and Sequence of Molt

During the early part of the northern summer the aspect of the feather coat of shearwaters is old and worn on the wings and tail. During the northern summer, they acquire a new feather generation of flight and tail feathers.

Body molt starts on the breeding grounds, and is apparently completed on the wintering grounds. Brood patches appear in some individuals at the end of the northern summer, just before the start of the southbound migration. Groups of feathers that are entirely molted in the Northern Hemisphere are well correlated, but body molt does not show any correlation with them.

There is a high correlation between the replacement of upper greater coverts and the corresponding primaries (r=0.99 in Short-tailed and r=0.97 in Sooty). The upper greater coverts molt just 1 or 2 feathers ahead of their matching primary feathers (Guzman, 1981). This could be an adaptive strategy to reduce part of the gap left by the primary or primaries being molted. Gaps left at the trailing edge by shed primaries will increase the drag force, and affect the performance of the wing. The greater coverts protect the quill bases of the primaries from being damaged, and this must be particularly important as new primaries start to grow in.

The correlation between molt in tail and primary feathers is also significant (r=0.85 in Sooty Shearwaters and r=0.73 in Short-tailed Shearwaters). Although primary molt starts earlier than tail molt, they are completed at about the same time.

The alula provides a midwing slot. Saville (1957) reported that the alula "may be of substantial size" in oceanic soaring birds. In the present study, the alula of a sample of ten birds of each species of shearwater was measured, using for this purpose birds that had already finished their alula molt. In the Sooty Shearwater the alula was 14.1% of the wing length, and it was 13.5% in the Short-tailed Shearwater (Guzman, 1981). These ratios are comparatively much higher than those given by Saville for albatrosses.

The alula helps to reduce drag over the upper surface of the wing. This may explain the earlier molt of the alula compared with the outer primaries. Only when one "slot" (the alula) is totally molted, does the next one (the outer primaries) undergo molt. In this manner, unwanted drag over the upper surface of the wing is avoided.

2. Effect of Molt on Flight

(1) Powered Flight

Towards the wing tip primary feathers are longer, so the shedding of the outer primaries (7 to 10) must be critical in terms of wing area, propelling power and lift to drag ratio. Storer (1948) stated "It is demonstrable that a slight change in the position or shape of two key primary feathers can make it nearly impossible for a bird to fly".

Shearwaters depend much more on powered flight than albatrosses. Thus (i) under calm weather conditions they rely almost exclusively on wing flapping to fly, (ii) wing flapping is of great importance in taking-off under almost all kinds of weather conditions, (iii) when climbing up over the crest of a swell, to initiate soaring, they usually depend on powered flight, and (iv) to correct flight direction when gliding they will flap the wings from 2 - 10 times.

It seems that, when molting the primary feathers, those that are left functional produce wider and deeper slots. Under these conditions thrust must be greatly reduced.

(2) Dynamic Soaring

When soaring above the swells or losing altitude by gliding, shearwaters normally keep the primaries together, showing a very narrow and pointed wing. But any change that requires an active -action by the wing, will produce immediately a spreading of the primary feathers, opening slots between them. The size of these slots varies with the maneuver to be accomplished? and requires a great degree of efficiency of the outer primaries. So, it is probably greatly reduced during molt of the outer primary feathers.

(3) Take-off from Water

In both species under study, the slots at the tips of the wings are of importance for producing the necessary lift to raise shearwaters from the water during take-off. Birds molting their outer primaries might have serious difficulty in getting enough lift.

(4) Pre-dive Stalling

One of the actions performed by shearwaters that requires a high degree of maneuverability is the stall before initiating a dive. Once prey is located from the air by the bird, it stalls. To do this the bird needs all of its ‘braking power’, using wings, tail and feet to brake.

To perform effective plunge-dives for food from stall positions, shearwaters might require complete sets of tail and flight feathers (at least primaries and alula), to fully control their movements at those moments. In fact, this kind of diving behavior was never seen during mid-summer, when the molt is in progress, except in May **when the old tail and outer primary feathers were still present.**

3. Summary

The breeding populations-of Sooty and Short-tailed Shearwaters do not molt flight and tail feathers on the breeding grounds, so by the end of the austral summer they have old, worn, feather coats. Other species of Procellariiformes that do not migrate across the equator into the North Pacific have different patterns of molt; in many of these species molt overlaps to some extent with the breeding season.

During molt, Sooty and Short-tailed Shearwater wing loadings do not change much. This is due to the fact that while there is a change in wing area there is also a compensating reduction in body weight. So, this does not seem to be critical for flight capabilities.

On the other hand, shearwater flight capabilities also depend on the glide ratio, or ratio of lift on drag (L/D), which can be drastically modified during molt (i) by changing the shape of the wing, (ii) by altering the aspect ratio, or (iii) by altering the slots that normally reduce drag. Powered flight can also be drastically affected if the primary feathers are reduced in number during molt, so that less thrust is possible. It can be concluded that shearwater flight is most affected during molt (i) when taking-off, (ii) when maneuvering in the air, and (iii) when stalling to initiate a dive.

Considering that during the molt shearwaters have difficulties in performing all the maneuvers required for plunge-diving, their feeding spectrum is probably reduced, as well as their capability of feeding in all kinds of weather conditions. Consequently, they are probably limited to feeding mainly by diving from the surface in relatively calm weather. Therefore, because they are molting then, Sooty and Short-tailed Shearwaters are vulnerable to any additional environmental stress (such as oiling) that may occur during their period of residence in Alaskan waters.

VIII. SUMMARY AND CONCLUSIONS

1. On their wintering grounds, in the Gulf of Alaska and Bering Sea, both species of shearwaters under study were present at least from May to August. Around Kodiak Island, they were still present in-September when that area was visited.

2. The analysis of the data on the distribution of Sooty and Short-tailed Shearwaters indicates that they occur along the length of the Alaskan Coastal Domain described by Favorite _et al._ (1976).

3. They are mostly found over Offshore Waters (Middle and Outer Shelf Zones), but smaller numbers may be seen over Oceanic Waters, particularly near seamounts.

4. Aggregations occur regularly close to shore in Unimak Pass and in Marmot Bay, Kodiak Island.

5* Elsewhere, the birds are widely dispersed and occur in low densities, but they sporadically gather in large aggregations from time to time at various locations when local feeding conditions become good as over upwellings at the margins of troughs in the Continental Shelf.

6. It is evident that part of the population of Short-tailed Shearwaters (probably non-breeding subadults) moves immediately into the Northeastern Gulf of Alaska, as soon as they arrive from the Southern Hemisphere; they were common in the Hinchinbrook Island - Icy Bay sector in May, and over Kiliuda Trough after that month.

7. Sooty Shearwaters were abundant in Kennedy Entrance and over Stevenson Trough. Both species were commonly found in mixed aggregations offshore over Amatuli Trough and inshore in Chiniak and Marmot Bays, Kodiak Island.

8. By July, the Short-tailed Shearwaters were not found east of Kodiak Island, but they were abundant on the southeast Kodiak Shelf.

9. The distributional data for the Kodiak Shelf shows that, even when both species are common in some locations, they tended to be segregated in different flocks, some distance apart, and that when mixed together one species is always far more abundant than the other. Thus, in Chiniak and Marmot Bays, for example, both species were abundant, but generally they were found in different blocks, during the same period of time.

10. In the NWGOA shearwaters were found to be very patchy and scarce, particularly south of the Alaska Peninsula west of the trough that emerges from Shelikof Strait west of Chirikof Island. Besides the few aggregations sighted, only a few birds were seen dispersed in the NWGOA.

11. Aggregations of shearwaters were sometimes encountered in the Chirikof - Trinity Islands area and between the Shumagin Islands and the Sanak Islands.

12. In the Bering Sea, Short-tailed Shearwaters were by far the most abundant species. Sooty Shearwaters were sometimes also found.

13. Sooty Shearwaters were present in, or close to, Unimak Pass, and in Inshore and Middle Shelf Waters off certain of the eastern Aleutian islands, and also sometimes associated with the Shelf Break Front.

14. By the second part of August and early September the numbers of both species of shearwaters sharply decrease in Kodiak Island waters.

15. Sooty and Short-tailed Shearwaters were recorded aggregating in waters that had a wide range of temperatures, and favored feeding locations also had (or experienced) wide temperature differences.

16. Differences in the favored foods between Sooty and Short-tailed Shearwaters appear to be greater in early and mid-summer (May - July) than in September, so differences in their distributions may be related to differences in the availability of their food species in different offshore zones or geographical regions.

17. For a high percentage of observation periods, no shearwaters may be seen, or only low numbers.

When aggregations do occur, they may be brought about either by a very high density in a very concentrated area or by intermediate or relatively low densities of birds spread out over a wide area.

19. Biotelemetric studies of movements of individual birds are needed to demonstrate the extent and patterns of local and regional movements of shearwaters off Alaska.

20. Shearwaters molt their flight feathers in Alaskan waters. When molting, their ability to feed and their ability to take off from the water would be impaired by oiling.

21. Because they breed in and visit a number of nations in both Northern and Southern Hemispheres, Sooty and Short-tailed Shearwaters are of international interest and importance. They are the predominant species in terms of their numbers in Alaskan waters in the summer months. The extent to which they become contaminated by, or are at risk from, fossil fuel hydrocarbons in the sea needs continued monitoring.

ACKNOWLEDGEMENTS

We are sincerely grateful to the entire staff of the Us. Fish and Wildlife Service in Anchorage, Alaska, for their support, encouragement and friendship during this study. In particular we wish to thank Dr. J. Bartonek and Dr. C. Lensink, for assisting in the initial project planning and in arranging for the 1975-76 contract with NOAA; Dr. Pat Gould and Mr. G. Sanger for advice and assistance throughout; and Mr. Doug Forsell, for providing many of the shearwater skins used in the analysis of molt. Their direct contribution to the study was in addition to the hospitality each of them showed to J.R.G. during his many visits to Anchorage.

The U.S. National oceanographic and Atmospheric Administration (NOAA), provided financial support with a Research Contract through OCSEAP, during the 1975 and 1976 field seasons.

The officers and crew of the NOAA vessels R/V SURVEYOR and R/V DISCOVERER were very helpful in providing logistic support.

We wish to express thanks to the following NOAA people: Mr. Mauri Pelto, for his advice on data preparation; Ms. Cheryl Brewer, for her help in getting data from NODC; and Dr. Herbert Bruce and Mr. Laurie Jarvela, who were responsible for directing and co-ordinating the bird research projects under contract with NOAA.

Understanding of seabird biology was greatly improved by discussions with Dennis Heinemann and Wayne Hoffman, who were also working on a seabird project for NOAA/OCSEAP in Alaskan waters. Their help and good judgement were invaluable in developing the censusing methodology used in the study.

Glenn Krahulic and Moray Lewis assisted with using computer services at different stages of this work.

Rich and Molly McIntosh, of Kodiak, Alaska, were generous in their hospitality to J.R.G.

LITERATURE CITED.

Ainley, D.G. and G.A. Sanger. 1979. Trophic relations of Seabirds in the Northeastern Pacific Ocean and Bering Sea. U.S. Fish and Wildlife Service, Wildlife Research Report 11: 95-122.

Ainley, D.G., C.R. Grau and S.H. Morell. 1981. Influence of petroleum on egg formation and embryonic development in seabirds. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators. 13: 315-356.

Albers, P.H. and R.C. Szaro. 1978. Effects of No.2 fuel oil on Common Eider eggs. Marine Pollution Bull. 9: 138-139.

Alton, M.S. and C.J. Blackburn. 1972. Diel changes in the vertical distribution of the euphausiids, Thysanoessa spinifera Holmes and Euphausia pacifica Hansen, in coastal waters of Washington. California Fish and Game 58: 179-190

Anderson, J.W., J.M. Neff, B.A. Cox, H.E. Tatem and G.M. Hightower. 1974. Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish. Marine Biology 27: 75-88.

Ashmole, N.P. 1971. Sea bird ecology and the marine environment. Pp. 223-286 in Farner, D.S. and J.R. King (eds). Avian Biology, Vol.1, Academic Press, New York.

Bailey, E.P. and G. H. Davenport. 1972. Die-off of Common Murres on the Alaska Peninsula and Unimak Island. Condor 74: 215-219.

Bailey, R.S. and W.R.P. Bourne. 1972. Notes on sea birds 36: Counting birds at sea. Ardea 60: 124-127.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-1971. U*S. Dept. of Commerce, NOAA Tech. Rep. NMFS SSRF-671.

Bakun, A. 1975. Daily and weekly upwelling indices, west coast of North America, 1967-1973. U.S. Dept. of Commerce, NOAA Tech. Rep. NMFS SSRF-693.

Bartonek, J.C. and D.D. Gibson. 1972. Summer distribution of pelagic birds in Bristol Bay, Alaska. Condor 74: 416-422.

Bartonek, J.C. and L.W. Sowl. 1972. Birds. Pp.296-344 in Environmental Setting between Port Valdez, Alaska, and west coast Ports. Final Environmental Impact Statement, Proposed Trans-Alaska Pipeline, Vol.3. Special Interagency Task Force for the Federal Task Force on Alaskan Oil Development, U.S.D.I. U.S. Dept. Commerce, NTIS, PB 206-921-3.

Berridge, S.A. 1968. Properties of persistent oils at sea. J. Inst. Petrol. 54(539): 300-309.

Birkhead, T.R. 1976. Effects of sea conditions on rates at which guillemots feed chicks. British Birds 69: 490-492.

Boersma, P.D. 1981. Storm-petrels as indicators of environmental conditions. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1981. 1: 39-70.

Boje, R. and M. Tomczac (eds). 1978. Upwelling Ecosystems. Springer-Verlag, New York.

Bourne, W.R.P. 1968. observations of an encounter between birds and floating oil. Nature 219: 362.

Bourne, W.R.P. 1970. Special Review - After the 'Torrey Canyons disaster. Ibis 112: 120-125.

Bourne, W.R.P. 1972. Threats to seabirds. International Council for Bird Preservation, Bulletin XI: 200-218.

Bourne, W.R.P. 1976. Seabirds and pollution. Pp. 403-502 in R. Johnson (Ed.). Marine Pollution. Academic Press.

Bourne, W.R.P. and C.J. Bibby. 1975. Temperature and the seasonal and geographical occurrence of oiled birds on west European beaches. Marine Pollution Bulletin 6(5): 77-80.

Boylan, D.B. and B.W. Tripp. 1971. Determination of hydrocarbons in seawater extracts of crude oil and crude oil fractions. Nature 230: 44-47.

Brinton, E. 1962. The distribution of Pacific euphausiids. Bull. Scripps Institute of Oceanography 8(2): 51-270.

Brown, R.A. and H.L. Huffman. 1976. Hydrocarbons in open ocean waters. Science 191: 847-849.

Brown, R.G.B. 1980. Seabirds as marine animals. Pp. 1-39 in J. Burger, B.L. Olla and H.E. Winn (eds). Behavior of Marine Animals, vol. 4. Plenum Publishing Co.

Brown, R.G.B., S.P. Barker, D.E. Gaskin and M.R. Sandeman. 1981. The foods of Great and Sooty Shearwaters Puffinus gravis and P. griseus in eastern Canadian waters. Ibis 123: 19-30.

Brown, R.G.B., W.R.P. Bourne and T.R. Wahl. 1978. Diving by shearwaters. Condor 80: 123-125.

Brown, R.G.B., D.N. Nettleship, P. Germain, C.E. Tull and T. Davis. 1975. Atlas of Eastern Canadian Seabirds. Canadian Wildlife Sevice. Environ. Canada (220pp.).

Butler, J.N. 1975. Pelagic Tar. Scientific American 232(6): 90-97.

Butler, R.G. and P. Lukasiewicz. 1979. A field study of the effect of crude oil on Herring Gull (Larus argentatus) chick growth. Auk 96: 809-812.

Canada. 1978. Potential Pacific Coast Oil Ports: a comparative environmental risk analysis, Volume 1. A Report by the Working Group on West Coast Deepwater Oil Ports, Fisheries and Environment Canada, Vancouver, B.C. 98pp + figures.

Clark, R.B. 1969. Oil pollution and the conservation of seabirds. Proc. Internat. Conf. Oil Pollution of the Sea, Rome, 1968: 76-112.

Clark, R.B. and J.R. Kennedy. 1968. Rehabilitation of Oiled Seabirds. Report to the Advisory Committee on Oil pollution of the Sea. Department of Zoology, University of Newcastle upon Tyne. 57pp.

Cretney, W.J., W.K. Johnson and C.S. Wong. 1977. Trace analysis of oil in sea water by fluorescence spectroscopy. Pacific Marine Science Report 77-5. Institute of Ocean Sciences, Victoria, B.C.

Crocker, A.D., J. Cronshaw and W.N. Holmes. 1975. The effect of several crude oils and some petroleum distillation fractions on intestinal absorption in ducklings (Arias platyrhynchos). Environ. Physiol. Biochem. 5. 92-106.

Croxall, J.P. 1971. Guide to Identification of Shearwaters and Petrels in New Zealand waters. Auckland War Memorial Museum, Auckland, New Zealand.

Grau, C.R., T. Roudybush, J. Dobbs and J. Watson. 1977. Altered yolk structure and reduced matchability of eggs from birds fed single doses of petroleum oils. Science 195: 779-781.

Green, C. de B. 1916. Note on the distribution and nesting-habits of Falco peregrinus pealei Ridgeway. ibis (series 10) 4: 473-476.

Grubb, T.C. 1972. Smell and foraging in shearwaters and petrels. Nature 237: 404-405.

Guzman, J.R. 1981. The wintering of Sooty and Short-tailed Shearwaters (Genus Puffinus) in the North Pacific. Ph.D. dissertation. University of Calgary, Calgary.

Guzman, J.R., M.T. Myres and T.R. Wahl. (In prep.). The migrations of Sooty Shearwaters (Puffinus griseus) in the eastern Pacific Ocean. M.S.

Harrison, C.S. 1979. The association of marine birds and feeding gray whales. Condor 81: 93-95.

Harrison, C.S. 1982. Spring distribution of marine birds in the Gulf of Alaska. Condor 84: 245-254.

Harrison, C.S., J.C. Bartonek, P.J. Gould and G.A. Sanger. 1977. Seasonal distribution and abundance of marine birds. Part II. Aerial surveys of marine birds. Environment Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1977. 3: 285-593.

Hartung, R. 1965. Some effects of oiling on reproduction in ducks. Journal of Wildlife Management 29: 872-874.

Hartung, R. 1967. Energy metabolism in oil-covered ducks. Journal of Wildlife Management 31: 798-804.

Hartung, R. and G.S. Hunt. 1965. Some toxic effects of ingested oils on waterfowl. Toxicol. appl. Pharmacol. 7: 484-485.

Hartung, R, and G.S. Hunt. 1966. Toxicity of some oils to waterfowl. Journal of Wildlife Management 30: 564-569.

Heinemann, D. 1981. A range finder for pelagic bird censusing. Journal of Wildlife Management 45: 489-493.

Hoffman, W., D. Heinemann and J.A. Wiens. 1981. The ecology of seabird feeding flocks in Alaska. Auk 98: 437-456.

Holmes, W.N. and J. Cronshaw. 1977. Biological effects of petroleum on marine birds. Pp. 359-398 in Malins (1977) Volume 2.

Hood, D.W. and J.A. Calder (Eds). 1981. The Eastern Bering Sea Shelf: oceanography and resources. University of Washington Press, Seattle. 2 Vols.

Hood, D.W. and E.J. Kelley (Eds). 1974. Oceanography of the Bering Sea with emphasis on renewable resources. University of Alaska, Institute of Marine Sciences, Fairbanks.

Hughes, F.W., L.K. Coachman and Aagaard. 1974. Circulation, transport and water exchange in the western Bering Sea. Pp. 59-98 in D.W. Hood and E.J. Kelly (eds). Oceanography of the Bering Sea. Inst. Marine Science, Fairbanks, Alaska.

Hunt, G.L., B. Burgeson and G.A. Sanger. 1981a. Trophic relation of seabirds of the eastern Bering Sea. In Hood, D.W. and J.A. Calder (eds). The Eastern Bering Sea Shelf. University of Washington Press, Seattle.

Hunt, G.L., Z. Eppley, B. Burgeson and R. Squibb. 1981b. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands, 1975-1979. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators 12: 1-258.

Hunt, G.L., J. Kaiwi and D. Schneider. 1982. Pelagic distribution of marine birds and analysis of encounter probability for the Southeastern Bering Sea. Environmental Assessment of the Alaskan Continental Shelf, Final Report of Principal Investigators 16: 1-160.

Hutchison, L.V. and B.M. Wenzel. 1980. Olfactory guidance in foraging by Procellariiformes. Condor 82: 314-319.

Ingraham, W.J.Jr., A. Bakun and F. Favorite. 1976. Physical oceanography of the Gulf of Alaska. R.U. No. 357. Pp. 491-624 in Environmental Assessment of the Alaskan Continental Shelf. Principal Investigator's Reports April-June 1976, Vol.2. OCSEAP, Environmental Research Laboratories, Boulder.

Isleib, M.E. and B. Kessel. 1973. Birds of the North Gulf Coast-Prince William Sound Region, Alaska. Biological Papers of the Univ. of Alaska. No. 14.

Iverson, R.L., T.E. Whitledge and J.J. Goering. 1979. Chlorophyll and nitrate fine structure in the southeastern Bering Sea shelf break front. Nature 281: 664-666.

Johnson, A.W. 1965. The Birds of Chile and adjacent regions. Vol.1. Platt Establecimientos, Buenos Aires.

Kaplan, M.M. and R.G. Webster. 1977. The epidemiology of influenza. Scientific American 237(6): 88-106.

Kessel, B. 1979. Avian habitat classification for Alaska. Murrelet 60:86-94.

King, C.A.M. 1975. Introduction to Physical and Biological Oceanography. Edward Arnold, Ltd., London;

King, J.G. and Sanger, G.A. 1979. Oil vulnerability Index for marine oriented birds. U.S. Fish and Wildlife Service, Wildlife Research Report No. 11: 227-239.

King, W.B. 1970. The Trade Wind Zone Oceanography. Pilot study part vii: observations of sea birds March 1964 to June 1965. U.S.F.W.S. Special Scientific Report: Fisheries No. 586.

King, W.B. (Ed.). 1974. Pelagic studies of seabirds in the central and eastern Pacific Ocean. Smithsonian Contributions to Zoology No. 158. Smithsonian Institution, Washington.

Kinney, P.J., D.K. Button and D.M. Schell. 1969. Kinetics of dissipation and biodegradation of crude oil in Alaska's Cook Inlet. Joint Conf. on Prevention and Control of Oil Spills, New York: 333-340.

Kitano, K. 1970. A note on the thermal structure of the eastern Bering Sea. J. Geophys. Res. 75: 1110-1115.

Komaki, Y. 1967. On the surface swarming of euphausiid crustaceans. Pacific Science 21: 433-448.

Krasnow, L.D., G.A. Sanger and D.W. Wiswar. 1979. Nearshore feeding ecology of marine birds in the Kodiak area, 1978. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the year ending March 1979. 2: 348-394.

Kuroda, N. 1955. Observations of pelagic birds of the Northwest Pacific. Condor 57: 290-300.

Kuroda, N. 1957. A brief note on the pelagic migration of the Tubinares. Mist. Rep. Yamashina Inst. Ornithol. Zool. 11: 436-449.

Kuroda, N. 1960. Analysis of sea bird distribution in the Northwest Pacific Ocean. Pacific Sci. 14: 55-67.

Kuroda, N. 1982. Survey of migration and mortality of the Short-tailed Shearwater along the Japanese coasts. Abstract of a paper presented at a seabird symposium organized by the International Council for Bird Preservation, Cambridge, England, August 1982.

Larrance, J.D., D.A. Tennant, A.J. Chester and P.A. Ruffio. 1977. Phytoplankton and primary productivity in the Northeast Gulf of Alaska and Lower Cook Inlet, Final Report. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators' for the Year ending March 1977. 10: 1-136.

Lee, R.F. 1975. Fate of petroleum hydrocarbons in marine zooplankton. Pp. 549-553 in Proceedings, 1975 Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington.

Lee, R.F. 1977. Food chain transfer of hydrocarbons. In Wolfe (1977).

Lee, R.F., R. Sauerheber and G.H. Dobbs. 1972. Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Marine Biology 17: 201-208.

Lensink, C.J. and J.C. Bartonek. 1976. Seasonal distribution and abundance of marine birds: Part I. Shipboard Surveys. Environmental Assessment of the Alaskan Continental Shelf, Principal Investigators' Reports for the Year ending March 1976, 3: 107-522.

Lensink, C.J., J.C. Bartonek and G.A. Sanger. 1976. Feeding ecology and trophic relationships of Alaskan marine birds. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1976. 4: 321-344.

Lensink, C.J., P.J. Gould, C.S. Harrison and D. Forsell. 1978. Distribution and abundance of marine birds - south and east Kodiak Island waters. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1978. 2: 614-710.

Malins, D.C. (Ed.). 1977. Effects of petroleum on arctic and subarctic marine environments and organisms. Vol. 2: Biological effects. Academic Press.

Malins, D.C. (Ed.) .1979. Assessment of available literature on effects of oil pollution on biota in arctic and subarctic waters. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators 5: 1-244.

Manikowski, S. 1971. The influence of meteorological factors on the behaviour of sea birds. Acts Zool. Cracoviensia 16(13): 581-667.

Martin, P.W. and M.T. Myres. 1969. Observations on the distribution and migration of some seabirds off the outer coasts of British Columbia and Washington State, 1946-1949. Syesis 2: 241-256.

McEwan, E.H. and P.M. Whitehead. 1978. Influence of weathered crude oil on liver enzyme metabolism of testosterone in gulls. Canadian Journal of Zoology 56: 1922-1924.

Miller, D.S., D.B. Peakall and W.B. Kinter. 1978. Ingestion of crude oil: sublethal effects in Herring Gull chicks. Science 199: 315-317.

Monaghan, P.H., J.H. Seelinger and R.A. Brown. 1973. The persistent hydrocarbon content of the sea along certain tanker routes - a preliminary report. American Petroleum Institute Report of the 18th Annual Tanker Conference, 1973.

Motoda, S. and T. Minoda. 1974. Plankton of the Bering Sea. Pp. 207-241 in Hood, D.W. and E.J. Kelley (Eds). Oceanography of the Bering Sea. University of Alaska, Fairbanks.

Muench, R.D. and J.D. Schumacher. 1981. Physical oceanographic and meteorological conditions in the Northwest Gulf of Alaska. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators 3: 75-230.

Murie, O.J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. U.S. Fish and Wildlife Service, North American Fauna No. 61.

Myres, M.T. and J.R. Guzman. 1976-1977. Ecology and behavior of southern hemisphere shearwaters (Genus Puffinus) and other seabirds, when over the Outer Continental Shelf of the Bering Sea and Gulf of Alaska during the northern summer. Environmental Assessment of the Alaskan Continental Shelf, Principal Investigator's Reports. For the year ending March

1976, 3: 1-51. For the year ending March 1977, 3: 179-191.

Nasu, K. 1974. Movement of baleen whales in relation to hydrographic conditions in the northern part of the North Pacific Ocean and the Bering Sea. Pp. 345-361 in Hood, D.W. and E.J. Kelley (Eds). Oceanography of the Bering Sea with emphasis on Renewable Resources. Institute of Marine Sciences, University of Alaska, Fairbanks.

Neff, J.M. and J.W. Anderson. 1981. Response of Marine Animals to Petroleum and Specific Petroleum Hydrocarbons. Applied Science Publishers.

Nemoto, T. 1959. Foods of baleen whales with reference to whale movements. Scientific Reports, Whales Research Institute No. 14.

Nemoto, T. 1962. (Distribution of five main euphausiids in the Bering Sea and the northern part of the North Pacific). J. Oceanogr. Soc. Japan (20th Anniv. vol.): 615-627 (in Japanese).

Nettleship, D.N. and C.E. Tull. 1970. Seabird transects between Valley Field and Funk Island, Newfoundland, summer 1969. Can. Field-Nat. 84:369-376.

Nunes, P. and Benville, P.E. 1978. Acute toxicity of the water-soluble fraction of Cook Inlet crude oil to the Manilla clam. Marine Pollution Bull. 9: 324-331.

Ocean Affairs Board. 1975. Petroleum in the Maritime Environment. National Academy of Sciences, Washington.

Ogi, H. 1981. Pacific feeding ecology of the Sooty Shearwater in the Northwestern Pacific Ocean. Pacific Seabird Group Bulletin 8(2): 89.

Ogi, H., T. Kubodera and K. Nakamura. 1980. The pelagic feeding ecology of the Short-tailed Shearwater _Puffinus tenuirostris_ in the subarctic Pacific region. Journal of the Yamashina Institute of Ornithology 12: 157-181.

Ohlendorf, H.M., R.W. Risebrough and K. Vermeer. 1978. Exposure of marine birds to environmental pollutants. U*S. Fish and Wildlife Service, Wildlife Research Report No. 9.

Palmer, R.S. 1962. Handbook of North American Birds. vol. 1. Loons through Flamingos. Yale University Press.

Payne, J.F. 1976. Field evaluation of benzopyrene hydroxylase induction as a monitor for marine petroleum pollution. Science 191: 945-946.

Peakall, D.B., D. Hallett, D.S. Miller, R.G. Butler and W.B. Kinter. 1980. Effects of ingested crude oil on Black Guillemots: a combined field and laboratory study. Ambio 9: 28-30.

Peaker, M. 1971. Salt balance of oiled sea-birds. Ibis 113: 536.

PhilLips, J.T-I. 1963. The pelagic distribution of the Sooty Shearwater, Procellaria grisea. Ibis 105: 340-353.

Pilpel, N. 1968. The natural fate of oil on the sea. Endeavour 27: 11-13.

Ponomareva, L.A. 1963. Euphausiids of the North Pacific, their distribution and ecology. Israel Program for Scientific Translations, 1966.

Reed, R.K. 1968. Transport of the Alaska Stream. Nature 220: 681-682.

Reed, R.K. 1971. Nontidal flow in the Aleutian island passes. Deep-Sea Research 18: 379-380.

Richdale, L.E. 1963. Biology of the Sooty Shearwater Puffinus griseus. Proc. Zool. Sot. London 31: 1-117.

Roden, G.I. 1967. On river discharge into the Northeastern Pacific Ocean and the Bering Sea. Journal of Geophysical Research 72: 5613-5629.

Royer, T.C. 1975. Seasonal variations of waters in the northern Gulf of Alaska. Deep Sea Res. 22: 403-416.

Royer, T.C. 1978. Ocean eddies generated by seamounts in the North Pacific. Science 199:1063-1064.

Royer, T.C. 1979. On the effect of precipitation and runoff on coastal. circulation in the Gulf of Alaska. Journal of Physical Oceanography 9: 555-563.

Sancetta, C. 1981. Diatoms as hydrographic tracers: example from the Bering Sea sediments. Science 211:279-281.

Sanger, G.A. 1970. The seasonal distribution of some seabirds off Washington and Oregon, with notes on their ecology and behavior. Condor 72: 339-357.

Sanger, G.A. 1972. Preliminary standing stock and biomass estimates of seabirds in the subarctic Pacific region. Pp. 589-611 in Takenouti, A.Y. et al. (Eds). Biological Oceanography of the Northern North Pacific Ocean. Tokyo: Idemitsu Shoten.

Sanger, G.A. and P.A. Baird. 1977. The trophic relationships of marine birds in the Gulf of Alaska and the southern Bering Sea. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1977. 4: 694-757.

Sanger, G.A., V.F. Hironaka and A.K. Fukuyama. 1978. The feeding ecology and trophic relationships of key species of marine birds in the Kodiak Island area. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1978. 3: 773-848.

Saville, D.B.O. 1957. Adaptive evolution in the avian wing. Evolution 11: 212-224.

Scaly, S.G. 1973. Interspecific feeding assemblages of marine birds off British Columbia. Auk 90: 796-802.

Serventy, D.L. 1956a. A method of sexing petrels in field observations. Emu 56: 213-214.

Serventy, D.L. 1956b. Age at first breeding of the Short-tailed Shearwater Puffinus tenuirostris. Ibis 98: 532-533.

Serventy, D.L., V. Serventy and J. Warham. 1971. The Handbook of Australian Sea-Birds. A. H. & A. W. Reed, Sydney.

Shuntov, V.P. 1961. Migration and distribution of marine birds in Southern Bering Sea during spring-summer season. Zoologicheskii Zhurnal 40(7): 1058-1069 (in Russian).

Shuntov, V.P. 1964. Transequatorial migrations of the Storm Petrel (sic) Puffinus tenuirostris (Temm.). Zoologicheskii Zhurnal 43(4): 590-598 (in Russian).

Shuntov, V.P. 1974. Sea Birds and the Biological Structure of the Ocean. U.S. Dept. of Commerce, National Technical Information Service. TT 74-55032.

Slater, P.J.B. 1976. Tidal rhythm in a seabird. Nature 264: 636-638.

Smith, D.C. 1975. Rehabilitating oiled aquatic birds. Pp.241-247 in proceedings 1975 Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington.

Sobey, E.J.C. 1980a. Physical Oceanography. Chapt. 3. in Environmental Assessment of the Alaskan Continental Shelf. Kodiak Interim Synthesis Report. Science Applications, Inc., Boulder.

Sobey, E.J.C. 1980b. Circulation. Chapt. 3. in Environmental Assessment of the Alaskan Continental Shelf. Northeast Gulf of Alaska Interim Synthesis Report. Science Applications, Inc., Boulder.

Sowl, L.W. and J.C. Bartonek. 1974. Seabirds - Alaska's most neglected resource. Transactions of the Thirty-ninth North American Wildlife and Natural Resources Conference: 117-126.

Stallcup, R.W. 1976. Pelagic birds of Monterey Bay, California. Western Birds 7: 113-136.

Stegeman, J.J. 1977. Fate and effects of oil in marine animals. Oceanus 20(4): 59-66.

Storer, J.H. 1948. The Flight of Birds. Cranbrook Inst. Sci. Bull. No. 28.

Straty, R.R. and R.E. Haight. 1979. Interactions among marine birds and commercial fish in the Eastern Bering Sea. U.S. Fish and Wildlife Service, Wildlife Research Report 11: 201-219.

Strauch, J.G. 1980. Birds. Chapt. 9. in Environmental Assessment of the Alaskan Continental Shelf. Northeast Gulf of Alaska Interim Synthesis Report. Science Applications, Inc., Boulder.

Strauch, J.G., G.R. Tamm, W.H. Lippincott, B.R. Mate and K.W. Fucik. 1980. Biology. Chapt. 5. in Environmental Assessment of the Continental Shelf. Kodiak Interim Synthesis Report. Science Applications, Inc., Boulder.

Sverdrup, H.U., M.W. Johnson and R.H. Fleming. 1942. The Oceans: their Physics, Chemistry, and General Biology. Prentice-Hall, Inc. New Jersey.

Swartz, L.G. 1967. Distribution and movements of birds in the Bering and Chukchi Seas. Pacific Science 21: 332-347.

Synder, S. B., J.G. Fox and O.A. Soave. 1971. Mortalities in waterfowl following Bunker C fuel exposure: an examination of the pathological, microbiological and oil hydrocarbon residue findings in birds that died after the San Francisco Bay oil spill, January 18, 1971. Division of Laboratory Animal Medicine, Stanford Medical Center, Stanford, California.

Tanaka, Y. and T. Kajihara. 1979. The distribution of Fulmarus glacialis and Puffinus tenuirostris in the North Pacific and the Okhotsk Sea during the summer. J. Yamashina Inst. Ornithol. 11: 79-86.

Tanis, J.J.C. and M.F. Morzer Bruyns. 1969. The impact of oil-pollution on sea birds in Europe. Proc. Internat. Conf. Oil Pollution of the Sea, Rome, 1968: 67-74.

Thompson, A.R. 1978. West Coast Oil Ports Inquiry - Statement of Proceedings. Vancouver, B.C.

Tully, J.P. 1964. Oceanographic regions and processes in the seasonal zone of the North Pacific Ocean. Pp.68-84 in K. Yoshida (cd.). Studies on Oceanography. University of Washington Press.

Uda, M. 1954. Studies of the relation between the whaling grounds and the hydrological conditions. Scientific Reports, Whales Research Institute No.9.

Uda, M. 1963. Oceanography of the Subarctic Pacific Ocean. J. Fish. Res. Bd. Canada 20:119-179.

United States Department of the Interior. 1970. Summary report, Kodiak oil pollution incident, February - March 1970. (28 pp. mimeo) (cited in Transactions of the Thirty-sixth North American Wildlife and Natural Resources Conference, pages 243 and 251).

Vermeer, K.and G.G. Anweiler. 1975. Oil threat to aquatic birds along the Yukon coast. Wilson Bulletin 87: 467-480.

Vermeer, K. and R. Vermeer. 1975. Oil threat to birds on the Canadian west coast. Canadian Field-Naturalist 89: 278-298.

Vermeer, R. and K. Vermeer. 1974. Oil Pollution of Birds: an abstracted bibliography. Canadian Wildlife Service, Pesticide Section Manuscript Reports No. 29.

Wahl, T.R. 1975. Seabirds in Washington's offshore zone. Western Birds 6: 117-134.

Wahl, T.R. 1978. Seabirds in the northwestern Pacific Ocean and south central Bering Sea in June 1975. Western Birds 9: 45-65.

Warham, J. 1977. Wing loadings, wing shapes, and flight capabilities of Procellariiformes. New Zealand Journal of Zoology 4: 73-83.

Watson, G.E. 1971. Moulting Greater Shearwaters (Puffinus gravis) off Tierra del Fuego. Auk 88: 440-442.

Webster, R.G., and W. G. Laver. 1975. Antigenic variations of influenza viruses. Pp.209-314 in E.D. Kilbourne (cd.). The Influenza Viruses and Influenza. Academic Press.

Webster, R. G., M. Morita, C. Prigen and B. Tumova. 1976. Ortho- and paramyxoviruses from migrating feral ducks: characterization of a new group of influenza viruses. Journal of General Virology 32: 217-225.

Webster, R. G., M. Yakhno, V.S. Hinshaw, W. J. Bean and K. G. Murti. 1977. Intestinal influenza: replication and characterization of influenza viruses in ducks. Virology 84: 268-271.

Wellman, A.M. 1973. Oil floating in the North Atlantic. Marine Pollution Bull. 4: 190-191.

Whipple, J.A., T.G. Yocom, D.R.Smart, M.H. Cohen, P.E. Benville and M.E. Ture. 1979. Transport, retention, and effects of the water-soluble fraction of Cook Inlet crude oil in experimental food chains. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators 1: 535-581.

Wiens, J.A., D. Heinemann and W. Hoffman. 1978. Community structure, distribution, and interrelationships of marine birds in the Gulf of Alaska. Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators 3: 1-178.

Wiens, J.A., G. Ford, D. Heinemann and C. Pietruszka. 1980. Simulation modeling of marine bird population energetics, food consumption, and sensitivity to perturbation. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1980. 1: 1-93. .

Wolfe, D.A. (Ed.). 1977. Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon.

Wolfe, D.A. (Ed.). 1978. Marine Biological Effects of OCS Petroleum Development. NOAA Technical Memorandum ERL OCSEAP-1. Boulder.

Wong, C.S., D.R. Green and **W.J. Cretney.** 1974. Quantitative tar and plastic waste distributions in the Pacific Ocean. Nature 247: 30-32.

Wong, C.S.,D.R. Green and **W.J.** Cretney. 1976a. Distribution and source of tar on the Pacific Ocean. Marine Pollution Bulletin 7(6): 102-106.

Wong, C.S., **W.J. Cretney, R.W.** MacDonald and P. Christensen. **1976b.** Hydrocarbon levels in the marine environment of the Southern Beaufort Sea. Beaufort Sea Technical Report No.38. Beaufort Sea Project, Victoria, B.C.

Zenkevitch, L.V. 1963. Biology of the Seas of the U.S.S.R. Wiley Interscience Publishers, New York.

ZoBell, C.E. 1964. The occurrence, effects and fate of oil polluting the sea. Proc. Internat. **Conf.** Water Pollution Research, London, 1962: 35-118.