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An Application of Automatic Data Processing To the Study of Seabirds, I

Numerical Coding [1]

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Seabird distribution, abundance, and movements in the open ocean are difficult to analyze because the limited data available have been collected by various methods, the observers have varied in reliability, and the information is scattered widely. Furthermore, publication of individual sightings, except those of rare vagrants, has been at best spotty with the result that abundance information is difficult to derive from the data. Records of at-sea bird observations are maintained in several institutions in different countries, but most of these are sortable only by hand, an exercise that is extremely time-consuming and invites clerical errors when the data are considerable. As a result, few analyses have been published that involve complicated correlations of extensive distributional and environmental data, and even fewer seabird distribution maps show detailed documentation of seasonal occurrence and abundance.

[1] Contribution no. 22 from the Pacific Ocean Biological Survey Program. A preliminary version of this paper was presented at the 14th International Ornithological Congress, Oxford, England, July 25, 1966.

[2] King and Gould: Department of Vertebrate Zoology; Watson: Division of Birds.

Smithsonian Institution scientists recorded data on seabirds observed during 15 cruises aboard the Bureau of Commercial Fisheries research vessel *Townsend Cromwell* while the ship was engaged in oceanographic research as a preliminary part of the Trade Wind Zone Oceanography Program. These data have been utilized in a pilot study to determine the feasibility of recording, storing, and analyzing seabird records in a computerized automatic data processing system. The system described herein is in part descended from a simpler one developed by the Bureau to store and analyze its own bird observations. Coding used in the various fields of data in this pilot project is presented in this paper and details of the codes are given in the tables. Computer programming for the system is discussed by Creighton (in prep.). A full report on the results of the analysis of bird observation data from these cruises will be published by King, but the preliminary results suggest that ADP may be applicable to a cooperative international system of seabird observation, data storage, and analysis.

The Bureau of Commercial Fisheries, Hawaiian Island area, has been a vital partner in the development of this pilot study. John C. Marr, area director and Gunter Seckel, coordinator of the Trade Wind Zone Oceanography Program, and their staff have made it possible for Smithsonian scientists to observe seabirds aboard the *Townsend Cromwell* and have given us access to BCF oceanographic data, punch cards, and computer programs. Reginald Creighton's close cooperation as programming analyst has turned the projected aims of this system into a working reality. The original impetus to undertake the computer analysis of the seabird observation data came from Philip S. Humphrey, Principal Investigator, Pacific Ocean Biological Survey Program. Nicholas J. Suszynski, Jr., Director of the Information Systems Division at the Smithsonian, provided valuable advice. Mrs. Anne Keenan Poulson patiently prepared the figures for this publication. We are deeply grateful to all of them.

Observations.—From March 1964 to July 1965 the Smithsonian Institution conducted an at-sea study to determine the distribution, movements, and abundance of seabirds in a 500,000-square-mile area of the central Pacific Ocean south and east of the main Hawaiian Islands between 148° and 158° west longitude and 10° and 26°30′ north latitude (fig. 1). Each of the 15 replicate cruises covered a fixed track of 4460 miles and lasted approximately 20 days. There was no cruise in August 1964.

Two experienced observers alternated 2-hour watches each day from sunrise to sunset. They identified birds at sea as accurately and specifically as possible and recorded all data on standardized reporting forms. Some identifications were confirmed through collection of specimens. The time of observation was recorded to the nearest minute. Whenever possible, an actual count was made but large flocks were only estimated within accuracy limits. The direction of movement, if any, was recorded. Notes were made on behavior, plumage, molt, age, sex, and any other data that appeared significant. Descriptions were recorded in cases of uncertain identification. Standard marine meteorological observations were taken every six hours. Bureau of Commercial Fisheries personnel took bathythermographs and recorded weather conditions every one-half degree, hydrographic stations every one and one-half degrees, and surface plankton tows every evening. Ship's position was reckoned hourly and early morn-

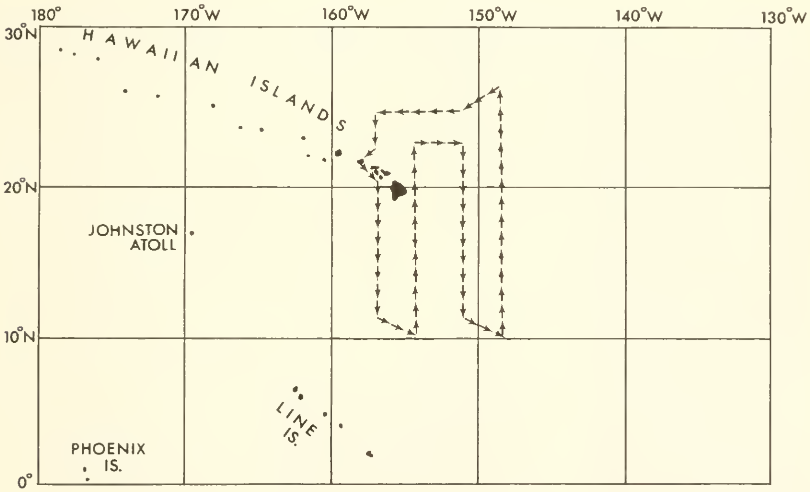

FIGURE 1.—Replicate track in central Pacific Ocean followed during 15 monthly cruises of the *Townsend Cromwell.*

ing; midday and evening celestial or LORAN fixes were taken, conditions permitting.

During the 15 months of the study, 13,080 sightings of 65,707 birds were made in 3561.1 hours of observation covering 34,384 linear miles.

Coding

The quantity and complexity of data accumulated necessitated use of an automatic data processing system for rapid and accurate sorting, compilation of tables, and the plotting of distribution and density charts. In addition, ADP made possible a sophisticated analysis of the effects of many enviromental factors, both oceanographic and meteorologic, upon the distribution and movements of seabirds in the area. And finally, ADP permitted more rapid statistical handling of the data in order to ascertain (1) whether apparent monthly population and distribution changes were real or were merely due to inadequate sampling, and (2) whether or not apparent correlations between environmental factors and bird distribution were statistically significant.

The large number of different parameters to be analyzed required the use of three decks of 80-column punch cards to retain a maximum amount of data in the system. The three decks were called "sighting deck," code number 99, "environment deck," 03, and "day deck," 98 (fig. 2). Of the three decks, the sighting deck was the largest, con-

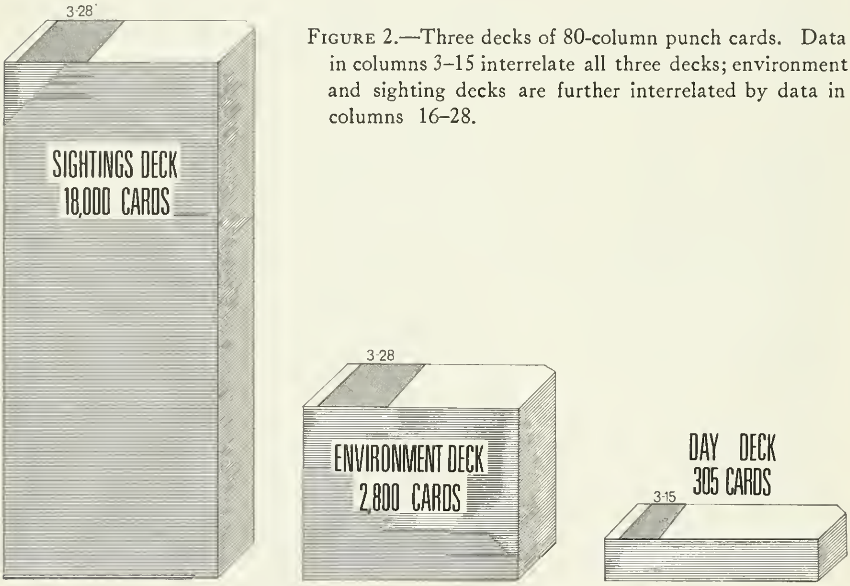

Figure 2.—Three decks of 80-column punch cards. Data in columns 3–15 interrelate all three decks; environment and sighting decks are further interrelated by data in columns 16–28.

taining 18,000 cards for the 13,080 sightings. The environment deck was smaller, containing 2800 cards. Each environment card was associated with all the sightings from the time of one set of environmental data observations to the time of the succeeding set of observations. Similarly, each of the 305 day cards was associated with all sightings and all environment cards on that day. Thus, each observation had a sighting card or cards, an environment card, and a day card. But it shared the environment and day cards with other sightings.

The three decks of cards were tied together by common data consisting of ship's name, cruise number, and date. The environment and sighting cards were further linked by hour and position.

The 80-column punch card system works on a numerical code into which all verbal data recorded by the observer at sea must be translated before entry. The *Cromwell* observations, oceanography, weather, and ship's position were checked for accuracy by a single editor and entered as numbers on intermediate coded sheets of different key colors. Data were punched on the cards directly from the intermediate coded sheets.

Sighting deck.—The sighting card includes all data that pertain to each individual sighting. We define a sighting as the observation of a bird or group of birds acting as a unit. Data for the following fields were entered in the indicated columns on the green intermediate sheets (fig. 3) for the sighting cards (card code 99 in columns 1–2):

Ship name 3–5
Cruise number 6–9
Date 10–15
Local time 16–19
Position 20–28
Species identification 29–34
Association code 35
Species identification reliability 36
Number 37–41
Number reliability 42
Direction of bird movement 43
Behavior 44
Color marking 45
Method of marking 46
Age 47
Sex 48
Color-plumage phase 49
Molt 50
Whether or not a specimen was collected 51
Food association 52
Special weather conditions 53
Special information 54
Duration of sighting (minutes) 55–57
Ship's speed (knots) 58–59
Ship's direction 60–61
Distance to nearest land (nautical miles) 62–65
Distance to nearest breeding area (nautical miles) 66–69
[Columns 70–80 were not utilized on the sighting cards for this program.]

Each ship used for observations was assigned a code number; the *Cromwell* was 006. Cruises were coded serially for each ship. The date was expressed as month, day, and year with only the final two digits being coded for year. Local and all other absolute times were expressed to the nearest minute in the 24-hour system.

Position of the sighting and all other localities were expressed as coordinates of longitude and latitude. In order to economize on columns, the world was divided into octants along the equator and each 90° meridian. The octants (column 20) were numbered from 0–3 in the Northern Hemisphere and from 5–8 in the Southern Hemisphere beginning at 0°–89°59′W and proceeding west. In this way it was not necessary to express the 100's figure and east and west for longitude nor north and south for latitude.

The numerical code for seabird species is based on a revised checklist of the seabirds of the world. It is designed to permit data retrieval hierarchically by class, order, family, genus, species, and/or subspecies. The code requires only six digits because of the relatively

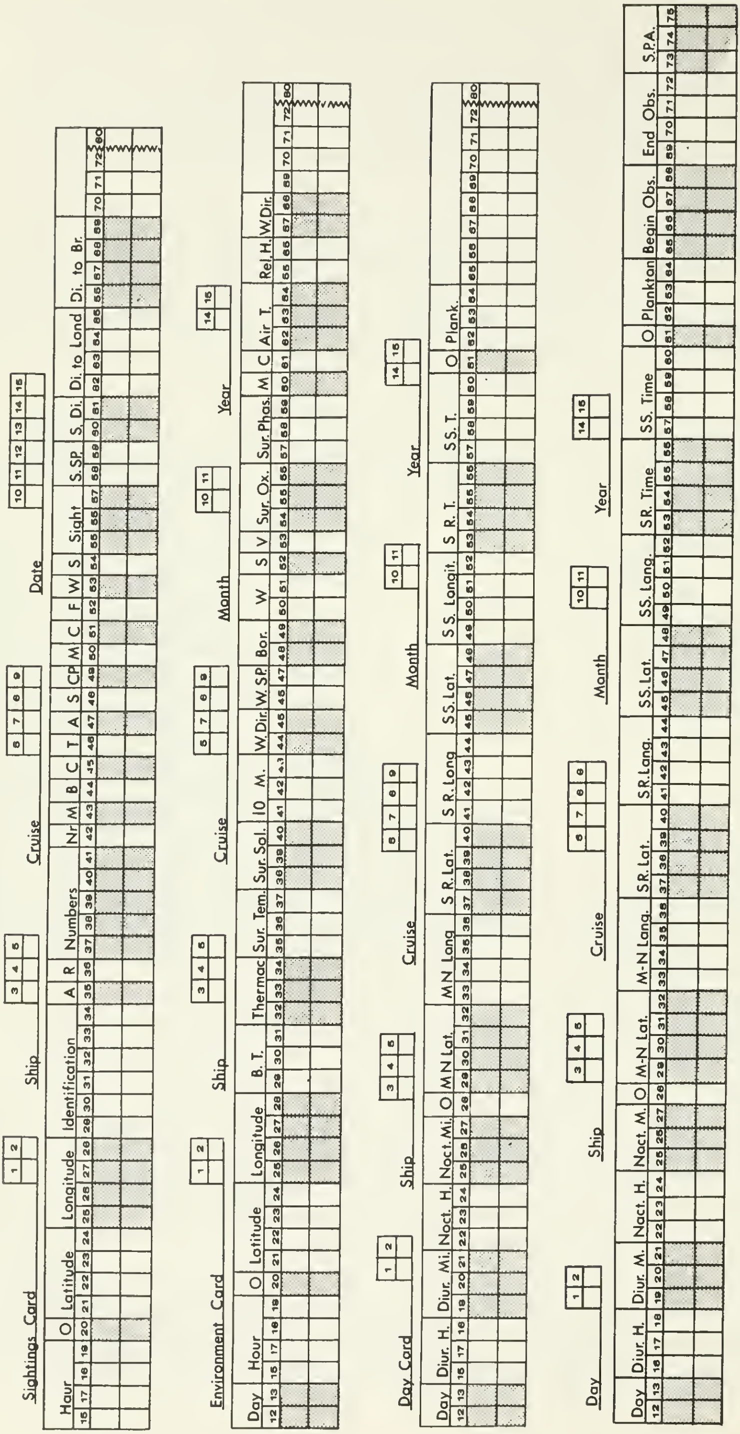

FIGURE 3.—The three intermediate coded sheets used in pilot project and revised format of the intermediate coded sheet for day deck.

low number of forms involved, yet it includes all known taxa of seabirds and has sufficient leeway for most synonymy and the inclusion of land-based accidentals, migrants, and marine mammals and reptiles. The first digit represents class; the second, order; the third, family; the fourth, genus; and the fifth and sixth, species or field-recognizable, nonoverlapping subspecies. The code for central Pacific Ocean birds used in this pilot program is given in table 1. Codes for seabirds (presently being revised) and marine mammals of the world are available from the Smithsonian Institution. Birds that are identifiable only to class, order, family, genus, and/or species may be entered and retrieved at the same level of reliable identification.

When the code translation of a single sighting involves more than one item of information in any category, additional sighting cards are needed for complete and unique expression. Thus, a complex sighting involving four species of birds of three color phases and of three age categories requires 10 cards. These 10 cards are tied together by their identical times and by a special code key known as the association key. A "0" in the association column (35) indicates a simple sighting expressible by one card. A "1" in the column indicates that the card has information pertaining to the same sighting as all other cards with the same time and a "1" in the association column. A sighting of a mixed flock of sooty terns and brown noddies feeding together would be represented by two cards each bearing a "1" association code number. When two or more cards of a sighting have identical data in the ship, cruise, date, time, position, species, and number fields but differ in other fields such as age or behavior, then the numbers 2, 3, 4, or 5 are used in the association column to preserve uniqueness. This is necessary because the computer automatically rejects, as duplicates, cards with identical data in columns 1–42. If a sighting involves two sooty terns, one adult and one immature, the first card bears the association number 1 and the second, number 2. A sighting of three sooty terns, one feeding, one sitting on the water, and a third searching, would have three cards with association code numbers 1, 2, and 3 respectively. If, on the other hand, two or more different sightings have identical data in the ship, cruise, date, time, position, species, and number fields but the birds were not associated in the same flock, we employ the numbers 6, 7, 8, 9, or 0 in the code to indicate uniqueness but nonassociation.

Note that "0" in the association code has a double function. It may be used merely to denote a simple, one-card sighting or one of five concurrent nonassociated sightings. When more than five nonassociated sightings occurred simultaneously, it was necessary to adjust the time of the supernumerary sightings by one minute to preserve uniqueness.

Codes for species identification and number reliability, direction of bird movement, behavior, marking, and other sighting fields are given in table 2. Reliability was determined and recorded by the observer in his at-sea notes. Some of the at-sea logs recorded doubtful identifications of dark shearwaters as "sooty-slender-bill" with a notation that the underwings appeared light. Such sightings were coded as "sooty shearwaters," 122519, in the species identification field (29–34), as "either this or the next most similar form," 2, in the species reliability field (36) and as [consult] "identification" [data in at-sea log], 1, in the special information field (54). The next similar species to the sooty shearwater in the central Pacific is the slender-billed shearwater, but in the southern Atlantic Ocean it might be the great-winged petrel, *Pterodroma macroptera*.

Special means of marking birds to show points of origin or other status were employed in studies of seabirds in the central Pacific Ocean. Birds marked by "painting" with body dye or by attaching leg bands and colored plastic streamers were expressed in code in the system. Colors were used for identification of birds at a distance when they could not be captured. In seabirds, color or plumage phases may indicate geographic origin or reproductive condition. Light and dark color phases in petrels, boobies, and jaegers may vary in relative proportions in different geographic populations. A pinkish or yellowish tinge in white tropicbird, gull, or tern plumage may indicate reproductive activity.

The special weather conditions field was used to refer to squalls, storms, or calms that were so local they could not be expressed in the environment deck. The special information column was used as a warning signal to alert the scientist to consult the raw data for a particular field in the observer's at-sea log. A routine sighting as a bird crossed the ship's bow was considered arbitrarily to have a duration of one minute. Birds following in the wake were counted periodically, and an attempt was made to determine duration of their association with the ship. Direction of ship movement and wind and wave directions on the environment card were recorded as the first two digits of the compass heading rounded off to the nearest 10 degrees (e.g., 165°=17, 24°=02). A stationary ship or calm air or sea was coded 00.

Part of a page of an at-sea observation log and its numerically coded translation onto the intermediate coded sighting sheet is shown ready for punching into cards in figure 4.

Environment deck.—The format of the environment card was slightly modified from cards already in use by the Bureau of Commercial Fisheries in the Hawaii area. Complete environmental data of this sort are recorded on standard forms and punched into cards on file at the BCF in Honolulu. The utilization of this existing card format in our system saved duplication of effort and man hours of work by permitting standardization of data collection and storage. The codes used by the BCF and by us in this program are based on number codes developed by the Hydrographic Office in Publication 607, "Instruction Manual for Oceanographic Observations," 1955, reprinted 1959, for use by deck officers of vessels. On the environmental punch card deck (code 03 in columns 1–2), the fields for ship's

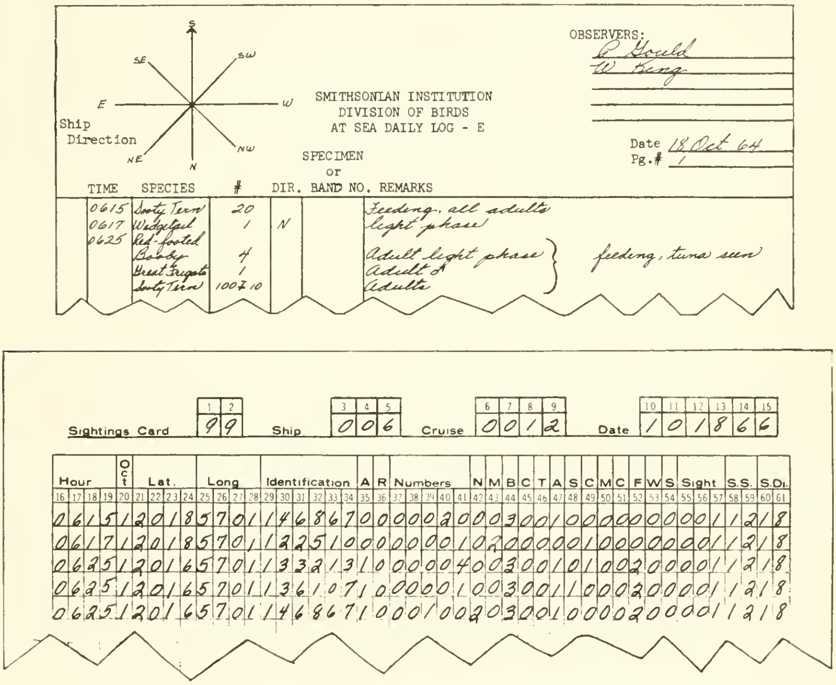

FIGURE 4.—Bird observation data in at-sea log (above) and part of the numerical translation onto the intermediate coded sheet for sighting deck.

name 3–5, cruise number 6–9, date 10–15, time 16–19, and position 20–28 provide linkage with a particular group of sighting cards. The following additional fields of data are found on the environment card and are coded on red intermediate sheets (fig. 3) in a manner analogous to that used for the sighting deck.

Bathythermograph file number for reference 29–31

Thermocline depth 32–34

Surface water temperature 35–37

Surface salinity 38–40

Water temperature at 10 meters 41–43

Wind direction 44–45
Wind speed 46–47
Barometer 48–49
Weather conditions 50–51
State of sea 52
Visibility 53
Surface oxygen 54–56
Surface phosphate 57–59
Moon age 60
Cloud cover 61
Air temperature 62–64
Relative humidity 65–66
Wave direction 67–68
[Columns 69–80 were not utilized on the environment cards.]

Thermocline depth was recorded in meters. Water temperatures at the surface and at 10 meters and air temperature were given to the nearest .1° C. Surface salinity was recorded in parts per thousand, omitting the initial 3 for any value. Wind and wave direction were coded in the same manner as direction of ship's movement, column 43 on the sighting card. The code for weather conditions is given in table 3 and those for state of sea, visibility, and cloud cover, in table 4. Wind speed was recorded in knots. Barometric pressure was recorded as the last two digits of a millibar reading, e.g., 1015 millibars was coded as 15. Surface oxygen was recorded in milliliters per liter to the nearest .01 and surface phosphate in microgram atoms per liter to the nearest .01. Relative humidity was expressed in whole percent. Moon age was not recorded for this study but a BCF code is given in table 4.

Day deck.—The day card includes information pertaining to all sighting and environment cards for one day and is concerned mainly with positions, distances, and times. From this card, in combination with the sighting cards from the entire day, the computer calculates daily density figures in terms of birds per hour and birds per linear mile. Through the use of such density figures, we can make direct comparison between bird density in different areas of the ocean and from day to day, month to month, and even year to year within the same area. It is important to be able to express density as a factor both of time and distance because the two are not correlated necessarily on a cruise with periodic stops such as the BCF *Cromwell* cruises. The day cards, code 98 in columns 1–2, are linked to the other two decks through information on the ship's name 3–5, cruise number 6–9, and date 10–15. In addition, the day card contains the following information coded on the blue intermediate sheets (fig. 3):

Diurnal hours of observation 16–18
Diurnal miles of observation 19–21
Nocturnal hours of observation 22–24
Nocturnal miles of observation 25–27
Position at midday 28–36
Position at sunrise 37–44
Position at sunset 45–52
Local time of sunrise 53–56
Local time of sunset 57–60
Number of observers on each watch 61
Quantitative plankton analysis 62–64
[Columns 65–80 were not utilized on the day cards.]

Hours and miles of observations were recorded to the nearest .1 hour and whole mile respectively. The ship's location at noon was recorded as midday position for a full day of observations but the midpoint of the diurnal track was recorded for a partial day of observation. Surface plankton was collected in a 25-minute tow with a 1 meter .308 millimeter terminal mesh net. Volume was measured by BCF personnel and recorded in cubic centimeters per cubic meter of water strained.

Computer Analysis

The coded information was transferred from the cards onto magnetic tape in the computer with the result that all data pertinent to each sighting were stored and printed out as a unit. Thus, environmental data and the raw materials for calculating densities were included with the print-out for any individual sighting.

The system has been programmed in COBOL [Common Oriented Business Language] for a General Electric 425 digital computer having 128,000 characters of core storage.

The data flow sheet for the system thus includes the sighting that is recorded in the observer's field notes, edited and coded on the intermediate sheets, punched into the cards, and transferred onto tape in the computer where it is available for print-out, plot-out, and analysis (fig. 5).

With this information fed into the system, various questions may be asked of the data. The simplest questions are descriptive: what species occur in what numbers, where, and when? We can ask for a detailed print-out of all the data for all sightings arranged by species, by locality, or by time. Part of such a code print-out of red-footed booby observations is shown in figure 6.

Relatively simple correlations of species distribution with environmental conditions may be requested as tallies to provide raw materials for graphs or statistical analysis. Tallies of black-footed albatross and sooty tern sightings at various surface water temperatures yield data for plotting bar graphs (fig. 7). The two species differ somewhat in water temperature preference.

More detailed compound questions involving several conditional clauses will give more restricted print-outs; thus, by asking for all records of sooty terns in aggregations greater than 25 seen feeding within the first two hours after sunrise during May in association with water 25°–27° C and having a salinity greater than 34.5 parts per thousand we obtain a much more selective listing. Indeed, only one sighting qualified (fig. 8). The instructions are in COBOL code language, which the computer understands. Asking this question of our 13,080 sightings took 20 minutes of computer time. Twenty-five questions of this complexity may be asked at the same time.

The most graphic application of automatic data processing to the observation data is for plotting distribution maps. Seasonal movements and changes in abundance may be depicted directly by machine print-outs in the form of annotated cruise tracks. Such machine printed distribution maps of the two color phases of wedge-tailed shearwaters from May to July are shown in figure 9. Light phase birds breed in the Hawaiian Islands to the north; dark phase birds, below

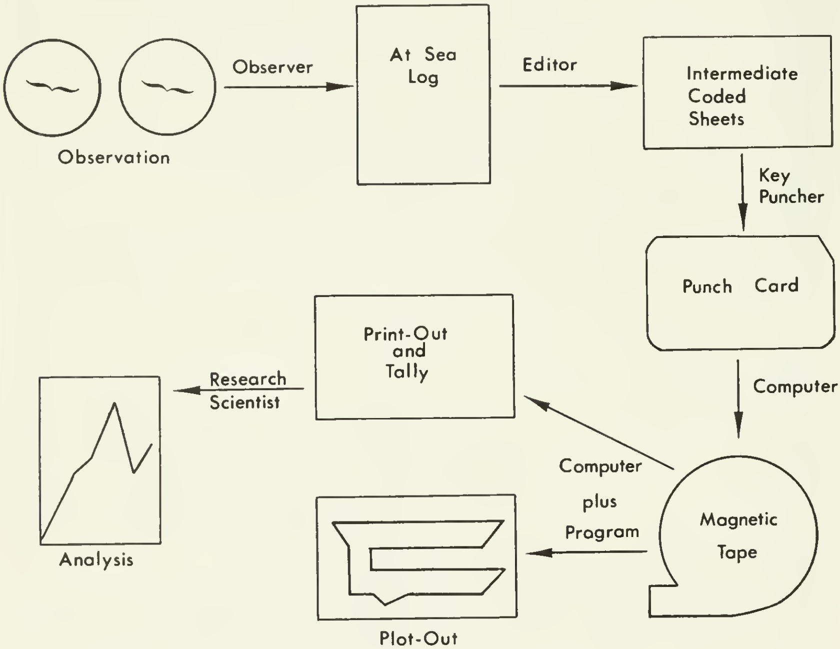

FIGURE 5.—Data flow chart for seabird ADP system.

the equator to the south. Density distribution maps of this sort may be requested to show actual numbers of birds observed as in figure 9 or rates of occurrence in birds per mile or per hour.

Worldwide Application

Because this ADP system was intended primarily to handle data obtained on this one set of cruises in the central Pacific Ocean, some modifications will be necessary in order to analyze data from elsewhere in the Pacific or in other oceans of the world. Some of these modifications already have been incorporated into the Smithsonian program;

others are suggested only for possible incorporation into a larger scale international program.

On the sighting cards (p. 5), the fields "distance to nearest land" (columns 62–65) and "distance to nearest breeding colony" (66–69) will be deleted. These distances have proved laborious to calculate but will be provided automatically by the computer when the necessary program has been written. It may be possible to incorporate a fourth deck of cards into the system that will give the phenology of

DATE	TIME	OCTANT	LATITUDE	LONGITUDE	SPECIES	A.R.	NUMBER	N-RELIAB.	S-R LATITUDE	S-R LONGITUDE	S-R TIME	HRS. AFTER S-R	HRS. BEFORE S-R	DI. TO LAND
640316	1625	1	2101	5742	133213	10	0000001	0	2117	5757	0640	10	00	0050
14	12 1	1	2100	5740			0000001	7	2044	5723	1836	00	03	0050
640316	1625	1	2101	5742	133213	20	0000001	0	2117	5757	0640	10	00	0050
14	12 1	1	2100	5740			0000001	7	2044	5723	1838	00	03	0050
640316	1629	1	2101	5742	133213	00	0000001	0	2117	5757	0640	10	00	0050
14	12 1	1	2100	5740			0000001	7	2044	5723	1838	00	03	0050

DIR SHIP, SHIP SPEED, NO. OBS, OCTANT, M-N LATITUDE, M-N LONGITUDE, NO. OF SIGHT., COMPLETENESS, SS. LATITUDE, SS. LONGITUDE, SS. TIME, HRS. AFTER SS, HRS. BEFORE SS, DI. TO BREED.

DIUR. HOURS	DIUR. MILES	BT SLIDE	SUR. TEMP.	SUR. OX.	WIND	BAR.	LEN. SIGHT	REL. HUM.	SEA	VIS.	MOON	CLOUD	DIR MOVE	BEHAVIOR	COLOR M.	SAND		CRUISE	LINE NO.
041	050	001	245	000	0903	18	001	66	2	9	1	2	3	0	0	0		0002	1
000	039	031	512	000	241	02	242	00	0	0	0	0	0	0	0	1	000	006	2
041	050	001	245	.000	0903	18	001	66	2	9	1	2	3	0	0	0		0002	1
000	039	031	512	000	241	02	242	00	0	0	0	0	0	0	0	3	000	006	2
041	050	001	245	000	0903	18	001	66	2	9	1	2	3	0	0	0		0002	1
000	039	031	512	000	241	02	242	00	0	0	0	0	0	0	0	0	000	006	2

NOCT. HRS., NOCT. MILES, THERMOCLINE, SALINITY, PHOSPHATE, 10 M., WEATHER, AIR TEMP., WAVE DIR., COLLECTED, FOOD ASSOC., WEATHER, SPECIAL, MOLT, C. PHASE, SEX, AGE, PLANKTON, SHIP NO., LINE NO.

FIGURE 6.—Part of a data print-out of records of red-footed boobies seen on *Cromwell* cruises.

breeding in individual colonies of seabirds in order that distribution may be compared directly with breeding schedule.

On the environment card, "relative humidity" (65–66) will be replaced by "dew point" or "depression of wet bulb air temperature under dry bulb." At sea, either of the latter two readings would give a more meaningful indication of the moisture content of the air than relative humidity.

Clarity of water may be an important factor in the feeding of seabirds that search for food visually from the air. Depth of visibility of a Secchi disc provides a good absolute measure for water clarity and one that is taken easily as a routine oceanographic measurement. At the same time, apparent water color may be recorded in the Forel scale. The BCF records and files both measurements on their punch cards. Photometric depth is another measure of water clarity made on oceanographic cruises, but it demands much more complicated instrumentation and the figures vary with intensity of illumination. It may be useful to record the presence of flotsam, large masses of weed, ice, or other floating debris. Some observations suggest that marine life and birds may be attracted locally to foreign matter in the water.

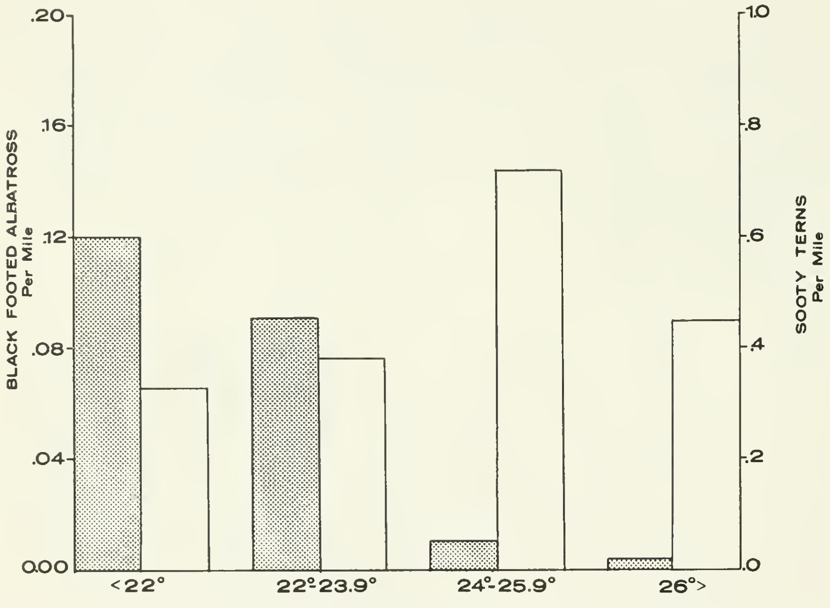

Figure 7.—Bar graphs of abundance of black-footed albatross (shaded) and sooty terns (white) in birds per mile seen at various surface water temperatures on *Cromwell* cruises.

On the day sheets several changes should be made. All observations for the pilot program were made in a single octant of the world, but other sets of observations may be made in several octants or a cruise track may cross the equator or a 90° meridian and thus require two octant codes for the same day. For this reason octant columns (37 and 46) should be added to sunrise position and sunset position fields. As a result, the fields for sunrise and sunset time and number of observers would be moved two columns to the right. It has not been feasible to make these octant additions in the Smithsonian program.

Three additional fields have already been added to the day sheets: time of beginning of observations (65–68), time of end of observations (69–72), and special parametric analysis (73–75). The times of beginning and end of observations coincided with the times of sunset and sunrise on the *Cromwell* cruises, but in other studies observations may begin or end earlier or later.

In the pilot study, density figures were computed on the basis of a full day's observations. In future studies, however, it may be necessary to determine abundance in areas that were covered in less

PROVIDE ALL RECORDS OF SOOTY TERNS IN AGGREGATIONS GREATER THAN 25 SEEN FEEDING WITHIN THE FIRST TWO HOURS AFTER SUNRISE DURING MAY IN ASSOCIATION WITH WATER 25 TO 27 DEGREES C AND HAVING A SALINITY GREATER THAN 34.50 PARTS PER THOUSAND.

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REQUEST PARAMETER CARDS, PACIFIC PROJECT, JUNE 8, 1966.

       IF IDENT EQUALS  146867 ,
        AND NUMB IS GREATER THAN  00025 ,
         AND HOURS-AFTER-SUNRISE IS GREATER THAN  00
         AND LESS THAN  03  ,
          AND BEHAVIOR EQUALS  3  ,
           AND WATER-TEMPERATURE IS GREATER THAN  249
           AND LESS THAN  271  ,
            AND SURFACE-SALINITY IS GREATER THAN  450  ,
             AND MONTH EQUALS  05  ,
              GO TO SR01.
```

DATE	TIME	SPECIES	NUMBER	HOURS AFTER SUNRISE	SURFACE TEMP	SURFACE SALINITY
05-29-64	0630	Sooty Tern	40	2	26.2°	34.6‰

FIGURE 8.—Complex conditional question, its COBOL translation, and answer concerning sooty tern observations on *Cromwell* cruises.

than a full day. The new special parametric analysis (SPA) field will be introduced on the revised day card for that purpose. An entry in this field will "flag" for restricted abundance analysis all observations made within the time segment represented on the day card. The use of all combinations of punches in each column (10 digits and 26 letters) permits designation of 36^3 (46,656) different areas.

On the day card the number of hours of observation, the actual times of observation, and the distance travelled within the designated area must be fractionized by entering them on two or more "fractional"

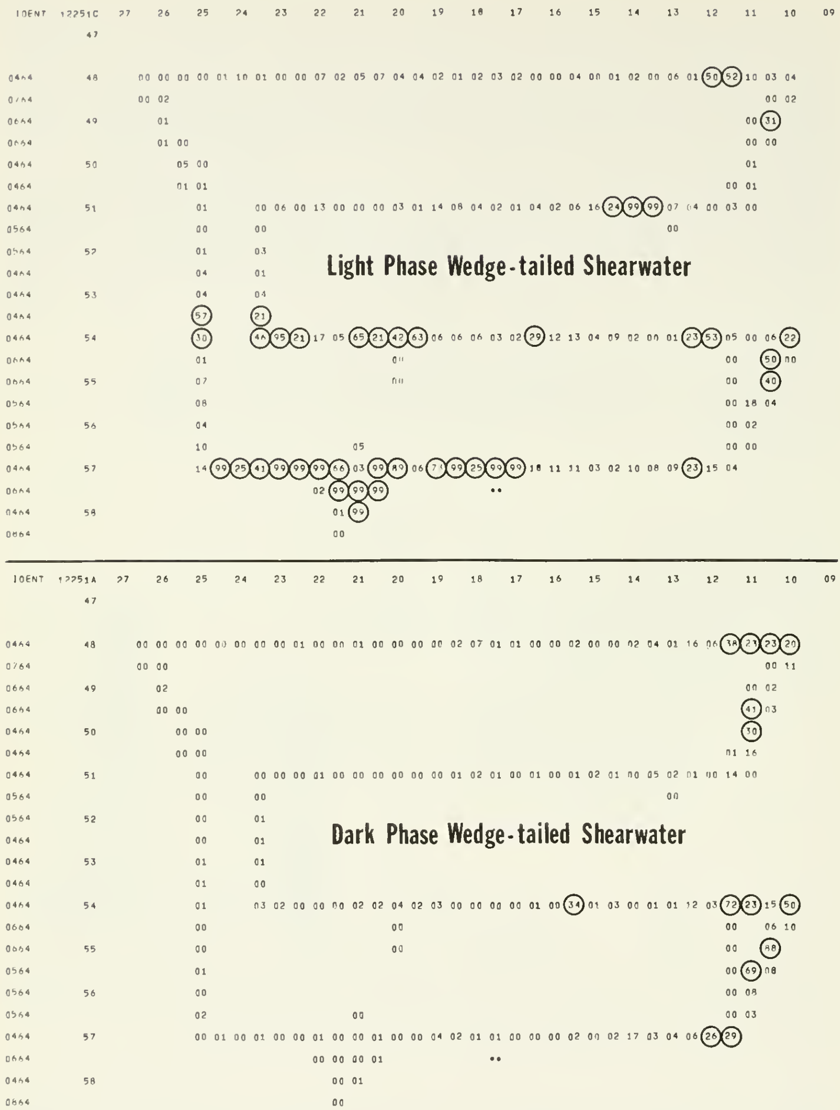

FIGURE 9.—Computer printed distribution maps of two color phases of wedge-tailed shearwaters May–July. Four-digit numbers in extreme left margin refer to *Cromwell* cruises by month and year on which first observation in that line was made. Note that, on April and July cruises, observations were made in May and August. North is to the left, latitude is read from right to left, and longitude from top to bottom. The cruise track is outlined by the number print-out. Asterisks indicate no observations were made in that half-degree square, 00 indicates observations but no birds. Abundance may be read directly from the printed numbers. Circles indicate 20 birds or more per half-degree square.

day cards. Only those sightings that were made within the time interval on the fractional day card are flagged for special parametric analysis. Because the data are flagged on the basis of times of observation, the computer does not require geographic information to define the area; thus, bird densities may be computed for areas of any size or shape. These areas may be mutually exclusive or may overlap wholly or in part (fig. 10). The computer also will provide density figures based on total observations made within a given area during all fractional days within a requested time span. Areas may

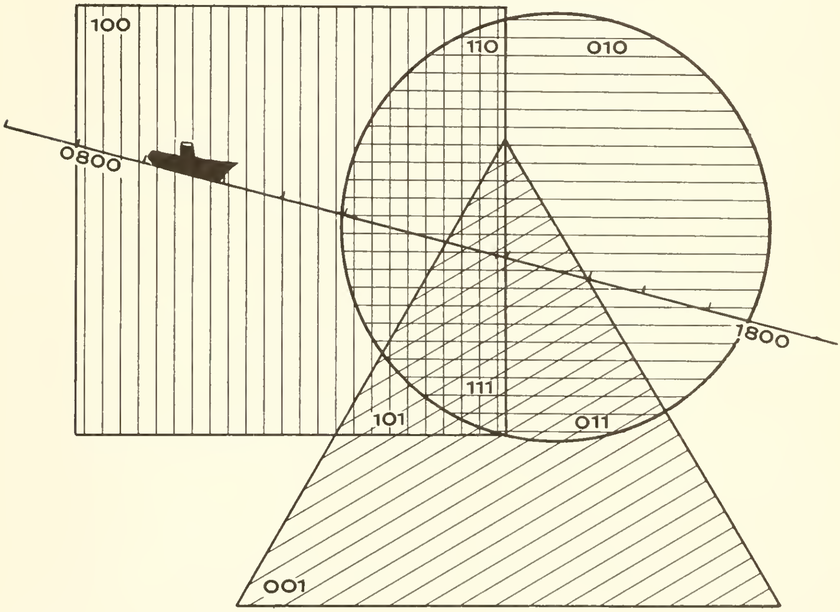

FIGURE 10.—Three overlapping areas along a day's cruise path with the coded representations for various subareas. All sightings made within the time the ship was in the square are flagged with a 1 in first column of the SPA field; those in the circle and the triangle, with 1's in the second and third columns respectively.

be selected for special parametric analysis either before the data have been entered on punch cards or at any future time by fractionizing the appropriate day cards.

The revised intermediate coded sheet for the day card is shown in figure 3.

Plankton measurements were made only once daily on the *Cromwell* cruises, but in other programs plankton abundance may be sampled more frequently. The plankton field (62–64), therefore, should be moved to the environment card where it would occupy columns 69–71.

Primary productivity, a measurement of the richness of environment and potential food supply, eventually may prove useful for comparison with bird distribution. At present, however, because there is no universally agreed-upon measure of productivity, we have used surface phosphate and plankton abundance as measures of the marine environment.

The data stored on tape reels in the computer may be altered through a revised program if these or any later modifications become necessary.

With some modifications, the coding used in this pilot seabird ADP system is suitable for storage of seabird records voluntarily sent in from all over the world to a central office or offices such as World Data Centers A and B for Oceanography in Washington and Moscow. Information submitted on standardized forms would be available for use by marine ornithologists and ecologists. The establishment of a world center for the storage of seabird distribution data and international agreement on uniform methods of observation, recording, and coding of data were two basic recommendations of a seabird committee authorized by the 14th International Ornithological Congress, Oxford, July 1966.

Varying reliability of observations and different techniques for gathering data, however, probably will necessitate uniform editing before the data are fed into the system. This suggests the need for a central editor for all the data and a staff to prepare them for entry. As an indication of the extent of the work that may be needed to prepare data for computer storage, two persons worked full time eight hours a day for 50 days transferring the raw at-sea data from the *Cromwell* cruises onto intermediate coded sheets before they could be punched into the system. Because of the far larger volume of data that may be collected by many more observers from all over the world in an international program, it might be necessary for them to submit data to the proposed editor or central files already translated onto intermediate coded sheets.

The worldwide scope of such a seabird data storage project and the fact that many species of seabirds associate with commercially valuable schooling fish make this an attractive candidate for support under the International Biological Program, the major theme of which is productivity and man.

TABLE 1.--Codes for sighting deck

Species Identification for Central Pacific Ocean: 29-34

100000 Aves
- 120000 Procellariiformes
  - 121000 Diomedeidae
    - 121100 *Diomedea*
      - 121110 *D. nigripes*
      - 121111 *D. immutabilis*
      - 121112 *D. melanophris*
  - 122000 Procellariidae
    - 122100 *Fulmarus*
      - 122101 *F. glacialis*
    - 122500 *Puffinus*
      - 122501 *P. carneipes*
      - 122504 *P. creatopus*
      - 122506 *P. pacificus*
      - 122518 *P. bulleri*
      - 122519 *P. griseus*
      - 122520 *P. tenuirostris*
      - 122521 *P. nativitatus*
      - 122524 *P. puffinus newelli*
      - 122534 *P. lherminieri*
    - 122600 *Pterodroma*
      - 122601 *P. hasitata*
        - 122607 *P. h. phaeopygia*
        - 122608 *P. h. externa*
        - 122609 *P. h. cervicalis*
      - 122615 *P. solandri*
      - 122620 *P. rostrata*
      - 122624 *P. inexpectata*
      - 122629 *P. hypoleuca*
        - 122630 *P. h. hypoleuca*
        - 122631 *P. h. nigripennis*
      - 122633 *P. neglecta*
      - 122636 *P. alba*
      - 122642 *P. arminjoniana heraldica*
      - 122645 *P. cooki*
        - 122646 *P. cooki cooki*
      - 122649 *P. leucoptera*
        - 122653 *P. l. masafuerae*

122700 *Bulweria*
122701 *B. bulwerii*
123000 Hydrobatidae
123100 *Oceanites*
123101 *O. oceanicus*
123400 *Oceanodroma*
123404 *O. castro*
123409 *O. leucorhoa*
123420 *O. tristrami*
123423 *O. furcata*
123500 Miscellaneous genera
123502 *Nesofregetta albigularis*
130000 Pelecaniformes
131000 Phaethontidae
131100 *Phaethon*
131106 *P. rubricauda*
131112 *P. lepturus*
133000 Sulidae
133200 *Sula*
133206 *S. dactylatra*
133213 *S. sula*
133217 *S. leucogaster*
136000 Fregatidae
136100 *Fregata*
136107 *F. minor*
136114 *F. ariel*
140000 Charadriiformes
141000 Charadriidae
141200 *Pluvialis*
141209 *P. dominica*
141400 *Arenaria*
141401 *A. interpres*
142000 Scolopacidae
142100 *Numenius*
142101 *N. tahitiensis*
142200 *Heteroscelus*
142201 *H. incanum*
142700 *Crocethia*
143000 Phalaropodidae
143100 *Phalaropus*
143101 *P. fulicarius*

144000 Stercorariidae
- 144100 *Stercorarius*
  - 144101 *S. pomarinus*
  - 144103 *S. longicaudus*
- 144200 *Catharacta*
  - 144201 *C. skua*

145000 Larinae
- 145100 *Larus*
  - 145101 *L. artricilla*
  - 145145 *L. delawarensis*
  - 145184 *L. glaucescens*
  - 145185 *L. hyperboreus*

146000 Sterninae
- 146100 *Anous*
  - 146101 *A. stolidus*
  - 146110 *A. tenuirostris*
- 146200 *Procelsterna*
  - 146201 *P. cerulea*
- 146300 *Gygis*
  - 146301 *G. alba*
- 146800 *Sterna*
  - 146801 *S. bergi*
  - 146829 *S. hirundo*
  - 146835 *S. paradisaea*
  - 146857 *S. sumatrana*
  - 146866 *S. lunata*
  - 146867 *S. fuscata*

TABLE 2.--Codes for sighting deck

Species identification reliability: 36	Number reliability: 42
0 Sighting as a whole reliable	0 Actual count
1 Sighting as a whole questionable	1 ± 5 per cent
2 Either this or next most similar form	2 ± 10 per cent
	3 ± 15 per cent
3 This or any similar form	4 ± 20 percent
4 Genus reliable, species unreliable	5 ± 25 percent
	6 ± 30 or 33 per cent
5 Genus unreliable, species unreliable	7 ± 40 per cent
	8 ± 50 per cent
6 Sighting as whole unreliable	9 Present, but no count possible

Direction of bird movement: 43

0 No data
1 No apparent direction
2 North
3 Northeast
4 East
5 Southeast
6 South
7 Southwest
8 West
9 Northwest

Behavior: 44

0 No information
1 Traveling
2 Sitting
3 Feeding
4 Searching
5 Following ship
6 Breeding (display)
7 Parasitism
8 Dispersing
9 Other

Color marking: 45

0 No data
1 Orange
2 Blue
3 Red
4 Green
5 Black
6 White
7 Yellow
8 Brown
9 Other

Method of marking: 46

0 No data
1 Painted
2 Band
3 Colored band
4 Streamer
5 Other

Age: 47

0 Not determined
1 Adult
2 Sub-adult
3 Immature
4 1st year
5 2nd year
6 3rd year

Sex: 48

0 Not determined
1 Male
2 Female

Color-plumage phase: 49

0 Not determined
1 Light phase
2 Intermediate phase
3 Dark phase
4 Pink
5 Other

Molt: 50

0 Not determined
1 Molt not present
2 Molt present
3 New plumage
4 Worn plumage
5 Other

Specimen: 51

0 Not collected
1 Collected

Food association: 52

0 Not determined
1 Flying fish
2 Predatory fish
3 Squid
4 Plankton
5 Food fish
6 Scavenging
7 Other

Special weather conditions: 53

0 No data
1 Birds in rain
2 Bird at edge of rain
3 Very high winds
4 Calm
5 Other

Special information: 54

0 No data
1 Identification
2 Species association
3 Behavior
4 Abundance
5 Location
6 Direction of movement
7 Food association
8 Other
9 Parasitism

TABLE 3.--Codes for environmental deck

Weather conditions: 50-51

00-49 No precipitation at the ship at the time of observation.

00-19 No precipitation, fog, duststorm, sandstorm, or drifting snow at the ship at the time of observation or during the preceeding hour, except for 09.

00	Cloud development not observed or not observable.	No hydrometers except clouds.
01	Clouds generally dissolving or becoming less developed.	
02	State of sky on the whole unchanged.	Characteristic change of the state of sky during past hour.
03	Clouds generally forming or developing.	

04	Visibility reduced by smoke, e.g., veldt or forest fires, industrial smoke, or volcanic ashes.	Haze, dust, sand, or smoke.
05	Dry haze.	
06	Widespread dust in suspension in the air, not raised by wind at or near the ship at the time of observation.	
07	Dust or sand raised by wind at or near the ship at the time of observation, but no well-developed dust devil(s), and no duststorm or sandstorm seen.	
08	Well-developed dust devil(s) seen at or near the ship within last hour, but no duststorm or sandstorm.	
09	Duststorm or sandstorm within sight of the ship or at the ship during the last hour.	
10	Light fog (visibility 1,100 yards or more).	
11	Patches of.	Shallow fog at the ship not deeper than about 33 feet.
12	More or less continuous.	
13	Lightning visible, no thunder heard.	
14	Precipitation within sight but not reaching surface at the ship.	
15	Precipitation within sight, reaching surface, but distant (i.e., estimated to be more than 3 miles from the ship).	
16	Precipitation within sight, reaching surface, near to but not at the ship.	

17	Thunder heard, but no precipitation at the ship.	
18	Squall(s)	Within sight during the last hour.
19	Funnel cloud(s) (tornado or waterspout).	Within sight during the last hour.

20-29 Precipitation, fog or thunderstorm at the ship during the preceding hour but NOT at the time of observation.

20	Drizzle (not freezing).	Not falling as showers.
21	Rain (not freezing).	Not falling as showers.
22	Snow.	Not falling as showers.
23	Rain and Snow.	Not falling as showers.
24	Freezing drizzle or freezing rain.	Not falling as showers.
25	Shower(s) of rain.	
26	Shower(s) of snow, or of rain and snow.	
27	Shower(s) of hail or of hail and rain.	
28	Fog.	
29	Thunderstorm (with or without precipitation).	

30-39 Duststorm, sandstorm or drifting snow.

30	Slight or moderate duststorm or sandstorm.	Has decreased during preceding hour.
31	Slight or moderate duststorm or sandstorm.	No appreciable change during preceding hour.
32	Slight or moderate duststorm or sandstorm.	Has increased during preceding hour.
33	Severe duststorm or sandstorm.	Has decreased during preceding hour.
34	Severe duststorm or sandstorm.	No appreciable change during preceding hour.
35	Severe duststorm or sandstorm.	Has increased during preceding hour.
36	Slight or moderate drifting snow.	Generally low.
37	Heavy drifting snow.	Generally low.
38	Slight or moderate drifting snow.	Generally high.
39	Heavy drifting snow.	Generally high.

40-49 Fog at the time of observation.

40 Fog at a distance at the time of observation, but not at the ship during the last hour, the fog extending to a level above that of the observer.

41 Fog in patches.

42 Fog, sky discernible. 43 Fog, sky not discernible.	Has become thinner during preceding hour.
44 Fog, sky discernible. 45 Fog, sky not discernible.	No appreciable change during preceding hour.
46 Fog, sky discernible. 47 Fog, sky not discernible.	Has begun or has become thicker during preceding hour.

48 Fog, depositing rime, sky discernible.

49 Fog, depositing rime, sky not discernible.

50-99 Precipitation at the ship at the time of observation.

50-59 Drizzle at time of observation.

50 Drizzle, not freezing, intermittent. 51 Drizzle, not freezing, continuous.	Slight at time of observation.
52 Drizzle, not freezing, intermittent. 53 Drizzle, not freezing, continuous.	Moderate at time of observation.
54 Drizzle, not freezing, intermittent. 55 Drizzle, not freezing, continuous.	Thick at time of observation.

56 Drizzle, freezing, slight.

57 Drizzle, freezing, moderate or thick.

58 Drizzle and rain, slight.

59 Drizzle and rain, moderate or heavy.

60-69 Rain at time of observation.

60 Rain, not freezing, intermittent. 61 Rain, not freezing, continuous.	Slight at time of observation.
62 Rain, not freezing, intermittent. 63 Rain, not freezing, continuous.	Moderate at time of observation.
64 Rain, not freezing, intermittent. 65 Rain, not freezing, continuous.	Heavy at time of observation.

66 Rain, freezing, slight.
67 Rain, freezing, moderate or heavy.
68 Rain or drizzle and snow, slight.
69 Rain or drizzle and snow, moderate or heavy.

70-79 Solid precipitation not in showers at time of observation.

70 Intermittent fall of snow flakes. 71 Continuous fall of snow flakes.	Slight at time of observation.
72 Intermittent fall of snow flakes. 73 Continuous fall of snow flakes.	Moderate at time of observation.
74 Intermittent fall of snow flakes. 75 Continuous fall of snow flakes.	Heavy at time of observation.

76 Ice needles (with or without fog.
77 Granular snow (with or without fog).
78 Isolated starlike snow crystals (with or without fog).
79 Ice pellets.

80-99 Showery precipitation, or precipitation with current or recent thunderstorm.

80 Rain shower(s), slight.
81 Rain shower(s), moderate or heavy.
82 Rain shower(s), violent.
83 Shower(s) of rain and snow mixed, slight.
84 Shower(s) of rain and snow mixed, moderate or heavy.
85 Snow shower(s), slight.
86 Snow shower(s), moderate or heavy.
87 Shower(s) of soft or small hail with or without rain, or rain and snow, slight.
88 Shower(s) of soft or small hail with or without rain, or rain and snow mixed, moderate or heavy.
89 Shower(s) of hail with or without rain, or rain and snow mixed, not associated with thunder, slight.
90 Shower(s) of hail, with or without rain, or rain and snow mixed, not associated with thunder, moderate or heavy.

91 Slight rain at time of observation. 92 Moderate or heavy rain at time of observation. 93 Slight snow, or rain and snow mixed, or hail* at time of observation. 94 Moderate or heavy snow, or rain and snow mixed, or hail* at time of observation.	Thunderstorm during preceding hour but not at time of observation.

*Hail, small hail, soft hail.

95	Thunderstorm, slight or moderate, without hail* but with rain and/or snow at time of observation.	Thunderstorm at time of observation.
96	Thunderstorm, slight or moderate, with hail* at time of observation.	
97	Thunderstorm, heavy, without hail* but with rain and/or snow at time of observation.	
98	Thunderstorm combined with duststorm or sandstorm at time of observation.	
99	Thunderstorm, heavy, with hail* at time of observation.	

*Hail, small hail, soft hail.

TABLE 4.--Codes for environmental deck

State of sea: 52
0 Flat calm
1 Less than 1 foot
2 1 to 3 feet
3 3 to 5 feet
4 5 to 8 feet
5 8 to 12 feet
6 12 to 20 feet
7 20 to 40 feet
8 40 feet and over
9 Very rough, confused sea

Visibility: 53
0 Dense fog....................50 yards
1 Thick fog ....200 yards
2 Fog.........................400 yards
3 Moderate fog ....1000 yards
4 Thin fog or mist ....1 mile
5 Visibility poor...............2 miles
6 Visibility moderate ....5 miles
7 Visibility good ....10 miles
8 Visibility very good.........30 miles
9 Visibility excellent .....over 30 miles
(Use range-finder readings of known land)

Moon age: 60
0 No data
1 New
2 1/4
3 1/2
4 3/4
5 Full
6 Not up

Cloud cover: 61
0 No clouds
1 Less than 1/10, or 1/10
2 2/10 and 3/10
3 4/10
4 5/10
5 6/10
6 7/10 and 8/10
7 9/10 and 9/10 plus
8 10/10
9 Sky obscured

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