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Seasonal Distribution of the Mottled Petrel in the Northwestern North Pacific

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Abstract

To determine the seasonal distribution of the mottled petrel (*Pterodroma inexpectata*) in the northwestern North Pacific Ocean, sighting data obtained by 23 research vessels during 1978-1990 were analyzed by month. Bird densities in 1° latitude × 1° longitude blocks were estimated.

Transequatorial migration from the southern ocean to the North Pacific lasted about 1.5 months from middle of May to end of June. After arriving to the subarctic North Pacific, all mottled petrels changed their styles to an undirected nomadic mode. During their stay in the subarctic waters from June to October, their distribution seemed to be strongly governed by the local or temporal occurrences of prey organisms. Dense distributions were often observed in frontal areas between heterogeneous water masses. From July to September, some mottled petrels in the North Pacific moved into the southeastern Sea of Okhotsk and central Bering Sea. These northward movements seem to be caused by the paucity of subarctic seabirds, most of which concentrate in coastal areas to breed. The distribution of the mottled petrel in pelagic sea areas may be determined partly by their avoiding competition with other seabird species.

Key words: Distribution, Migration, Density, Gadfly petrel, *Pterodroma inexpectata*

Introduction

Since the first record of a mottled petrel (*Pterodroma inexpectata*) in the Northern Hemisphere in 1881 (Brewster, 1881), the distribution and migration of this species in the North Pacific remained unknown until the mid-1900's. Since then, with the increase of research activities in oceanic waters of the North Pacific, sighting records have increased in various regions, but most were fragmental or local information derived from a single research cruise in a given sea area (Kuroda, 1955, 1960; Hamilton, 1958; Palmer, 1962; Kenyon and Phillips, 1965; King, 1967; Nakamura and Tanaka, 1977; Wahl et al., 1989; Meeth and Meeth, 1985; Shuntov, 1995). Shuntov (1972) suggested that the distribution of mottled petrels extends

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further north into the oceanic waters of the Okhotsk and Bering Seas in summer, but he did not show any definite data other than describing estimates derived from scattered sighting records from many fishing vessels. Ainley and Manolis (1979) established the entire distribution of the mottled petrels from the Antarctic to the Bering Sea based on many scattered sighting records. Furthermore, Kuroda (1991) summarized the monthly distribution patterns of shearwaters and petrels, including the mottled petrel, in relation to surface water temperatures in the entire northern North Pacific.

Several population estimates have been made for mottled petrels in the North Pacific. Gould et al. (1982) estimated a population size of about 110,000 birds from the Gulf of Alaska during summer, and found this bird to sojourn in the gulf from early May to late October. Furthermore, Ogi et al. (1986) estimated the population of mottled petrels in the Bering Sea in summer to be approximately 1.5 million birds during late summer based on the systematic seabird census data. Taking the above two population estimates into account, the total population of mottled petrels in subarctic areas of the North Pacific during summer would amount to over 1.6 million birds. In New Zealand, the estimated numbers of breeding mottled petrels ranged from 20,000 to 100,000 birds due to incomplete survey efforts (Robertson and Bell, 1984). The combined mottled petrel population of the Gulf of Alaska and Bering Sea was 16～80 times larger than the breeding population. Furthermore, if the number of the birds in the northwestern and central North Pacific and Okhotsk Seas is added to the above total birds, the number of birds over the entire North Pacific becomes unexpectedly large.

Much remains unknown about the population, distribution, and pelagic life history of the mottled petrel. This study was done to clarify the seasonal distribution pattern of the mottled petrel in the northwestern North Pacific Ocean by summarizing the seabird census data obtaining by 23 research cruises during 1978–1990.

Materials and Methods

Mottled petrels were observed from the leeward bridge wing or flying bridge using an 8～10×binocular. Individuals were counted to a distance of 200～400 m in a 180° arc from the bow to stern. At sea conditions equal or more than Beaufort 4 or when visibility was less than 100 m, censuses were not conducted.

Census transects were done on a straight course; if the ship changed course, a new transect was started. For each census transect, the total number of birds by species per distance traveled and per area (km^2) were calculated. Each census transect usually lasted 30 minutes, but varied sometimes according to the environmental conditions from five minutes to one hour.

Census data used in this study were obtained from 23 research cruises which were undertaken from 1978 to 1990. All census data were classified into six groups by months from May to October. In each month, the census transects were further grouped into blocks of 1° latitude ×1° longitude. Numbers of mottled petrels per 1 km^2 were then calculated by block. This number per one square kilometer was regarded as a density index (D) of mottled petrels in each 1° ×1° block.

To clarify the relationship between the distribution and movement patterns of

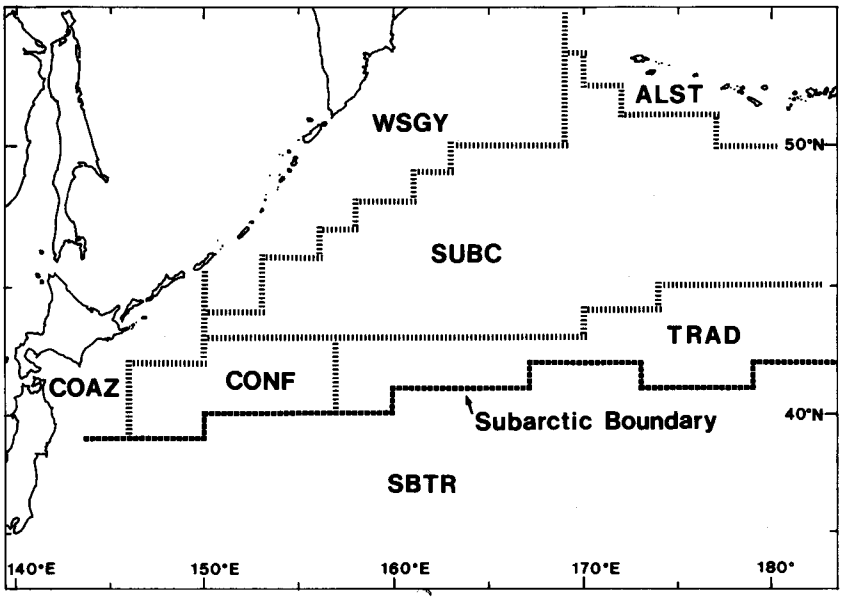

Fig. 1. Oceanographic areas of the northwestern North Pacific Ocean.
COAZ : Coastal zone, WSGY : Western Subarctic Gyre,
CONF : Confluence Zone, TRAD : Transition Domain,
SUBC : Subarctic Current, ALST : Alaska Stream,
SBTR : Subtropical Zone

mottled petrels and water masses, oceanographic domains and current systems were divided into the following regions (Fig. 1): Coastal Zone (COAZ), Western Subarctic Gyre (WSGY), Confluence Zone (CONF), Transition Domain (TRAD), Subarctic Current (SUBC), Alaska Stream (ALST), Subtropical Zone (SBTR). Above oceanographic assignments was mainly based on the studies of Favorite et al. (1976) and Wahl et al. (1989).

Furthermore, the relationship between the occurrence of mottled petrels and surface water temperatures was also examined to determine seasonal habitat preferences.

The general distribution and migration patterns of the mottled petrel in the subarctic nothwestern North Pacific were estimated during May to October.

Since the research cruises have not been adequately planned to clarify the distribution and migration for pelagic seabirds, but have been undertaken to study fish, squids and porpoises, the study areas in each month did not necessarily cover the entire subarctic northwestern North Pacific in terms of time and space, particularly in May, June, September, and October, where ships were restricted to certain local areas or transects. In these months, interpretation of seasonal distribution pattern for mottled petrels was made by irregular latitudinal or longitudinal census blocks.

Results

Total census efforts and results for mottled petrels

An outline of the total census efforts and results by months is shown in Table 1. A total of 3,250 census transects performed over 2,135 hrs. 31 min., along 39,738 km, and covering 11,073 km^2 were conducted during 1978 to 1990. The total number of mottled petrels observed was 3,613 composing 0.8% of the total birds observed. Densities per 1 km^2 varied from 0.003 in October to 0.546 in August. The average density was 0.326 birds per 1 km^2 over all months. Surface water temperatures where mottled petrels occurred ranged from 2.1°C in May to 25.6°C in September and October.

Seasonal distribution patterns

May: First sighting date for mottled petrels in this study was 12 May 1982 at 41°59′N, 171°26′E. Most mottled petrels in May occurred west of 157°E and south of 43～46°N in SUBC (Fig. 2). High densities were observed along 158°E and 175°E. These blocks were mostly censused during late May. No birds were observed in early May (46 census transects), only one bird was observed in mid-May (104 census transects), and 248 birds were observed in late May (336 transects). The occurrence of mottled petrels in the blocks other than the high density blocks described above was sporadic, and densities were low over a wide area (Fig. 2). The first arrival of mottled petrels from the Southern Hemisphere to the northeastern North Pacific probably occurred in mid-May. The first migrants seemed to be solitary individuals or members of small groups. Though no observations were recorded in WSGY, the northern distribution limit in May seemed to be formed in SUBC. Furthermore no observations occurred in the sea areas of ALST and COAZ.

June: Though seabird censuses were made by 9 research cruises, the covered areas were restricted roughly to two sea areas, one west of 157°E between 34°N and 45°N, and one east of 157°E and north of 44°N including former Japanese mothership salmon fishing grounds (Fig. 2). No seabird census efforts were done in WSGY. High density blocks of mottled petrels were observed between 46°N and 49°N, not extending to the adjacent areas of the Aleutian Islands. These high density blocks might be a first resting zone in the subarctic region just after the transequatorial migration from the Southern Hemisphere. Because of the geographical limitation of bird census blocks, a comparison of distribution patterns between oceanographic areas was not successful. However, mottled petrels in June seemed to reach the southern parts of WSGY. Along 155°E, bird censuses was conducted twice during 5～11 June 1984 and 8～13 June 1985. No mottled petrels were observed in 1984, but 122 birds were observed north of 39°N in 1985, suggesting that the timing of the northward migration through the survey area had some temporal and geographical variations. In each block along 155°E in 1985, all mottled petrels observed were heading north with typical flying behavior, consisting of fast, high arcing and sustained gliding, and individual birds occurred in a scattering pattern, not forming groups. Therefore the birds seemed to be migrating actively in SBTR and TRAD.

The westernmost occurrence of the species was at 39°22′N, 146°20′E on 2 June 1984, about 400 km off of northern Japan. The distribution in June extended further west than in May.

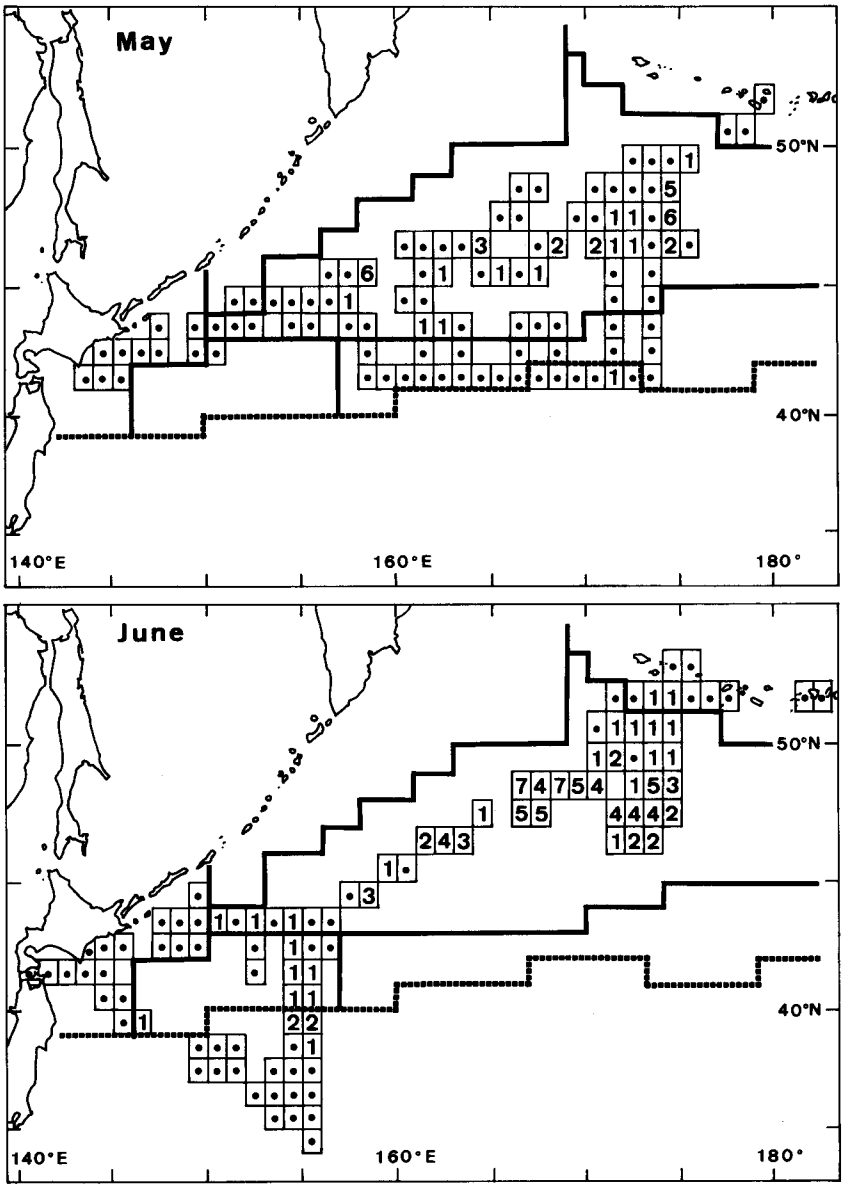

Fig. 2. Densities of the mottled petrel in May and June.
Density indices (D) are ●: D=0; **1**: 0<D≤0.5; **2**: 0.5<D≤1.0; **3**: 1.0<D≤1.5; **4**: 1.5<D≤2.0; **5**: 2.0<D≤2.5; **6**: 2.5<D≤5.0; **7**: 5.0<D≤7.5; **8**: 7.5<D≤10.0; **9**: 10.0<D≤12.0 (see Figs. 2 to 4).

July: Distribution of the census blocks was broader than in the previous months, but the number of mottled petrels observed was less than in the previous month (Table 1). The southern and western distribution limits were 39°N and 146°E, respectively (Fig. 3). In the waters of ALST west of Attu Island, the

Table 1. Census efforts and results of the Mottled Petrel (MP) observation by month.

Month	Total number of transects (n)	Total sighting hours (h : m)	Total sighting distance (km)	Total sighting area (km^2)	A Total birds observed (n)	B Total MP observed (n)	Percent MP (B/A) $\times 100$ (%)	No. of birds per 1 km^2 $\pm$SE	No. of MP per 1 km^2 $\pm$SE	Range of sea surface temperature in transects (°C)
May	486	339 : 57	6,114.2	1,634.78	28,479	293	1.03	17.42 $\pm$1.44	0.179 $\pm$0.082	2.1–11.7
Jun.	880	504 : 52	9,561.7	2,708.72	158,156	990	0.62	58.39 $\pm$8.03	0.365 $\pm$0.028	3.6–20.8
Jul.	721	469 : 23	9,081.8	2,409.03	90,534	540	0.60	37.58 $\pm$7.80	0.224 $\pm$0.027	4.6–22.1
Aug.	789	554 : 21	10,070.6	2,845.52	136,058	1,553	1.14	47.81 $\pm$5.73	0.546 $\pm$0.060	4.8–22.5
Sep.	219	171 : 23	2,839.3	845.75	29,842	235	0.79	35.28 $\pm$6.92	0.278 $\pm$0.086	11.5–25.6
Oct.	155	95 : 35	2,070.4	614.10	10,778	2	0.02	17.55 $\pm$3.98	0.003 $\pm$0.001	9.6–25.5
Total	3,250	2,135 : 31	39,738.0	11,057.90	453,847	3,613	0.80	41.04	0.326	2.1–25.6

mottled petrel was observed in late July. This suggests that the birds may move northward from south of the Aleutian Islands to the Bering Sea. Furthermore, in the waters of WSGY south of the Kuril Islands, mottled petrels occurred.. This also suggests that a northward shift to the Okhotsk Sea may occur during late July. Though in June high density blocks were observed in the middle of SUBC between 46°N and 48°N, these were mostly observed in the southern part of SUBC between 44°N and 47°N in July. The shift of high density areas of the birds was probably due to the exodus of the mottled petrels from WSGY, ALST and northern SUBC to the Okhotsk and Bering Seas. As described above, in July, the distribution of mottled petrels expanded further north to the southern marginal waters of WSGY and ALST (Fig. 3). In TRAD, the distribution of mottled petrels was restricted to the northern blocks. One bird was seen at 39°00′N, 173°59′E on 24 July. Based on our observation on its flying pattern, this bird might have been a straggler and not an active migrator.

August: The distribution of mottled petrels was restricted to subarctic North Pacific waters (Fig. 3). The southern limit of the birds was ca. 40°N, but the western limit was west ca. 150°E, showing that birds were distributed further east than in July. As one of the most prominent features, mottled petrels did not show flying to a definite northward direction but flying randomly in all directions. During their stay in the subarctic waters from 4 to 5 months, the birds are thought to become more nomadic as they search for feeding spots, which appear sporadically or locally. In August the entire distribution of Mottled petrels was principally restricted to subarctic waters, but their dense distribution areas seemed to occur more often in favourable foraging areas than in the other months.

Interestingly, no or few mottled petrels were observed in the blocks along the Kuril Islands in WSGY and COAZ, or along the Aleutian Islands in ALST. In the above blocks, high densities of southern shearwaters, such as sooty shearwaters (*Puffinus griseus*) and short-tailed shearwaters (*P. tenuirostris*), were observed.

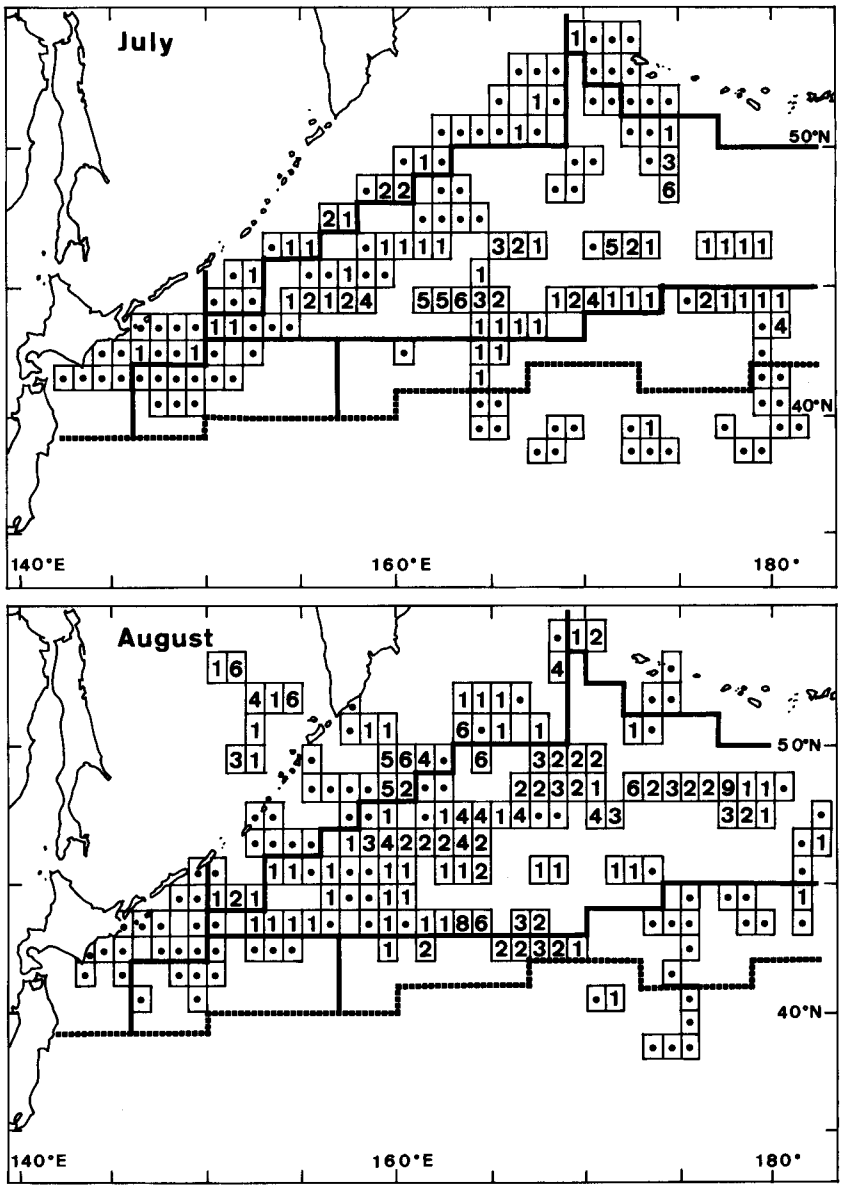

Fig. 3. Densities of the mottled petrel in July and August. (for indices see Fig. 2)

Accordingly, the distribution of mottled petrels had been seriously affected by the presence of other abundant seabird species. No mottled petrels were seen in COAZ, CONF, and SBTR. In TRAD, mottled petrels occurred in quite restricted blocks adjacent to SUBC. These blocks seemed to be located on the waters where local or temporal southward extension of the subarctic surface waters occurred like a tongue.

In Fig. 3, we have included supplemented density indices of mottled petrels in

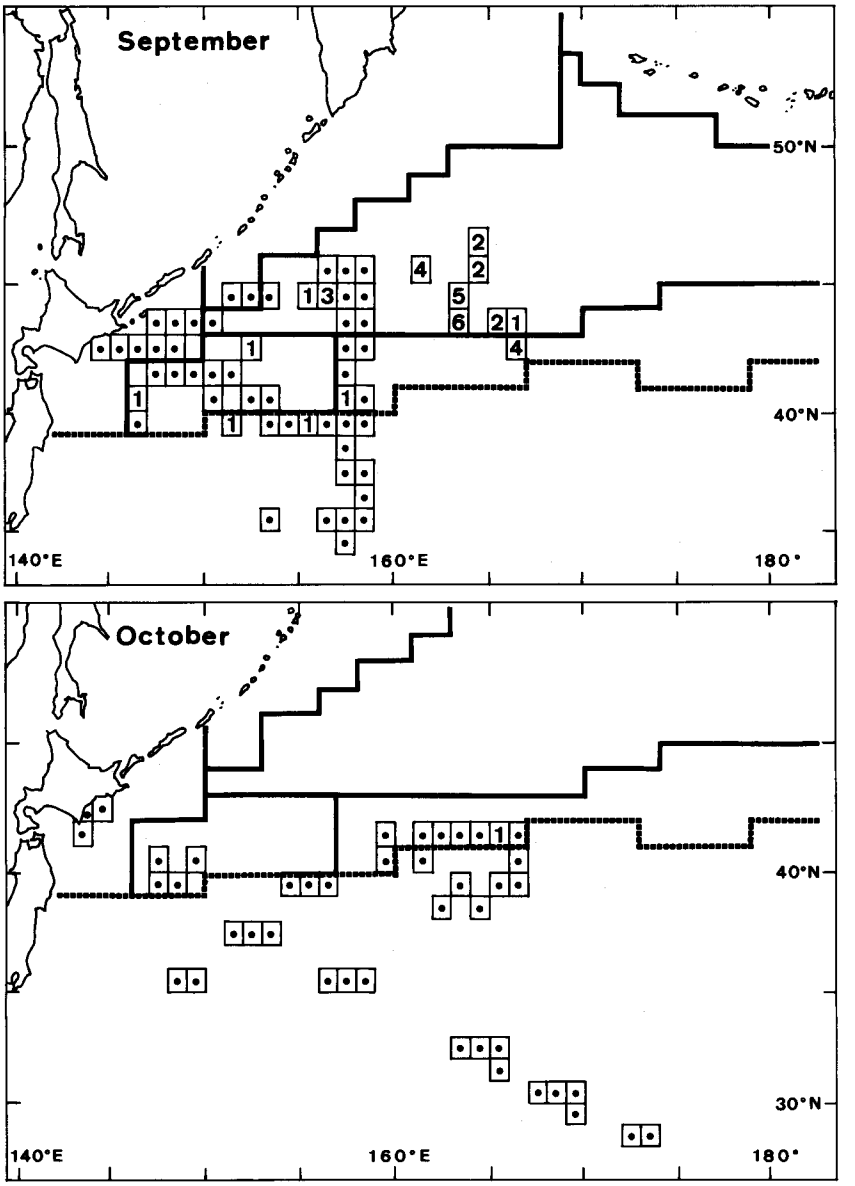

Fig. 4. Densities of the mottled petrel in September and October. (for indices see Fig. 2)

seven 1°×1° blocks in the southeastern Okhotsk Sea that were surveyed in 1989. This shows that the bird migrates to oceanic waters in the Sea of Okhotsk, where it stays for a few months as described by Shuntov (1972).

September: The census blocks were quite restricted in a western part of the northwestern North Pacific west of 167°E and south of 47°N (Fig. 4). High densities were observed from 161° to 167°E and from 42° to 46°N. Unlike the previous month,

mottled petrels occurred in several blocks in CONF, TRAD and SBT. This indicates that southward transequatorial migration of the birds had already begun. Judging from the census results on other southern shearwaters in North Pacific areas, the first departure of mottled petrels seemed to begin at least during end of August or early September. Therefore, the density distribution in Fig. 4 was thought to be a initial southward migrating period of the bird. Thus, this month seems to be quite important for mottled petrels to prepare long distant southward migration.

However, active feeding activities seemed to continue in this month. During our census efforts from 43°31′N, 163°08′E at 0420 to 44°30′N, 163°04′E at 1600 in 3rd September 1983, all mottled petrels and southern shearwaters (*Puffinus* sp.), which should have been migrating to the southern hemisphere at this season, were flying rapidly to northeast direction or to windward (Ogi and Fujise, 1984). Because their destination was considered to be a frontal area (ca. 46°00′N, 164°33′E) where was formed around an isolated warm water mass. We reached the frontal area on 4 September. The above fact suggests that during their stay in subarctic North Pacific waters in summer, the daily food searching distance of the mottled petrels is 200～300 km.

October: Almost all blocks censused in this month were located in COAZ, CONF, TRAD, and SBTR south of 42°N (Fig. 4). Only two mottled petrels were seen in a block in TRAD. As in the previous month, we saw no southward flying mottled petrels in SBTR. Because there were no census efforts in SUBC, the general distribution pattern of mottled petrels in this month is unknown. However, according to Kuroda (1991), the mottled petrels mainly occur in a sea surface temperature range of 8～12°C.

Relation between density of mottled petrels and surface water temperature

During the stay of mottled petrels in the subarctic northwestern North Pacific from May to October, the main habitat areas of the birds were chiefly confined to the subarctic waters north of the Subarctic Boundary located trans-Pacifically at about 39～42°N. As mentioned in the former section, the arrival of the birds to the subarctic northwestern North Pacific would extend from the middle of May to the end of June. However, having arrived at subarctic waters, some remain over the subarctic North Pacific waters and others shift further north to the Okhotsk and Bering Seas. This additional northward movement would last until early or mid-August. The behavioral pattern of the mottled petrels alters probably from a directional migrating mode to an undirected nomadic mode immediately after they arrived in subarctic North Pacific waters. During their subarctic life phase, their distribution and movement should be dominated mainly by the surface appearance of available food organisms and/or the surface water temperatures. In this section, to determine the preferable habitat areas for the mottled petrels which occur temporarily, the relationship between density of mottled petrels (No. of birds per one km^2) and surface water temperatures was examined by month and oceanographic area. To determine a typical distribution pattern of the birds by month, census transects used were limited to the following longitudinal ranges: 157°E～176°E in May, 154°E～175°E in June, 155°E～179°W in July, 155°E～180° in August, 151°E～167°E in September, and 157°E～174°E in October. The results are shown in Table 2.

Table 2. The monthly density (N/km²) of the mottled petrel (MP) by temperature zone.

Sea surface temperature zone (°C)	Number of the Mottled Petrels per 1 km²					
	May	Jun.	Jul.	Aug.	Sep.	Oct.
2.1～ 3.0	0	–	–	–	–	–
3.1～ 4.0	0.838	2.093	–	–	–	–
4.1～ 5.0	0.441	1.092	–	–	–	–
5.1～ 6.0	0.017	0.232	–	–	–	–
6.1～ 7.0	0.007	0.226	0.370	0	–	–
7.1～ 8.0	0.013	0.091	0.379	0	–	–
8.1～ 9.0	0	0.437	0.232	0.487	–	–
9.1～10.0	0	0.131	0.037	1.026	–	–
10.1～11.0	0.007	0.105	0.132	1.189	–	–
11.1～12.0	0	0.111	0.097	0.527	4.344	–
12.1～13.0	–	0.876	0.564	0.931	0.763	–
13.1～14.0	–	0.226	1.519	0.770	1.899	0
14.1～15.0	–	0.096	0.204	0.287	0.344	0
15.1～16.0	–	0	0	1.364	0	0.051
16.1～17.0	–	0	0	0.371	0	0
17.1～18.0	–	0	0	0.039	0	–
18.1～19.0	–	0	0	0.135	0	0
19.1～20.0	–	0	0	0.205	0.119	0
20.1～21.0	–	0	0.019	0	0.023	0
21.1～22.0	–	–	0	0	0	0
22.1～23.0	–	–	–	–	0.031	0
23.1～24.0	–	–	–	–	0	0
24.1～25.0	–	–	–	–	0	0
25.1～26.0	–	–	–	–	0	0
Total no. of transects	358	589	470	516	155	90
Total no. of MP observed	293	986	527	1,471	234	2
Total area observed (km²)	1,200.615	1,816.886	1,657.446	1,953.286	590.955	364.418
Average MP density (n/km²)	0.244	0.543	0.318	0.753	0.396	0.005
Longitudinal range	157～176°E	154～175°E	155°E～179°W	155°E～180°	151～167°E	157～174°E

In May, the density of mottled petrels was higher in low temperature zones than in high temperature zones. However, the birds' distribution did not extend to sea areas with temperatures below 3.0°C in SUBC. These results suggest that northward migrating petrels consist of comparative small groups or solitary individuals that occur like waves, not a constant stream.

In June, mottled petrels occurred at the following temperature zones: 4.1～7.0°C in ALST, 3.1～10.0°C in SUBC, 8.1～15.0°C in CONF and 13.1～14.0°C in

STRO. High densities were observed at 3.2～5.0°C and 12.1～13.0°C. The former was located at the northern part of SUBC and the latter just north of the Subarctic Boundary (Table 2).

In July, the highest density was observed at 13.1～15.0°C in the southernmost part of SUBC. In other temperature zones, densities were much lower. This seemed to be due to the exodus of a part of the bird population from the North Pacific to the Okhotsk and Bering Seas.

In August, high densities (>0.9 birds/1 km^2) of mottled petrels occurred at the following temperature zones by oceanographic area: 9.1～12.0°C in WSGY; 9.1～11.0°C, 12.1～13.0°C and 15.1～16.0°C in SUBC; and 16.1～17.0°C in TRAN. Petrels were not observed in the waters with temperatures below 8°C or above 20.1°C (Table 2). In this month, the mottled petrels were thought to concentrate at several local areas in the subarctic North Pacific waters. In these high density areas, favourable foraging environments for the birds, such as surface appearances of dense plankton patches and/or small fish shoals, might have appeared at the surface layer of the water column.

In September, mottled petrels were observed in the following temperature zones: 11.1～15.0°C in SUBC, 12.1～13.0°C in TRAD, 19.1～20.0°C in CONF, and 20.1～21.0°C and 22.1～23.0°C in STRO. In this month the southward migration seemed to begin. At the temperature zone of 11.1～12.0°C in SUBC, the highest density was observed. This indicates that just before starting from the North Pacific to the South Pacific, the birds would have concentrated at a certain area, like a staging area.

In October, only two mottled petrels were observed at the temperature range of 15.1～16.0°C in TRAN. Even in this month dense distribution area of the bird would had been formed also in SUBC as same in the previous month as observed by Kuroda (1991).

Discussion

The distribution of the mottled petrels in the northwestern North Pacific Ocean during the May to October was mainly restricted to subarctic waters. The bulk of the mottled petrels, including breeding, hatching year, and non-breeding birds, arrived successively to the subarctic waters in waves during the middle of May to the end of June. King (1967) observed fairly large numbers of this species flying north through the Hawaiian Islands in April and May. Owing to the above finding and lack of large flocks of mottled petrels during May, the present survey areas were probably next to the main migration route of mottled petrels to the northern hemisphere. Also, based on their rapid travelling speed along a diagonal path through Hawaiian waters to the Gulf of Alaska during the northward migration (Ainley and Manolis, 1979) and sighting records summarized by Marchant and Higgins (1990), most mottled petrels must reach subarctic North Pacific waters at least by the end of June. The westward extension of mottled petrels' occurrence in this study area from May to June suggests an increase of unexperienced young birds. These later migrants, which swerved from the shortest adult migration course, might be hatching year birds or older non-breeding birds.

After arriving at the subarctic North Pacific, the behavioral pattern seemed to

change from the directional migrating mode to an undirected nomadic mode. During their stay in the subarctic waters, the birds had a tendency to concentrate in favorable foraging areas. This tendency was clear in August when high density blocks were found often near the frontal areas between heterogeneous water masses (Fig. 3). This also suggests that the distribution of mottled petrels must be governed by temporal and spatial bio-oceanographic processes of the ocean. High density blocks in August also occurred in mid latitudes of SUBC (Fig. 3). Even in a certain water mass, favorable foraging spots for seabirds seemed to be formed locally or temporarily in coarse or fine scale (e.g. Hunt and Schreiber, 1987) such as a plime-type upwelling event accompanying plankton patches and/or fish shoals. From late July to late August, a part of the mottled petrel population in the subarctic North Pacific shifted to oceanic waters in the Okhotsk and Bering Seas. The population seemed to include mostly adults which arrived earlier than their chicks. Though the ecological reason of these additional shifts of the petrel is still unknown, one of the most reasonable reasons of their shift comes from the formation of preferable habitat areas in neighboring waters. In fact, most seabirds native to the subarctic North Pacific Ocean and adjacent waters breed in coastal areas. As for Alaskan seabirds, at least a half of the total population consisting of approximately 40 million seabirds are estimated in breeding (Sowls et al., 1978). Therefore, seabird abundance becomes low in the pelagic areas in the North Pacific Ocean, and Bering and Okhotsk Seas. This phenomenon seems to acceralate the additional invasion of the southern shearwaters and petrels from the first resting and foraging areas in the North Pacific to the neighboring northern areas, such as the Bering and Okhotsk Seas, which become a vacant habitat niche for the southern seabirds.

The duration of the arriving time of birds to the study areas ranged about 45 days. According to Warham et al. (1977), the breeding birds for this species require about 18 weeks to migrate to and from the North Pacific. This shorter duration of the arrival time may be due to lack of census effort in March and April and in the main northward migration route proposed in Ainley and Manolis (1979). They concluded that the northward migration of the species to the North Pacific occurs earlier in the year than previously expected. If this is true, census areas in this study should be deviated far from the main migration route which follows a diagonal path between New Zealand and the Gulf of Alaska as shown in Ainley and Manolis (1979). This main route is supposed to be the same in the seabird census results by Kuroda (1991). He also observed mottled petrels in the northeastern North Pacific, including the Gulf of Alaska, in March and April, and northwestern North Pacific in April. Furthermore, he recorded the petrel in November and January in the eastern section of the North Pacific.

The life of mottled petrels in the northwestern North Pacific Ocean is summarized schematically in Fig. 5.

The lowest water temperature zone where mottled petrels were observed in this study was 3.1～4.0°C. This temperature zone is the same as that observed by Kuroda (1991) in the northern North Pacific. Whereas in the Antarctic waters in their breeding season, their southern distribution limit was governed by the northern edge of the pack ice or the −0.5°C isotherm (Nakamura, 1982; Ainley et al., 1984). Whereas, the highest water temperature zones where mottled petrels were sighted in the North Pacific were 22.1～23.0°C in this study and 22°C in Kuroda's study (1991).

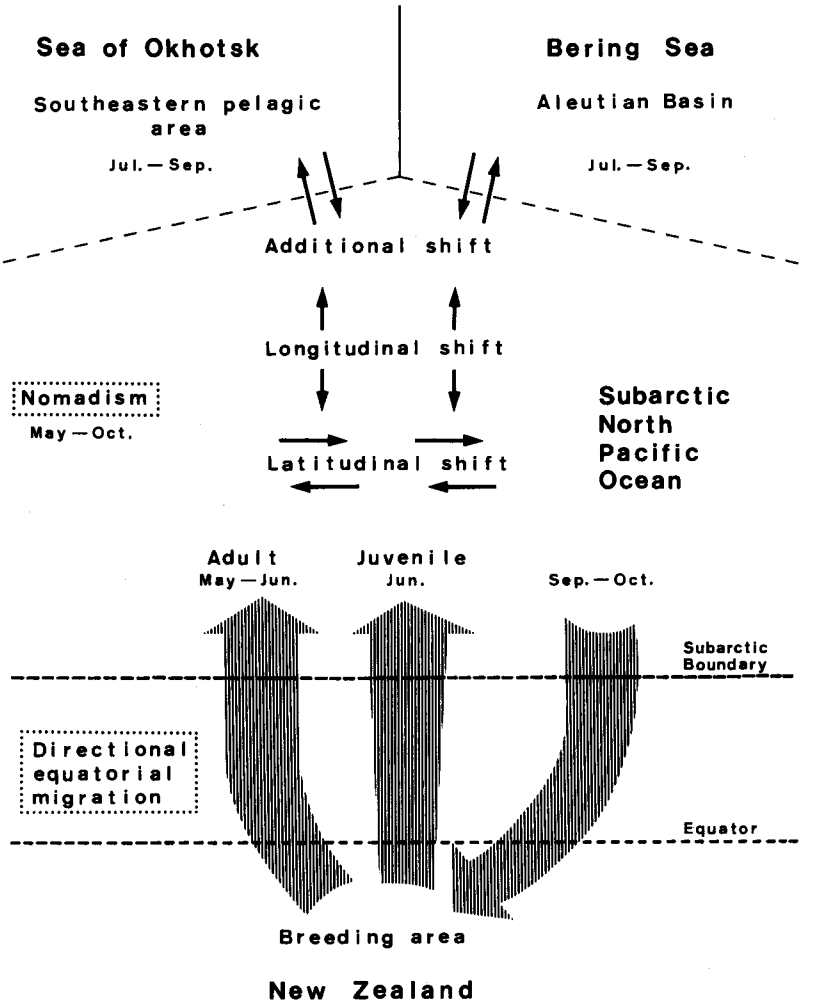

Fig. 5. A schematic life of the mottled petrel in the northwestern North Pacific Ocean.

Birds were also observed at a range of 5.0~10.9°C in July to September in the Bering Sea (Ogi et al., 1986) and 9.0~14.0°C in August in the southeastern Okhotsk Sea (Ogi unpublished data).

During the stay of mottled petrels in the North Pacific from May to October, their movement and distribution may be strongly dominated by preference of specific water masses and abundance of other seabird species with which they are not able to coexist. In other words the bird's behaviors in the North Pacific seem to be closely related with meso- and course-scale oceanographic and biological events.

Though the mottled petrel is a highly pelagic seabird and a skillful flyer, its grasping and tearing power with its bills is extremely weak compared to other seabirds (Ogi et al., 1986). The first author observed two mottled petrels hovering above a feeding flock of 50-100 short-tailed shearwaters on the sea surface in late

August in the southeastern Bering Sea. These petrels were scanning the foraging spot among the crowd of shearwaters and tried to touch down on the sea surface several times, but all attempts failed.

During mid August to early September, we have sometimes encountered enormous numbers of sooty and short-tailed shearwaters making a southward endless stream. In such cases, the mottled petrel has never been observed among or around the shearwater flocks. This scarce distribution of the bird was observed clearly in the southern sea areas along the Kuril Islands and Aleutian Islands as shown in Fig. 3. Furthermore, as mentioned by Nakamura and Tanaka (1977), mottled petrels sometimes occur together with other small-sized seabirds, such as storm petrels, phalaropes, and little alcids.

The above facts suggest that the distribution of mottled petrels in the pelagic oceans may be regulated partly by the presence and abundance of other larger seabird species. Due to the mottled petrel's weakness in case of competition with other seabirds described above, their main habitat areas may have become pelagic as an inevitable consequence.

Though the mottled petrel has not been considered as a vulnerable seabird to commercial fisheries, 9 mottled petrels were entangled and recorded by the Japanese squid driftnet fishery in the 1990 fishing season (Ogi et al., 1991). Of these, 5 specimens were taken between 38°N and 43°N, and between 155°W and 179°W. While in the Japanese salmon driftnet fishery, as far as we know, net-mortality of mottled petrels has not been reported.

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