Monk Seal Movement and Haul-Out Patterns in the NWHI

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Understanding the movement dynamics of monk seals in the Northwestern Hawaiian Islands (NWHI) will help us anticipate the behavior of monk seals in the main Hawaiian Islands (MHI). However, because the biological "drivers" that motivate monk seals to move among atolls in the NWHI (or to choose certain sites over others) may be very different from the operative drivers in the main islands, we caution against making strict extrapolations from one system to the other. Such factors as the available forage base, the age/sex composition at the atoll, the type of substrate, the level of disturbance, and a myriad of other subtle biological and anthropogenic factors could prompt a seal to travel to another site. Even within the NWHI, monk seals exhibit very different movement and haulout patterns from one site to another.

There are two main aspects to consider when evaluating monk seal movement patterns. First, there are the localized movement patterns within an atoll, which may be referred to as "haulout patterns." Second are the more long distance movements in which seals travel between atolls or move far out to sea to forage. Haulout patterns will be considered first.

1. Monk Seal Haulout Patterns

A. Factors Influencing Haulout Patterns

Seals tend to use certain islets within an atoll more than others and even certain sites (beaches) on those islands more than other sites. There are undoubtedly many factors that determine local preferences, among them the degree of isolation afforded by the site (both from other seals and from humans); the exposure of a site to high surf or winds; the accessibility of the site; the proximity to foraging areas; and possibly the substrate (for example, sand versus old reef).

Throughout the Hawaiian Archipelago, monk seals have demonstrated considerable flexibility in their choice of haulout sites. Seals have been observed hauling out in virtually every type of setting and substrate from gnarled emergent reef with constant active surf, to rocky escarpments, to sandy beaches on the main islands frequented by tourists. It is not always clear why seals choose some sites over others, especially when some of those sites appear (to the human eye) to be superficially harsh or inhospitable. In fact, it is rarely clear. However, both individually and collectively, seals do display preferences for certain sites. It may be that an element of individual preference is at play: some seals may be more flexible and adaptable in

choosing haulout sites than are others. This consideration will be important if monk seals become more abundant in the main islands.

The suitability of a particular site varies according to a seal's current biological demands. The two conditions with the most dramatic effect on a seal's physiological state are parturition (giving birth) and molting. Females are very selective about where they give birth, although the features that attract them to certain sites may not be apparent. On each atoll, certain beaches seem to be preferred by parturient females, and it is not unusual for a single beach to harbor multiple mother/pup pairs at one time. Conversely, other females choose more isolated birth sites and may reuse the same site in multiple years. Monk seals typically give birth to pups on sandy beaches that are adjacent to shallow shoreline with coral substrate that tends to limit sharks access to pups before they are weaned and to provide protection from large surf conditions. (Westlake and Gilmartin 1990).

During molting, monk seals are especially selective in their choice of haulout sites. Along with elephant seals, monk seals are among the few pinnipeds that undergo a complete synchronous molt of both their fur and skin once each year (Kenyon and Rice 1959; Johanos et al. 1994). This process generally takes approximately 10-14 days, during which seals forage and move very little, and often choose sites different from those where they are otherwise found. While molting, seals often appear restless and uncomfortable and seem to be particularly sensitive to disturbance.

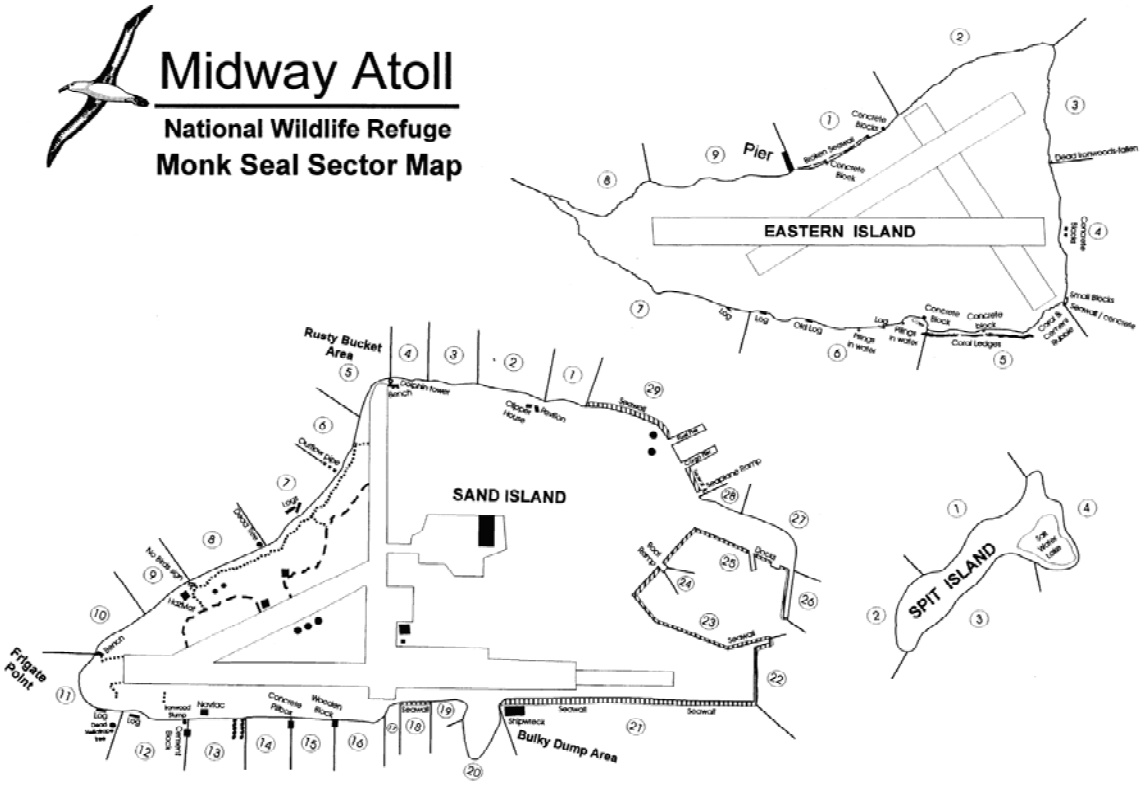
B. Midway Island: A Case Study of Monk Seal Haulout Patterns

The preceding discussion makes it clear that attempts to generalize about the monk seal's haulout patterns are apt to be disproved when the monk seal appears where least expected. The atoll with the most extensive data on monk seal seasonal haulout patterns is Midway Atoll, the penultimate atoll of the northwestern chain. During 1998 and1999, research personnel were on-site at Midway continuously and were able to compile an extensive record of monk seal movement patterns within the atoll. Seals were surveyed year-round (using a standardized protocol for conducting atoll counts) at all three of the atoll's islands (Sand, Eastern, and Spit; Figure 1). Since nearly all of these seals were marked with flipper tags or temporary "bleach" marks, it was also possible to determine the identity, and sex and size class of the seals on the beaches.

When discussing seal distribution and movements on Midway Atoll, several aspects of the atoll must be kept in mind. Certain beaches are unavailable to monk seals because of human emplacements. In particular, sectors 20-28 of Sand Island (Figure 1) are largely inaccessible to monk seals because of the protective seawall. In addition, human presence may influence seal usage patterns. This applies primarily to Sectors 1-4 of Sand Island (known as Pavilion Beach), which were open for public use during 1998-99. Also, surf conditions change seasonally so that some beaches suitable for monk seals during one season may be less attractive at other times.

Figures 2-6 depict seal distribution on the three main islands at Midway Atoll. It should be noted that seal presence is recorded and plotted by "sector" (a length of beach that is

Figure 1: Map of Midway Atoll showing island sectors used for haulout analysis.



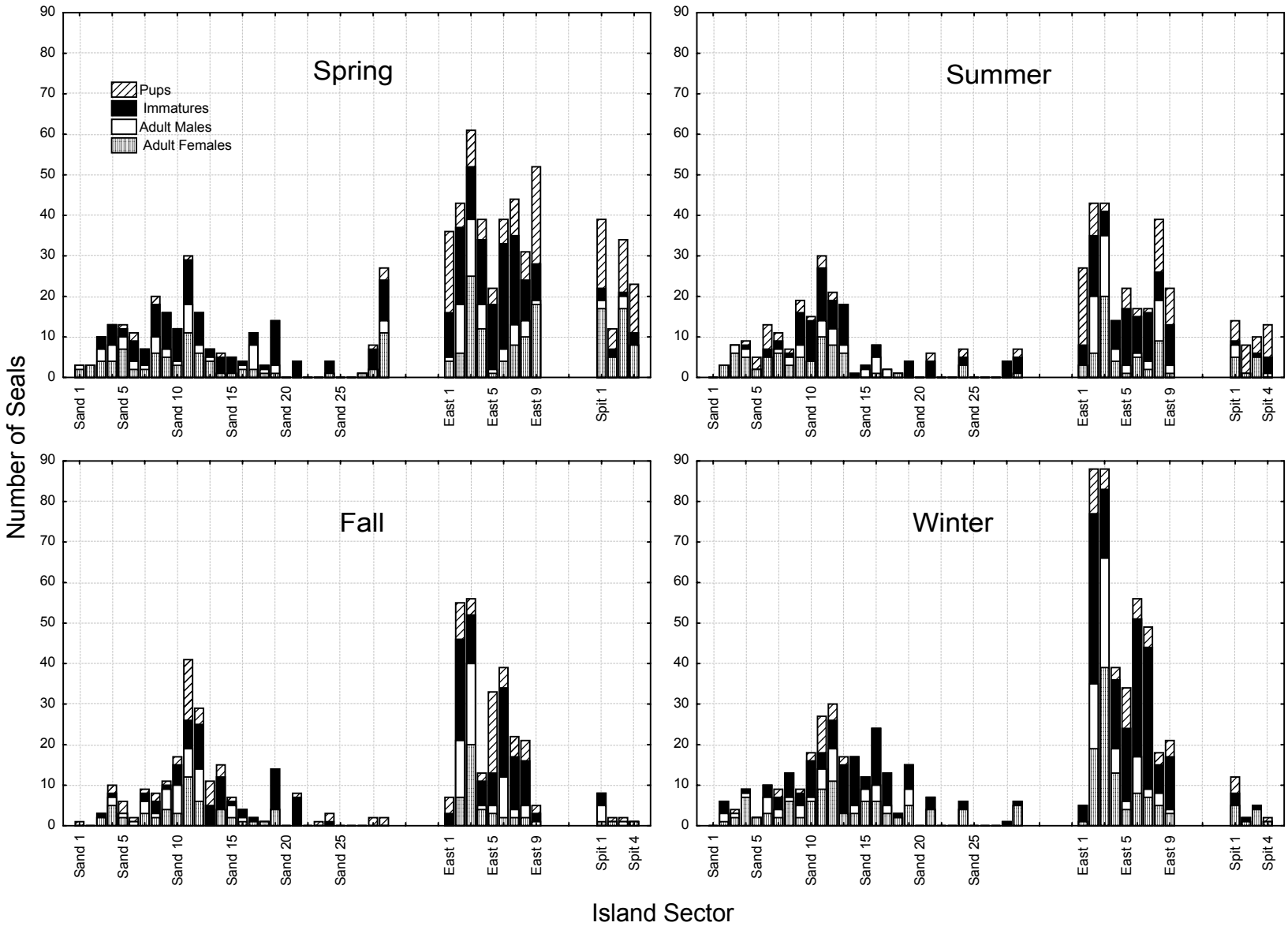


Figure 2: Seasonal distribution of monk seals (all size/sex groups) at Midway Atoll, 1998-1999.

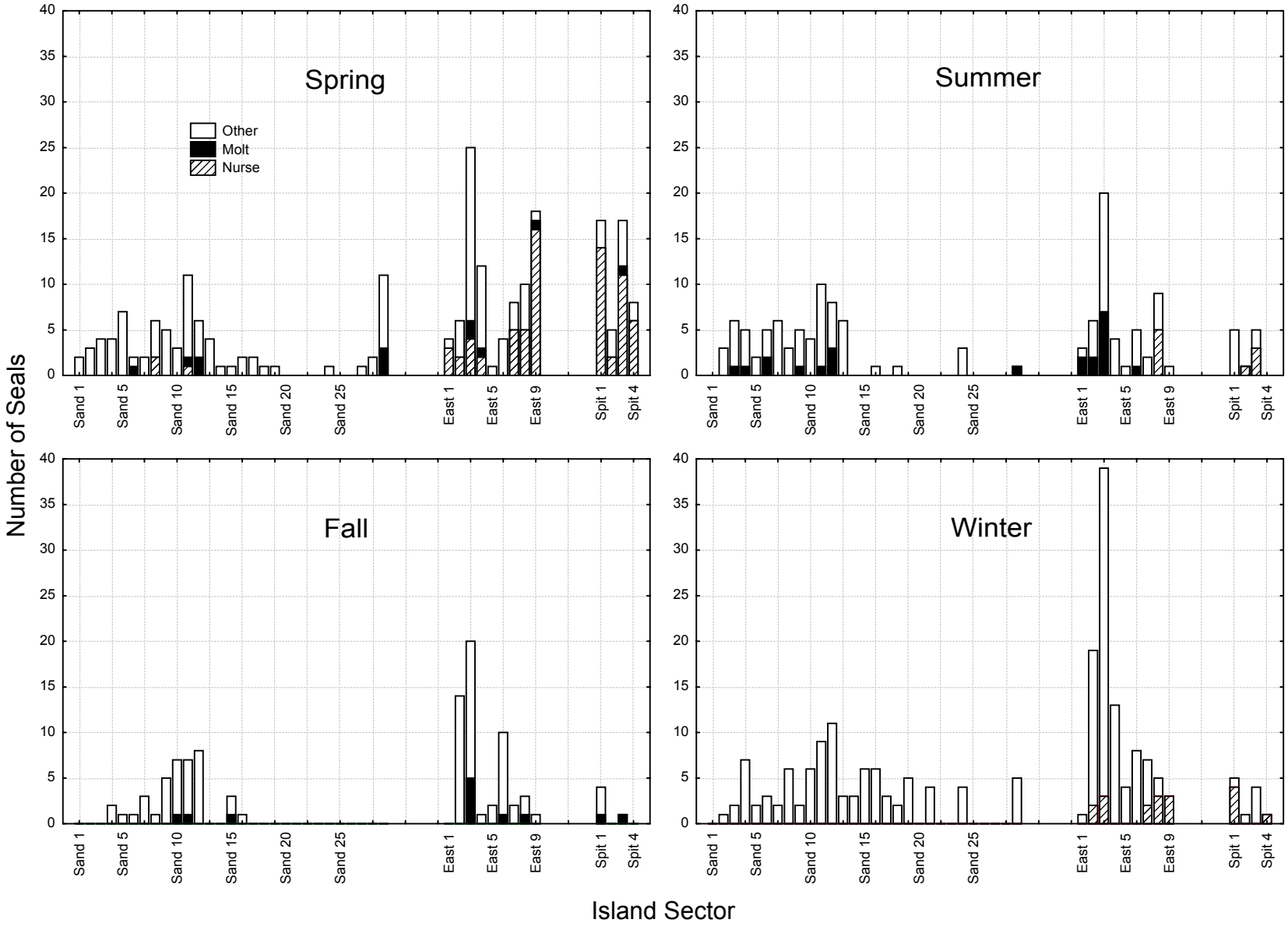


Figure 3: Seasonal distribution of adult female monk seals at Midway Atoll, 1998-1999.

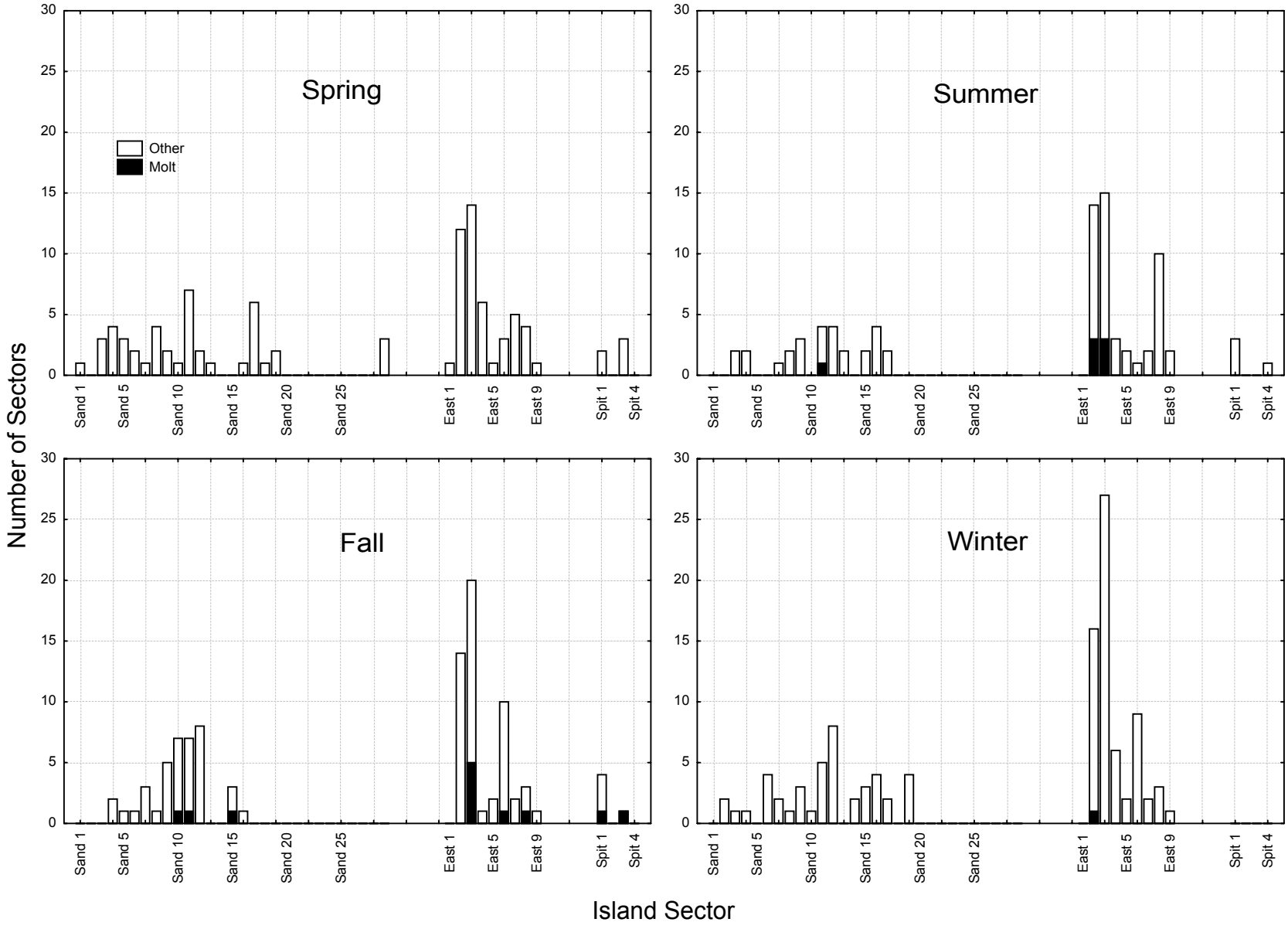


Figure 4: Seasonal distribution of adult male monk seals at Midway Atoll, 1998-1999.

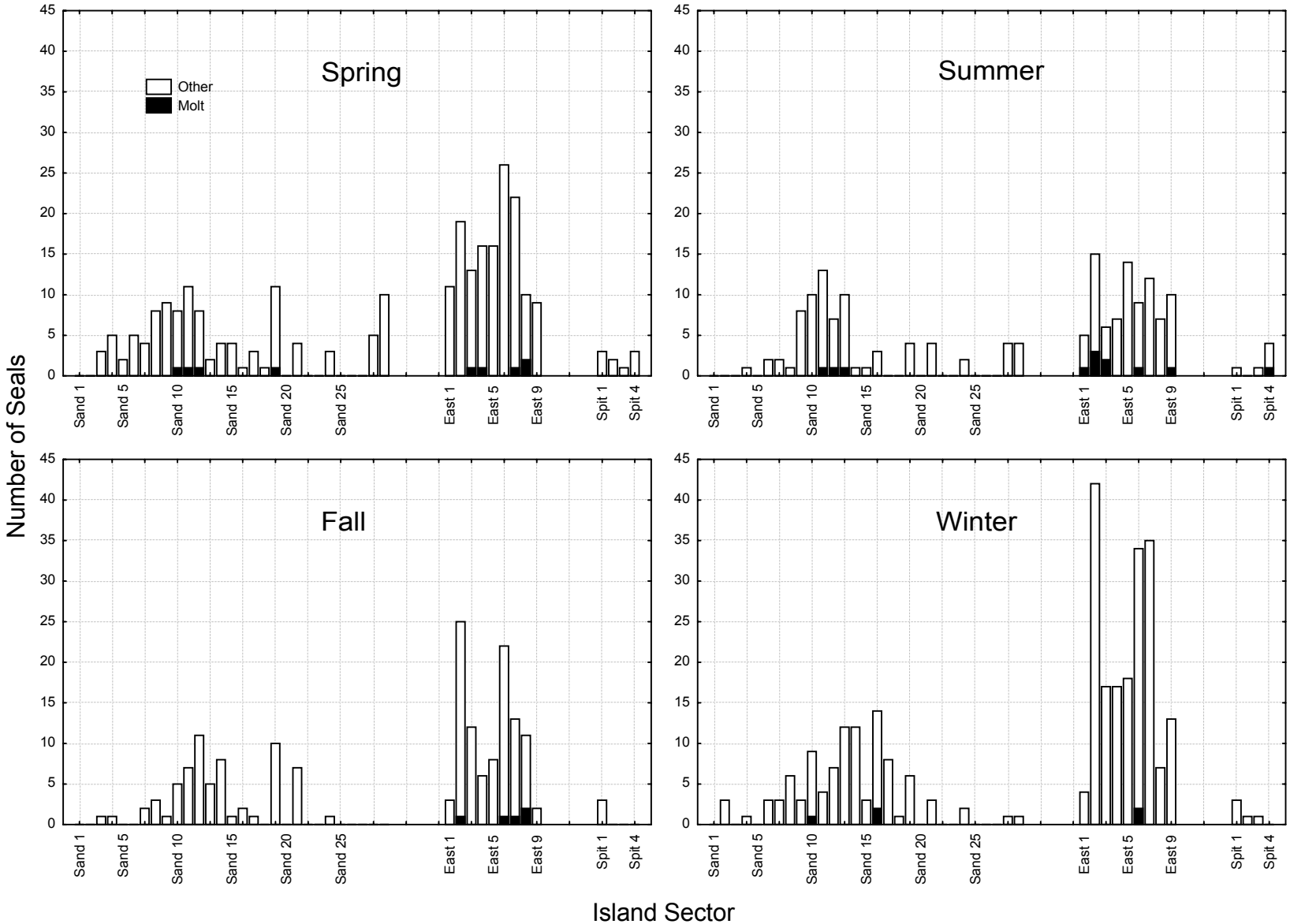


Figure 5: Seasonal distribution of immature monk seals at Midway Atoll, 1998-1999.

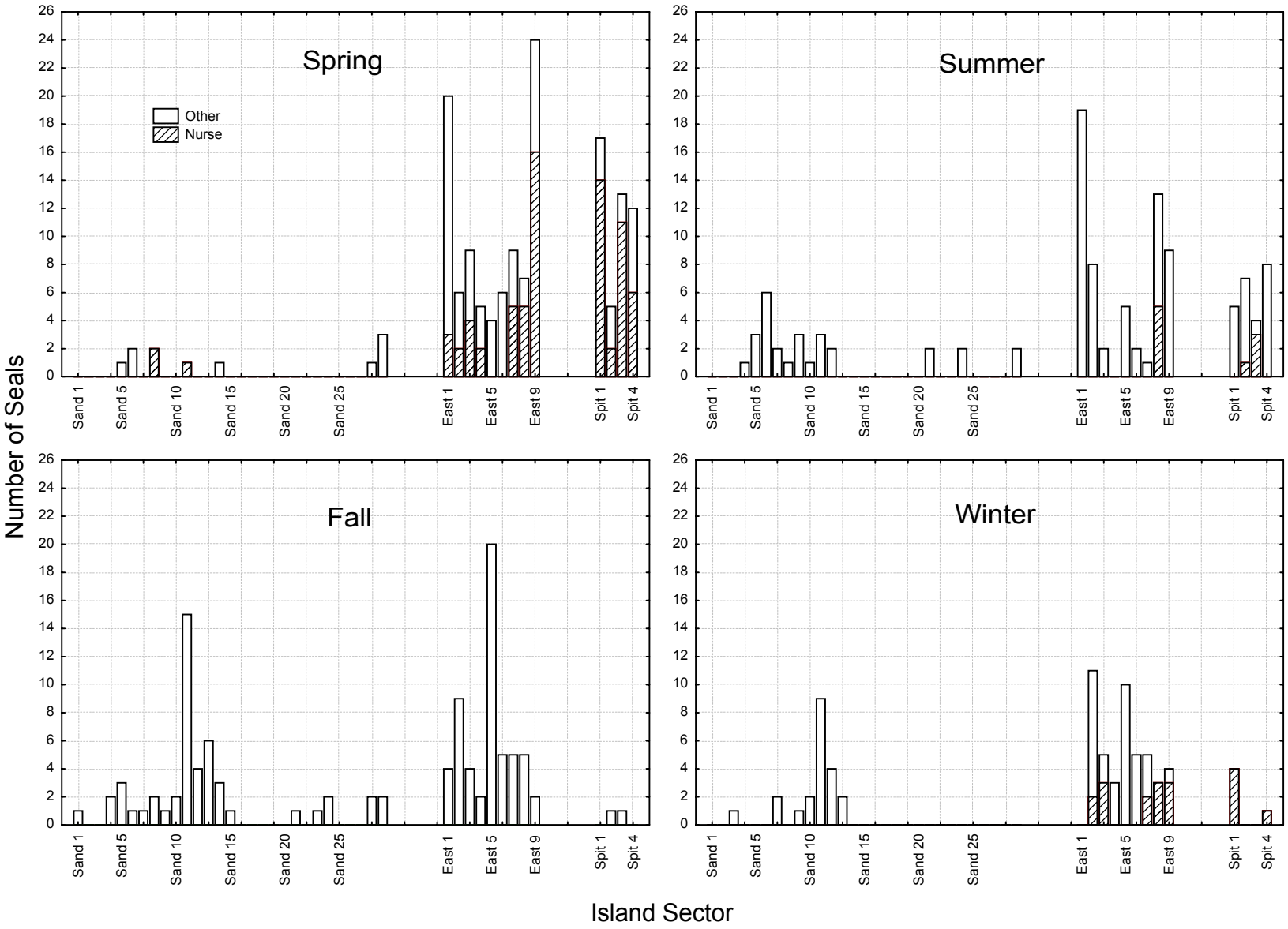


Figure 6: Seasonal distribution of monk seal pups at Midway Atoll, 1988-89.

usually more or less homogenous and easily identified by the observer: see Figure 1). Although the term "seal density" will be loosely used to describe differences in numbers of seals per sector, these are not true densities (number per unit area or length) because the sectors are not of uniform length.

It is evident that seal distribution on Midway Island differs both seasonally and by size/sex class (Figures 2-6). Among the salient observations are the following:

- The numbers and distribution of seals varied seasonally (Figure 2). For example, some sectors on East Island had nearly twice as many seals during winter as during summer.
- Seal density was highest on the two uninhabited islands (Eastern and Spit)
- Molting occurs primarily at Eastern Island for all size classes (Figures 3-6)
- Females with pups tended to segregate from other seals, and were found primarily in sectors 7-9 on Eastern Island, or on Spit Island (Figure 3)

As noted previously, some of the seasonal differences are likely attributable to surf conditions. In the summer, when seas are calm, some immature seals haulout on the fringing reef that surrounds the atoll. During this period the density of immature seals on the three islands (Sand, Eastern, and Spit) is lower than at other times of the year when storm surf precludes use of the exposed reef.

2. Interatoll Movements

A. Methodology for Determining Monk Seal Interatoll Movements

Most of the information available for evaluating interatoll movement rates is gleaned from the sighting records of seals first tagged as pups on their natal island. Numbered tags in the rear flippers of these seals (referred to as "cohort-tagged" seals, or simply "cohort" seals) help to identify them wherever they occur, so that their presence on multiple atolls is reliably detected and documented.

There are certain problems inherent in characterizing monk seal movements in this fashion. Foremost is the bias resulting from unequal field effort at the different atolls. The movements of individual seals can be documented only if biologists are present to detect the seal at each atoll. Some of the atolls have traditionally had longer, more regular field presence than have others. Seals that travel to these atolls are more likely to be detected than are seals that travel to locations with a more abbreviated field season, especially if their stay is brief. Another problem is that the data do not directly address the biological significance of the movement event. A movement record for a seal that briefly stops to rest at an atoll during a foraging excursion is of less demographic significance than that of an adult female that travels to another atoll to give birth. Ideally, we would like to know how each movement fits within the life history of the monk seal, but since that is rarely known (with the notable exception of reproductive events), we must be content with knowing that the movement plays some role in the species survival.

For all of the reasons cited above, the movement results reported here should be regarded as a good, but not complete, depiction of monk seal movement patterns. The deployment of satellite transmitters and other technologies will eventually help to fill in the remaining gaps in our understanding of monk seal movement patterns.

There are a number of ways to approach an analysis of monk seal movement patterns. Three will considered herein:

1. Annual movement rates (for each atoll, the proportion of seals in a particular size/sex class that move to some other atoll).
2. Destination (where do seals that leave the atolls go?)
3. Fidelity to natal atoll (how likely is it that a seal born on a particular atoll will remain there?)

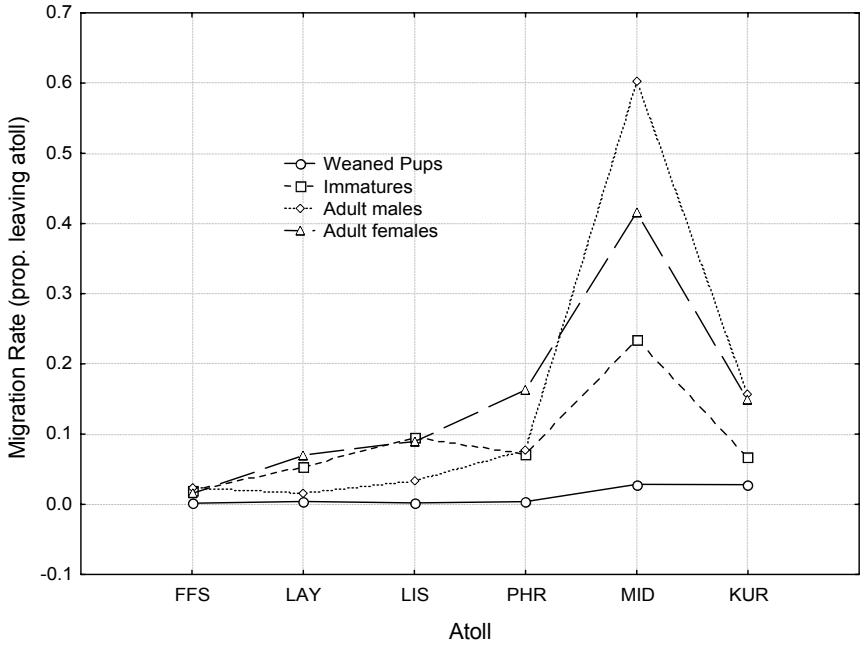
Each of these approaches reveals a different aspect of monk seal movements, and a complete portrayal of the movement patterns requires that all three be considered.

B. Annual Movement Rates

Annual movement rates were analyzed for four classes of seals: weaned pups (young-of-the-year), immatures (juvenile and subadult seals), adult males, and adult females. The primary results for the movement analysis are presented in Figure 7. For all four classes, there is a general pattern of increased inter-atoll movement rates proceeding from the eastern to the western end of the chain (Figure 7).

Adult seals are the most mobile of the four groups. Adult movement rates differ little between males and females, except at Midway Atoll where 60% of the males are resighted at another atoll each year, compared to only 40% of the adult females. Movements of weaned pups between atolls are rarely recorded except in the westernmost end of the chain (Midway and Kure). Immatures (approximately ages 1-5) are more likely to move than are weaned pups, but their movement rate remains well below that of adult seals. The exceptionally high rates for Midway Island (all classes) may be due to its unique geographic context, situated between Pearl and Hermes Reef and Kure Atoll. (The issue of geographic distance as a determinant of monk seal movements is considered further below). In addition, the extended field season throughout the year at Midway Atoll increases the likelihood that interatoll movement will be detected.

Figure 7. Monk seal migration rates for the six breeding atolls, by size/sex class.



C. Movement Destination

The preceding section dealt with the *rate* of movement in the outer atolls, that is, how likely is it that a seal found on one atoll will later be found at some other atoll? Now we consider the *destination* for seals that leave each atoll. This answers the question: "If a seal leaves this atoll, where will it go?"

Table 1. Destination probabilities for seals that move from each of the six breeding atolls. Rates given are the probability that an individual seal that moves from one atoll (the source) will be sighted at the destination atoll (French Frigate Shoals - FFS, Laysan Island – LAY, Lisianski Island – LIS, Pearl and Hermes reef – PHR, Midway Atoll – MID, Kure Atoll – KUR).

		Destination					
		FFS	LAY	LIS	PHR	MID	KUR
Source	FFS	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
	LAY	0.1720	0.0000	0.7930	0.0350	0.0000	0.0000
	LIS	0.0250	0.8154	0.0000	0.1481	0.0115	0.0000
	PHR	0.0100	0.0531	0.0089	0.0000	0.5058	0.2836
	MID	0.0000	0.0108	0.0000	0.3371	0.0000	0.6522
	KUR	0.0000	0.0000	0.0116	0.2584	0.7299	0.0000

Not surprisingly, seals that leave an atoll are most likely to travel to adjacent atolls (Table 1). This supports the conclusion that distance is a major determinant of monk seal movements to other landmasses. Thus the relatively high rate of interchange among the western atolls as compared to the eastern atolls may be attributed to geographic opportunity. The observation that

the three western atolls are geographically clustered (Table 2) and have the highest rate of interchange would seem to support such an interpretation. However, as revealed through satellite telemetry studies, monk seals are capable of undertaking long forays out to sea up to at least 200 km from their haulout site (Abernathy 1999). Individual seals have made exceptionally long journeys, including a Midway seal that gave birth on the Big Island, and a seal from French Frigate Shoals that traveled to Johnston Atoll (NMFS: unpublished data).

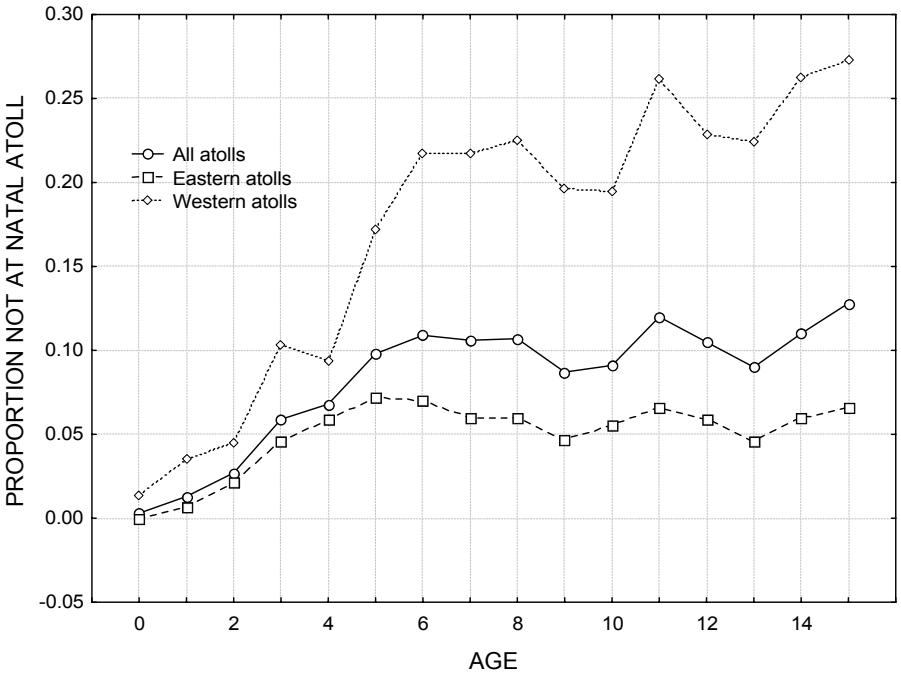
Table 2. Interatoll distance matrix for the six primary breeding atolls in the NWHI. Distances given are in statutory miles.

	FFS	LAY	LIS	PHR	MID	KUR
FFS	0	379	621	690	794	863
LAY		0	138	311	414	483
LIS			0	173	276	345
PHR				0	104	173
MID					0	69
KUR						0

D. Monk Seal Fidelity to the Natal Site

Another perspective on monk seal movements pertains to fidelity to the birth atoll. Not all seals born on a particular atoll remain there for their entire lifetime. As they explore their surroundings, a significant number of them eventually become expatriates (either temporarily or permanently) from their natal site (Figure 8).

Figure 8. Age-specific fidelity of monk seals to their natal site.



Monk seals born at one of the three western atolls (PHR, MID, and KUR) are more likely to be found at some site other than their natal atoll than are seals born at one of the three eastern atolls (FFS, LAY, and LIS). This is consistent with the previous discussion that seals in the western atolls are more mobile than their eastern counterparts. If all of the seals in the entire population are considered (regardless of which end of the chain they were born on), almost 10% of them are found on some atoll other than their natal site by age 10. By age 15, this number increases to 13%. (Because very few of the cohort seals are currently older than age 15, it is difficult to determine whether the percentage continues to increase with age).

3. Implications for Monk Seals in the main Hawaiian Islands

The preceding sections described monk seal movement and haulout patterns in the NWHI. It is worth considering the implications of these findings for potential movement patterns in the MHI. The greatest distance between two adjacent main islands (Kauai to Oahu: 72 miles) is comparable to the distance between Midway Atoll and its nearest neighbor atoll, Kure (*cf.* Tables 2 and 3). Seal movements between these two atolls are a fairly regular occurrence, suggesting that seals present in the main islands might be expected to move among the islands relatively freely. But, as noted previously, there are likely to be many factors other than distance that determine whether, or how frequently, seals travel to other sites. This will depend on how well the seal's biological demands are satisfied at its current site, the suitability of the habitat at the destination site, the level of disturbance, protection from storm surf, and other factors.

Table 3. Distance matrix for the main Hawaiian Islands. Distances shown are in statutory miles. For adjacent islands, distances are the width of the interisland channels (all other distances are approximated).

	Niihau	Kauai	Oahu	Molokai	Lanai	Maui	Kahoolawe	Hawaii
Niihau	0	17	161	202	223	246	259	312
Kauai		0	72	152	174	195	210	263
Oahu			0	26	49	70	86	139
Molokai				0	9	9	35	81
Lanai					0	10	30	73
Maui						0	7	30
Kahoolawe							0	53
Hawaii								0

Among the many insights derived from research in the NWHI data is that while the monk seal is an exceedingly versatile animal, certain areas fulfill the species biological requirements better than others. At this time, monk seals have been observed on all of the MHI and some sites are more commonly used for haulout than others. Although systematic investigations of the NWHI and the MHI indicate that most seals select haulout locations where there is little or no disturbance, some may occur and even give birth on beaches where there are large numbers of

people. As more research is conducted on monk seals in the MHI, preferred habitat for resting, molting, pupping, and foraging will be determined.

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