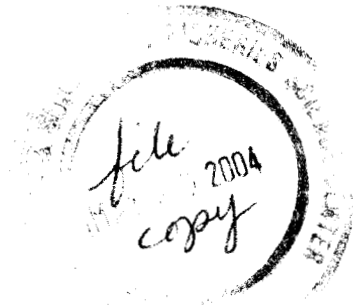


NOAA Technical Memorandum NMFS



OCTOBER 1984

**HAWAIIAN MONK SEAL OBSERVATIONS  
ON FRENCH FRIGATE SHOALS, 1980**

Patricia A. Johnson

Brian W. Johnson

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U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Southwest Fisheries Center

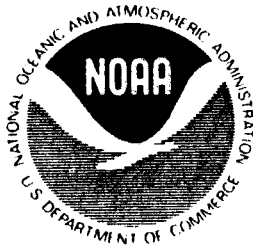
## NOAA Technical Memorandum NMFS

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## **NOAA Technical Memorandum NMFS**

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**OCTOBER 1984**

# **HAWAIIAN MONK SEAL OBSERVATIONS ON FRENCH FRIGATE SHOALS, 1980**

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**Prepared for National Marine Fisheries Service  
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**U.S. DEPARTMENT OF COMMERCE**

**Malcolm Baldrige, Secretary**

**National Oceanic and Atmospheric Administration**

**John V. Byrne, Administrator**

**National Marine Fisheries Service**

**William G. Gordon, Assistant Administrator for Fisheries**

## PREFACE

This report was prepared under Contract No. 80-ABC-00124 to the National Marine Fisheries Service by Patricia A. Johnson and Brian W. Johnson. The primary purpose of the contract was to summarize Hawaiian monk seal observational data collected during 1980 for the purpose of estimating the size of the French Frigate Shoals seal population. The statements and findings in this report are those of the contractors and do not necessarily reflect the view of the National Marine Fisheries Service.

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## ABSTRACT

A non-disturbance method of estimating Hawaiian monk seal populations, developed and tested previously on Laysan Island, was tested at French Frigate Shoals (FFS) during 1980. This Molt-Summation technique counts molting seals seen at 8-day intervals (the number of days seals normally take to molt) from May through November (the molting season). A total of 429 molting seals were counted on all islands except Shark and Disappearing, where molting seals could not be counted regularly. Adding the number of seals that could have molted on Shark and Disappearing Islands (extrapolated from the proportion of seals that used the two islands for haul-out) raises the estimate to 557 seals. Over 100 pups were born at FFS during 1980, resulting in a total population estimate of about 660 seals. The mean total atoll count during 1980 was 226 seals, suggesting only one-third of the population is normally ashore.

Although pups were born on eight islands within the atoll, over 90% were born on East, Round, and Whale-Skate. Both pupping and molt seasons were about 6 weeks later at FFS than at Kure or Laysan. The age structure of the FFS population was similar to Laysan, while the sex structure data suggested a nearly equal sex ratio, unlike other populations to the northwest where males may outnumber females 3:1. (A method is suggested for correcting the female bias inherent in counts made during the pupping season when only a part of the population is sexed.)



## INTRODUCTION

French Frigate Shoals (FFS) is located approximately 450 nmi northwest of Oahu (Fig. 1). Little is known about the use of the atoll by the Hawaiian monk seal, Monachus schauinslandi, prior to counts made in the 1950's which reported fewer than 50 seals (Rice 1960). The number of seals using the Shoals increased dramatically during the next 20 years with 274 seals counted in 1975 (Johnson et al. 1982). Although counts have apparently stabilized, the present high numbers and the increase over recent years are in marked contrast to conditions at all other major breeding atolls, where seal numbers have shown large declines during the same time period. Another difference in the FFS population is the ratio of males to females seen on most counts. The sex ratio is nearer equal than that found at other major breeding locations, where males generally outnumber females.

The haul-out areas available to seals at FFS include sand islands with and without vegetation, periodically exposed coral reefs, and a rock outcropping (La Perouse Pinnacle). As sand shifts with storms and currents, the islands vary in size, and some occasionally disappear for days or months.

The U.S. Coast Guard (USCG) maintained a 20-man station on Tern Island (the largest of the sand islands at FFS) from the mid-1940's until 1979. The U.S. Fish and Wildlife Service (FWS) assumed responsibility for the facilities at Tern Island when the USCG decommissioned the Loran station on 30 June 1979. The FWS biologists and dependents currently maintain the structures as a research station.

Censuses were conducted during 1980 to test the usefulness of a population estimation technique developed for the monk seal on Laysan Island (Johnson and Johnson 1981a). Testing the applicability of this "Molt Summation" technique (based on counts of molting seals) on a population such as FFS was necessary to assess the appropriateness of the technique to Hawaiian monk seals in general. Visits to the various islands and the amount of information collected were restricted to the minimum necessary to test the population estimation methodology. Incidental to collection of information on molting seals, data on mortality, natality, distribution, etc., were recorded, when possible. Two researchers, Susan Schulmeister and Ruth Ittner, were contracted to conduct the molt surveys. The study was conducted under MMPA/ESA Permit No. 258.

French Frigate Shoals and Laysan Island differ in several ways. French Frigate Shoals is a collection of small islands, dispersing the available haul-out area; Laysan is a single island, with the continuous beach and nearby barrier reef the only areas available for haul out. Counts at Laysan Island indicate males outnumber females by as much as 3:1, whereas counts at FFS indicate a more equal sex ratio. Lastly, the Laysan Island population experienced a major die-off in 1978, with up to one third of the seals either disappearing or known to have died (Johnson and Johnson 1981b). The FFS population, after experiencing a dramatic

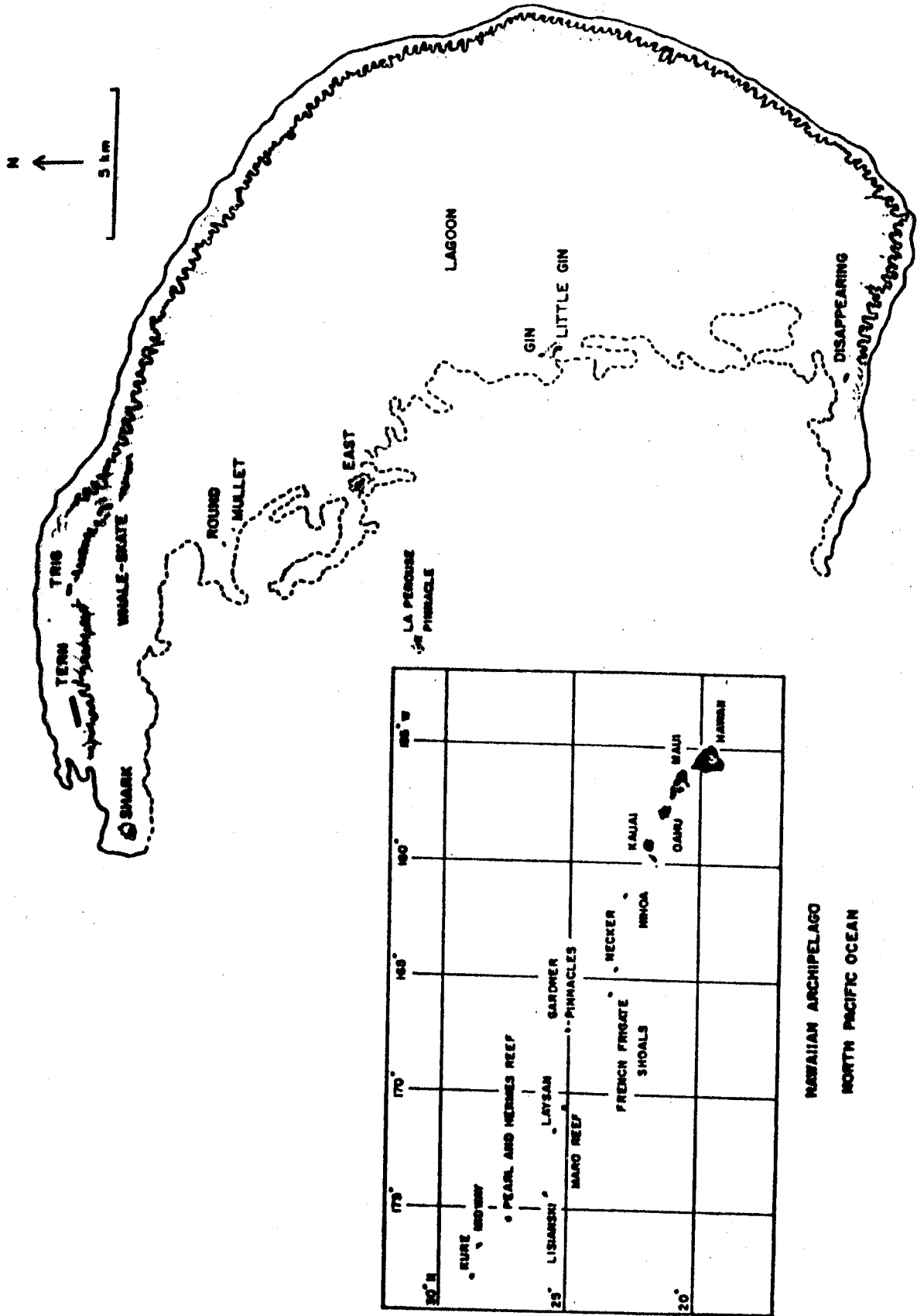


Figure 1. French Frigate Shoals, 23°45'N, 166°10'W.

population increase during the 1960's and early 1970's, appears to have remained stable since 1975 (Johnson et al. 1982).

This report summarizes the objectives, methods, and results of observations made at FFS during 1980. For a detailed description of the geography and history of the atoll, see Amerson (1971). Additional data on counts, behavior, mortality, tagged seal sightings, and the Tern Island population can be found in Schulmeister (1984). For comparative data from Laysan Island see Johnson and Johnson (1984).

## METHODS

The primary data for this report come from contracted molt surveys conducted between May and December of 1980. To familiarize ourselves with conditions and personnel and to train the observers, the authors spent a week at FFS in March of 1980. Brief visits were also made in September and November. Regular radio contact was maintained with the contracted observers throughout the study.

All areas available to seals could not be surveyed during the molt counts. Travel to Shark and Disappearing Islands was generally not possible due to rough sea conditions and time constraints. When conditions permitted, occasional visits were made by FWS and National Marine Fisheries Service (NMFS) personnel to both Disappearing and Shark Islands to count seals and look for molting animals. A few seals are known to visit La Perouse Pinnacle, including the use of underwater "sleeping caves" (Taylor and Naftel 1978), and some have been observed hauled out on exposed coral reefs, but these areas were also excluded from molt counts.

Counts of seals were made at 8-day intervals during the molting season, with occasional delays of up to 3 days. Data were generally collected by one of the contracted observers, but when possible, both observers participated in the molt surveys. Surveys were made by observers traveling between islands in a Boston whaler. Landings were made on the larger islands (Whale-Skate, East, Trig, Gin, and Little Gin) where animals were counted from shore. Counts of seals on the smaller islands (Bare, Mullet, Round, and the sand spits) were made from a boat offshore. Rough seas prohibited visits to Gin and Little Gin on five surveys. Atoll counts took 5 to 10 hours to complete, and usually started around 0900.

Onshore counts allowed more complete collection of data on age-class, sex, molt, and pupping rather than counts made from offshore. Landing spots were carefully selected to avoid disturbance. Binoculars were used for seal observations, and telephoto lenses for photographing seals. Care was taken to minimize disturbance to seals at all times.

In the course of other research, occasional visits were made to some islands between January and mid-May during which pup production and molting seals were noted. The contracted atoll surveys began in May, when the first seals were expected to begin molting. The initial molt surveys were done on 14 and 30 May, then at 8-day intervals, with the last survey

conducted on 1 December (data from 1 December have been included in the means for November unless otherwise noted.)

Information collected on each animal included age, sex (when possible), haul-out location, and stage of molt. The animals were classified as follows.

Age.--Animals were classified as either adult, subadult, juvenile, or pup. Subjective assessment of length was the primary criterion for age determination of animals older than pups. Because of the subjective nature of age classification, data from the juvenile and subadult age classes have usually been combined into a single "immature" age class. A description of the age classification system used can be found in Johnson and Johnson (1981a).

Sex.--A clear view of the ventral surface was required to determine sex. The only exceptions were adults attending pups (assumed to be female) and previously identified seals.

Molt.--Seals were classified as pre-molt (old pelage generally showing green algal growth), molting (visibly shedding the hair), or post-molt (silver gray color) as described in Johnson and Johnson (1981a). Pre-molt and post-molt seals were readily distinguishable by trained observers, the color difference remaining distinct for several months. The post-molt coloration was similar to the gray coat color of weaned pups (also in new pelage after shedding the black natal coat) and it became increasingly difficult to distinguish between small post-molt juveniles and weaned pups as the season progressed.

Data for estimating population size (using the Molt-Summation technique) were collected using methodology developed on Laysan Island (Johnson and Johnson 1981a). The assumptions of the Molt-Summation technique are:

1. All monk seals molt once, and only once, each year.
2. The shedding phase of the molt, when hair still attached to patches of the outer layers of epidermis is shed, can easily be recognized by trained observers.
3. Molting seals remain hauled out throughout most of the shedding phase (data from Laysan Island indicate molting seals are ashore approximately 90% of the time).
4. The average animal sloughs hair for 9 days.

Based on these assumptions, an accurate estimate of the population can be obtained by summing the number of molting seals counted at 8-day intervals throughout the molting season. Since the shedding phase lasts about 9 days and molting seals are ashore about 90% of the time, the molt estimate technique can be expected to overestimate the population size by roughly 5% if all molting seals ashore are counted. At FFS, the risk of

disturbance to animals and the difficulty in censusing islands from offshore probably resulted in some molting seals being missed on counts. Therefore, it is unlikely the Molt-Summation technique would overestimate the population.

Two additional factors affect the interpretation of the molt survey results. Due to the rotational system for FWS biologists at FFS, periods of overlap were infrequent for the two contracted observers. The lack of a photographic inventory of well-identified seals to help calibrate the observers' size classifications and infrequent chances to compare ageing, criteria may have resulted in inconsistencies in age classification between observers. Secondly, some areas available to seals were not included in the molt survey censuses, thus limiting discussion of results to partial atoll rather than total atoll statements.

## RESULTS AND DISCUSSION

### Population Counts

Mean monthly counts for all islands are listed in Table 1. Data are taken from counts listed in Appendix A. Additional counts of some islands, including aerial counts, can be found in Schulmeister (1984). The mean number of seals counted each month on the molt survey islands, both including and excluding pups, are shown in Fig. 2. Including pups, the counts increased through July, then declined. When pups are excluded, the mean monthly counts showed little change throughout the study period.

The mean monthly counts (including pups) for the individual islands showed a variety of trends. The most dramatic differences are shown in Fig. 3. The haul-out pattern for Whale-Skate Island was similar to that of the total molt survey islands but Round and Trig Islands show divergent patterns. Round (and to a lesser extent East Island) was used primarily during the pupping season, while use of Trig (and to a lesser extent Tern Island) was low in the pupping season but increased during the latter part of the molting season.

Table 1.--Monthly mean count data (with sample size) from French Frigate Shoals, 1980. Count data are listed in Appendix A.

| Island       | Mar. | Apr. | May  | June | July | Aug. | Sept. | Oct. | Nov. | Mean |
|--------------|------|------|------|------|------|------|-------|------|------|------|
| Tern         | 17-3 | 15-2 | 15-2 | 14-3 | 14-4 | 26-4 | 18-4  | 20-4 | 27-4 | 18   |
| Trig         | 26-3 | 16-2 | 12-2 | 17-3 | 18-4 | 26-4 | 29-4  | 42-3 | 50-4 | 26   |
| Whale-Skate  | 33-3 | 39-2 | 52-2 | 61-3 | 74-4 | 68-4 | 72-4  | 57-3 | 55-4 | 57   |
| East         | 24-3 | 29-2 | 48-2 | 47-3 | 50-4 | 35-4 | 29-4  | 21-4 | 18-4 | 33   |
| Round        | 3-3  | 7-2  | 31-2 | 38-3 | 32-4 | 16-4 | 8-4   | 2-4  | 4-4  | 16   |
| Mullet       | 5-3  | 5-2  | 4-2  | 1-3  | 1-4  | 5-4  | 4-4   | 2-4  | 1-4  | 3    |
| Bare         | 2-3  | 1-2  | 3-2  | 2-3  | 5-4  | 3-4  | 2-4   | 2-4  | 2-4  | 2    |
| Gin          | 8-2  | 10-2 | 10-2 | 8-3  | 7-4  | 7-3  | 7-4   | 8-3  | 3-1  | 8    |
| Little Gin   | 6-2  | 8-2  | 10-2 | 9-3  | 9-4  | 9-3  | 6-4   | 6-3  | 5-1  | 8    |
| Spits        | 12-2 | 2-2  | 6-2  | 5-3  | 2-4  | 3-3  | 5-4   | 1-3  | 0-1  | 4    |
| Subtotal     | 136  | 132  | 191  | 202  | 212  | 198  | 180   | 161  | 165  | 175  |
| Shark        | 22-2 | 24-1 | 7-1  | 11-2 | 9-3  | 6-1  | 13-1  | --   | 31-1 | 15   |
| Disappearing | 27-1 | 33-3 | 27-2 | 44-1 | --   | 25-1 | 40-1  | --   | 54-1 | 36   |
| Total        | 185  | 189  | 225  | 257  | --   | 229  | 233   | --   | 250  | 226  |

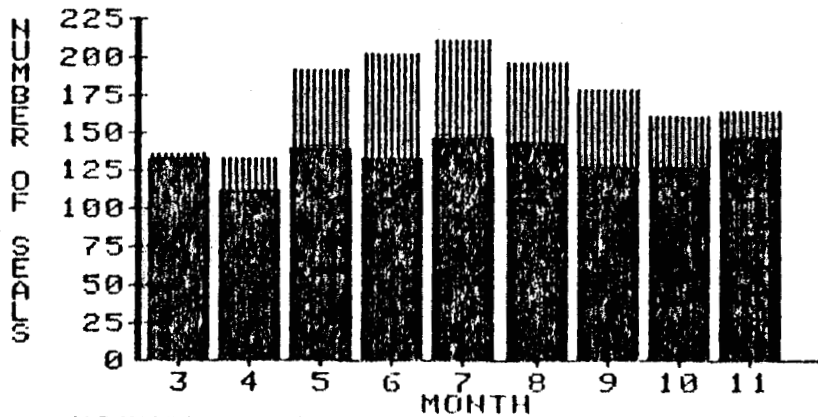


FIGURE 2. MEAN MONTHLY COUNTS AT FFS IN 1980. SOLID BARS ARE NONPUP COUNTS, STRIPES INCLUDE PUPS.

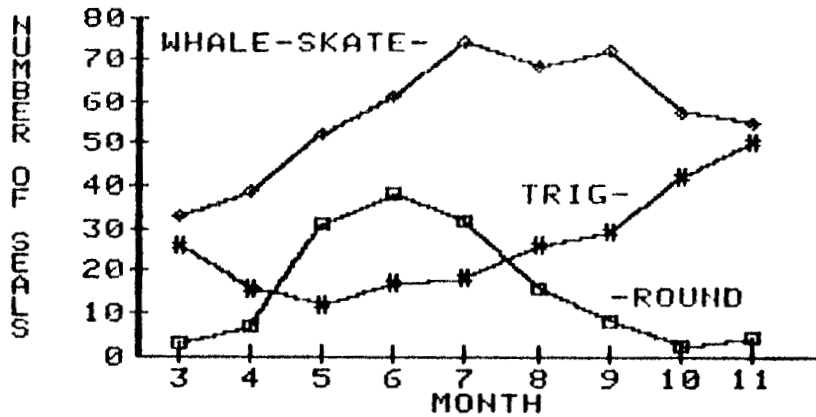


FIGURE 3. PATTERNS OF USE FOR THREE HAUL-OUT ISLANDS AT FFS, 1980.

The authors participated in two aerial counts which included both Shark and Disappearing Islands. The higher of these counts was made on 18 November, when ground counts of all molt survey islands (except Gin and Little Gin) and the aerial counts of Shark and Disappearing Islands resulted in a total seal count of 238.

While only two aerial counts were made of seals on Shark and Disappearing by the authors, additional counts were made by NMFS, FWS, and other personnel (counts listed in Appendix B). Table 2 presents total atoll counts, including only surveys when a count of Disappearing Island was made within 3 days of a count of the molt survey islands. The highest total atoll count of 258 seals on 30 May includes a count of Disappearing on 2 June. (No counts were made of Disappearing during July, the time when most seals were hauled out on the molt survey islands.)

The highest counts from 1975 through 1980 are listed in Table 3. They indicate the atoll population has remained relatively stable during the last few years.

## Distribution

### Total Atoll

Seals regularly hauled out on some islands that were not visited in the course of the molt surveys. These areas include Shark, Disappearing, La Perouse Pinnacle, and exposed reefs. Of these areas, only Shark and Disappearing were known to have had enough use to affect the calculation of distribution patterns.

Table 4 presents data on the relationship between island size and seal usage for the 12 commonly used sand islands. The percentage of the seals ashore using each area is calculated from the mean monthly count data (Table 1). These results suggest about 77% of the seals haul out on the areas regularly included in the molt surveys. The largest number of seals hauled out on Whale-Skate, followed in descending order by Disappearing, East, and Trig. These four islands accounted for about two-thirds of the seals. The density of seals on three of the smaller islands, Round, Bare, and Shark, was much greater than that found on any other haul-out area. Mullet and Disappearing were also used by more seals than would be expected based on size.

Three islands accounted for 91% of the pups born at FFS. The greatest number of pups were born on East, followed by Round and Whale-Skate. On Whale-Skate the pupping activity was roughly proportional to size and total seal count. On both East and Round islands, a higher proportion of births occurred than would be expected based on size and total seal use. In particular, it is surprising that so many births occurred on an island as small as Round (0.5 acres). At the other extreme, both Tern and Trig were well below the births that would be predicted based on size and total use.



Table 2.--Total atoll surveys. (Includes all dates when a count of Disappearing was made within 3 days of a molt survey count. S = surface count, A = aerial count, O = offshore count, R = count made from roof of building on Tern island.)

| Molt survey |     |      | Disappearing |     |      | Shark |     |      | Total |
|-------------|-----|------|--------------|-----|------|-------|-----|------|-------|
| Date        | No. | Type | Date         | No. | Type | Date  | No. | Type |       |
| 3/05        | 154 | A    | 3/05         | 27  | A    | 3/05  | 10  | A    | 191   |
| 4/17        | 113 | A    | 4/17         | 23  | A    | 4/17  | 24  | A    | 160   |
| 4/28        | 151 | S    | 4/29         | 43  | A    |       | --  | --   | 194   |
| 5/30        | 210 | S    | 6/02         | 44  | S    | 5/30  | 4   | R    | 258   |
| 8/27        | 190 | S    | 8/29         | 25  | O    | 8/27  | 4   | R    | 219   |
| 9/10        | 174 | S    | 9/08         | 40  | A    | 9/10  | 13  | A    | 227   |
| 11/18       | 153 | S    | 11/18        | 54  | A    | 11/18 | 31  | A    | 238   |

Table 3.--Highest count for each year from 1975 through 1980 at French Frigate Shoals.

| Year | Month  | Count | Source                         |
|------|--------|-------|--------------------------------|
| 1975 | *      | 274   | Johnson et al. 1982            |
| 1976 | March  | 195   | Johnson et al. 1982            |
| 1977 | April  | 223   | Johnson et al. 1982            |
| 1978 | August | 200   | Coleman, FWS, unpublished data |
| 1979 | May    | 241   | Rauzon, FWS, unpublished data  |
| 1980 | May    | 258   | Present study                  |

\*The date of this count is not available in published accounts.

Table 4.--Distribution of seals at French Frigate Shoals during 1980, including comparisons between the size of each island and the percentage of the population using the island for haul-out and for pupping.

| Island       | Percent area <sup>1</sup> | Percent seals <sup>2</sup> | Percent births <sup>3</sup> | Seals/acre |
|--------------|---------------------------|----------------------------|-----------------------------|------------|
| Tern         | 24.4                      | 8                          | 0                           | 1.0        |
| Trig         | 13.8                      | 12                         | 1                           | 2.6        |
| Whale-Skate  | 23.4                      | 25                         | 27                          | 3.4        |
| East         | 15.7                      | 15                         | 34                          | 2.9        |
| Round        | 0.7                       | 7                          | 30                          | 32.0       |
| Mullet       | 0.6                       | 1                          | 0                           | 7.5        |
| Bare         | 0.1                       | 1                          | 0                           | 20.0       |
| Gin          | 4.5                       | 3                          | 1                           | 2.5        |
| Little Gin   | 7.1                       | 3                          | 3                           | 1.6        |
| Spits        | ?                         | 2                          | 0                           | ?          |
| Shark        | 1.1                       | 7                          | 1                           | 18.8       |
| Disappearing | 8.6                       | 16                         | 3                           | 5.8        |

<sup>1</sup>Area (acres) for each island taken from Amerson (1971), except for Tern Island. G. H. Balazs and W. G. Gilmartin (personal communication) recalculated the area of Tern to be 35 acres rather than 56.8 listed in Amerson (1971). For these calculations, the acreage of Tern was halved since about that much of the island is unavailable for haul-out. Area of all islands varies with season and year.

<sup>2</sup>Seal numbers based on mean count from Table 1.

<sup>3</sup>Birth numbers are based on mean estimate from the 40-day interval pup production estimate in Table 6.

Disappearing and Shark Islands also appear to have comparatively few pups but births could have been missed on these islands.

#### Molt Survey Islands

The counts of seals on the molt survey islands were the only counts for which age/sex composition and number of molting seals could be determined. While seals were generally seen on all the islands during censuses, there were marked differences in the degree of use for the various haul-out locations.

Table 5 presents data on usage of the molt survey islands. The islands most used for haul-out were Whale-Skate, East, and Trig. When pups and nursing females were excluded, the most used areas were Whale-Skate, Trig, and Tern. East Island was used by the most nursing mothers, followed by Round and Whale-Skate. East was second to Whale-Skate in use by weaned pups. Whale-Skate and Trig were used by 78% of the molting seals, with Tern and East the only other islands where molting seals were seen regularly.

Absolute determination of the age/sex structure was not possible for FFS due to observer differences in classifying seals (see Age Structure section). On any particular census, however, the biases which exist should affect all islands equally, allowing the islands to be ranked. The three areas with the highest percentage of males were the sand spits, Trig, and Tern. The four areas having the highest percentage of females were Round, Mullet, Bare, and East. The highest percentage of adults was found on Round, East, Trig, and Little Gin. The highest percentage of immatures occurred on Mullet, the sand spits, Tern, and Bare.

#### Summary of Individual Islands

The following summaries are based on data from Table 5 which excluded Shark and Disappearing. Brief summaries of the limited data from those two islands are included at the end of the section.

Tern.--Tern is the largest of the sand islands and is the only island with regular human habitation. Part of the shoreline is unavailable to seals due to man-made structures. Much of the beach crest is vegetated. With each year since the closing of the USCG facility, the number of seals using Tern Island has increased (Schulmeister 1981). Tern Island was used by about the same number of seals as Round Island but unlike the pattern seen at Round, seals used Tern throughout the study period with numbers increasing in the fall. No pups were born on Tern although pregnant females and weaned pups were frequently sighted. Tern was used regularly by molting seals, particularly adult males.

Table 5.--Distribution of Hawaiian monk seals on the molt survey islands at French Frigate Shoals, 1980 (excludes Disappearing and Shark Islands).

| Island      | Mean count <sup>1</sup> | Sub-total <sup>2</sup> | Weaned pups <sup>3</sup> | Births <sup>4</sup> | Molting seals <sup>5</sup> |
|-------------|-------------------------|------------------------|--------------------------|---------------------|----------------------------|
| Tern        | 19                      | 18                     | 1.2                      | 0                   | 3.7                        |
| Trig        | 27                      | 24                     | 2.1                      | 1                   | 10.0                       |
| Whale-Skate | 59                      | 42                     | 9.4                      | 25                  | 15.0                       |
| East        | 33                      | 15                     | 8.4                      | 32                  | 3.0                        |
| Round       | 17                      | 3                      | 4.4                      | 28                  | 0.0                        |
| Mullet      | 3                       | 2                      | 0.6                      | 0                   | 0.0                        |
| Bare        | 3                       | 3                      | 0.1                      | 0                   | 0.1                        |
| Gin         | 8                       | 7                      | 1.0                      | 1                   | 0.1                        |
| Little Gin  | 7                       | 6                      | 0.5                      | 3                   | 0.3                        |
| Spits       | 4                       | 4                      | 0.2                      | 0                   | 0.0                        |

<sup>1</sup> Numbers from Table 1, except all April counts and aerial counts are excluded.

<sup>2</sup> Subtotal excludes parturient females and all pups.

<sup>3</sup> Mean count of weaned pups, from Appendix A.

<sup>4</sup> Mean of five 40-day estimates of pup production from pupping section of report.

<sup>5</sup> Mean number of molting seals seen on all molt surveys made between 14 May and 1 December.

Trig.--Trig is vegetated over about half of its area. The mean count ranked Trig third in total usage. When sightings of parturient females and all pups are excluded from the counts, Trig became the second most used haul-out area. Trig also ranked second in use by molting seals. An average of two weaned pups were seen on Trig; one pup was born on the island.

Whale-Skate.--The second largest of the islands, Whale-Skate is long and narrow with vegetation along the beach crest of much of the island. It was used by the largest number of seals throughout the study period, and the largest number of molting animals. Whale-Skate ranked third in use by parturient females, and was used by large numbers of weaned pups.

East.--East island is the third largest island and is vegetated. It has been the focus of much of the green sea turtle, Chelonia mydas, research done since 1972 (Balazs 1980). East ranked highest in use by parturient females and near Whale-Skate in use by weaned pups. When parturient females and all pups were excluded, East dropped from second to

fourth in seal usage. An average of three molting seals were seen during censuses.

Round.--A small, circular island, Round has no vegetation. The island is surrounded by coral reefs and shallow water. The island was primarily used by parturient females, suckling, and weaned pups. Excluding parturient females and pups, the mean count for Round drops from 17 to 3 seals. Round ranked second to East as a rookery area, with an estimated 28 births.

Gin and Little Gin.--Both Gin and Little Gin are unvegetated sand islands. Little Gin, the larger of the two, is the highest of the sand islands at FFS. Counts were generally low, with a combined island mean of 15 seals. At least one pup was born on each island, but the pup born on Gin apparently did not survive to weaning. Occasional molting seals and weaned pups were seen on Gin and Little Gin.

Bare, Mullet, and Sand Spits.--These small sand islands were used infrequently by seals and all were subject to tidal inundation. The mean count for all areas combined was eight seals. Molting seals and weaned pups were rarely seen hauled out on these small islands and no births were recorded.

Shark.--Shark Island was visited on six of the molt surveys. Rough water prohibited close approach on most days. One pup was known to be born on Shark. Aerial and occasional ground counts ranged from 5 to 34 seals.

Disappearing.--Because of the rough water normally around Disappearing and the distance from Tern, the only counts available from 1980 were aerial counts and infrequent visits from personnel on research vessels. At least three pups were born on Disappearing, and counts ranged from 23 to 54 animals.

## Pupping

### Seasonal Distribution

Pups were born on eight islands during 1980; Round, East, Whale-Skate, Gin, Little Gin, Trig, Disappearing, and Shark. The first pup was born in early March, the last in October. The maximum number of mothers attending pups was 49, seen on 7 June. The maximum total pup count (including attended and weaned pups) was 71, also on 7 June.

The pupping season can be described in two ways: by actual births, beginning with the first birth and ending with the last; or by counts of mother-pup pairs, beginning with the first birth and ending when the last pup is weaned. The peak of pupping and the midpoint of the pupping season will be later when based on counts of mother-pup pairs.

The 1980 pupping season at FFS can best be described by counts of mothers attending pups because surveys were too infrequent to record actual

births. Figure 4, which presents the maximal monthly counts of mothers attending pups, shows the peak of pupping occurred in June. Data are taken from incidental ground counts prior to May and from molt surveys after May.

Although the actual number of births was not determined, the number of births per month can be estimated from data collected on the size of pups seen on each census. Whenever possible, attended pups were subjectively assigned a size, either small, medium, or large. Based on growth stages of pups on Laysan Island, a pup was called small for about a week, medium for 20 to 24 days, and large, thereafter. One pup was present in early March on Round Island. By the end of March two more pups had been born, one on East, the other on Whale-Skate. By the end of April, there were an additional 24 births. Figure 5 shows the births per month, with births from May through September estimated by the 8-day interval counts of small pups (see Appendix C). Since pups were not sized on all surveys, some data were extrapolated, resulting in at best a rough estimate of births per month at FFS. However, the shape of the curve is similar to that shown by counts of mother-pup pairs. The peak in May was about 1 month earlier than that shown by count data, as expected.

Appendix D compares pupping data from FFS with data from Kure and Laysan. The comparison shows the pupping season at FFS occurred about 45 days later than at other atolls to the northwest.

#### Pup Production

It was not possible to count the total number of pups born, or the number born per island, as visits were infrequent and the pups could not be individually recognized. Pup production can be estimated using a technique first mentioned by Kenyon and Rice (1959). They suggested that counting attended pups at intervals approximating the mean lactation period can provide an estimate of total pup production. The technique was tested on data collected from 1977 through 1980 on Laysan Island, where the mean weaning age (36 days) and actual pup production were known. The data presented in Appendix E suggest that on Laysan, the method underestimated the number of births (by roughly 9%), but correctly estimated the pup recruitment (as defined by the number of pups surviving through weaning). The greater the mortality of pups prior to weaning, the greater the degree of underestimation of total births.

Molt surveys at FFS were made every 8 days. Counts of pups during the surveys allowed five 40-day interval estimates. The 40-day interval was selected over a 32-day interval to err on the conservative side as mean weaning age was not known. Table 6 presents data showing the estimated number of pups born on Round, East, and Whale-Skate Islands to be between 81 and 91. The minimum number of pups known to have been born on the other islands was nine (three pups each on Disappearing and Little Gin, one each on Shark, Gin, and Trig). The mean of the five series (85) added to the pups born on other islands gives an estimated pup production of 94.

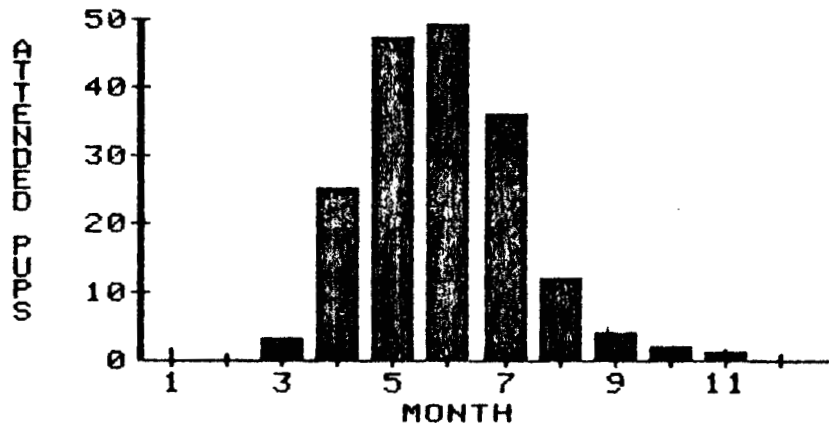


FIGURE 4 MAXIMUM MONTHLY COUNT OF MOTHER/PUP PAIRS AT FFS, 1980.

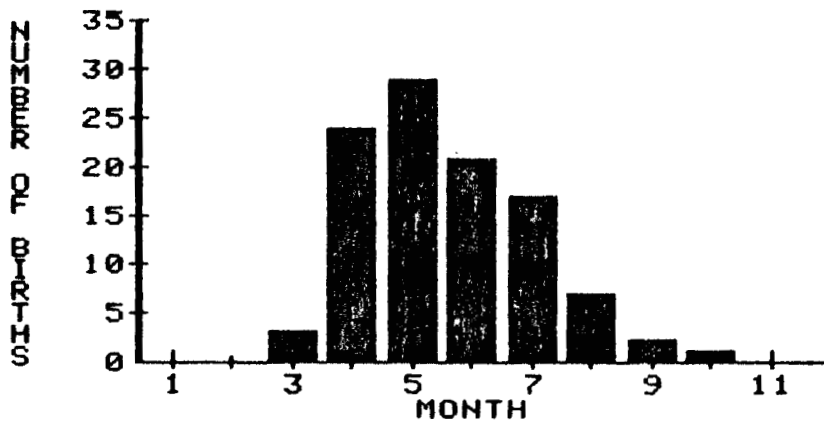


FIGURE 5 ESTIMATED NUMBER OF BIRTHS PER MONTH AT FRENCH FRIGATE, 1980.

Table 6.--Estimate of 1980 pup production at French Frigate Shoals based on 40-day interval counts of attended pups.

| Series | Start date | Round | East | Whale-Skate | Other | Total |
|--------|------------|-------|------|-------------|-------|-------|
| 1      | 3/03       | 30    | 33   | 22          | 9     | 94    |
| 2      | 3/11       | 28    | 32   | 25          | 9     | 94    |
| 3      | 3/19       | 29    | 34   | 28          | 9     | 100   |
| 4      | 3/27       | 25    | 31   | 25          | 9     | 90    |
| 5      | 4/04       | 27    | 31   | 26          | 9     | 93    |
| Mean   |            | 28    | 32   | 25          | 9     | 94    |

While little data on lactation interval or pup survival are available for FFS, pups appear to be weaned at about the same size and stage of molt as at Laysan. At least five pups were known to have died or been abandoned prior to normal weaning. Assuming mothers at FFS nurse pups about 36 days (for pups surviving until normal weaning), then using a 40-day interval will underestimate pup production by 10% (correcting for the pups that could have been born and weaned between counts). Adding 10% of 94 gives a total pup estimate of 104. If mortality of pups on FFS is similar to that on Laysan, then a further correction of 9% should be made to account for births that would not be detected when using a 36-day interval. This would bring the FFS estimate to 114 pups. (If the mean weaning age is longer, or if pup mortality is less than at Laysan, this estimate could be high.)

Two different approaches to determining pup production also indicate over 100 pups were born. First, the small pup tally mentioned in the Seasonal Distribution section estimated 104 pups. The second method extrapolates the ratio of maximum mother-pup count to total pup production from Laysan Island to the FFS population. The mean ratio for Laysan Island from 1977 through 1980 was 0.43. The yearly ratios were 0.43, 0.52, 0.41, and 0.39, respectively. Applying these ratios to the maximum mother-pup count of 49 at FFS results in an estimate of 94 to 126 pups, with 114 pups the mean.

The small pup results and the 40-day estimate can be compared to known pup production numbers using the 7 June survey data. On 7 June a total of 71 pups were counted on the molt survey islands. An additional three attended pups were seen on Disappearing on 2 June, and one dead pup had been seen on Round Island earlier. Added together, the lowest number of pups that could have been born by 7 June was 75. On 7 June the small pup tally accounted for 74 pups, and the total for the 40-day series falling on that date was 75 pups. This close fit with the minimum number of pups known to have been born shows both estimates are reasonable but conservative methods of assessing pup production.



In conclusion, the best estimates indicate about 114 pups were born at FFS in 1980, with about 104 surviving through weaning. Data from 1977 and 1981 indicate over 100 pups were born in each of those years (Appendix F), suggesting that the pup production at FFS in 1980 was not unusual.

#### Breeding: Female Dorsal Scars

In 1978 a breeding encounter was observed about 1 km off Laysan Island (Johnson and Johnson 1981b). Numerous males encircled an adult female and some males repeatedly bit the back of the female causing extensive injury. The lesion exposed blubber and muscle, and probably resulted in the death of the female. A similar incident was observed again at Laysan in 1982 (W. G. Gilmartin, personal communication).

Although other breeding encounters have been observed which involved only one male and did not result in injury to the female (Johnson and Johnson 1981b; Schulmeister 1984), adult females with extensive scars along the dorsal midline have been observed at all major hauling areas. This raises the possibility that breeding related injuries to adult females are not uncommon and may occur primarily when the encounters involve more than one male.

One test of this theory is to compare the percentage of females with dorsal scars at Laysan and at FFS. At Laysan, where adult males outnumber adult females 3:1 (Johnson and Johnson 1981a), the probability of multi-male breeding encounters should be greater than at FFS where the sex ratio is nearly equal (see Sex Ratio section). Comparing the frequency of dorsal scars from animals seen on ground counts would probably be biased as conditions for viewing animals are different at Laysan and FFS. The presence of a sample of seals individually recognizable by natural marks at both haul-out locations provides a less biased basis for comparison.

Based on photographs and sketches made primarily by Susan Schulmeister and Ruth Ittner from 1979 through 1981, 52 adult females with individually recognizable natural marks were identified at FFS (S. Schulmeister, personal communication). Of these, only six (12%) had the distinct dorsal midline scars which might have resulted from a breeding injury.

On Laysan, where a much more intensive effort was made to identify all seals, 96 adult females were recognizable as distinct individuals over the 4 years of the study. Of these, 21 were recognizable only on the basis of tags or minor marks. Of the remaining 75 females with natural marks comparable to those used for identification at FFS, 26 (35%) had distinct dorsal midline scars.

Chi-square analysis indicated the dorsal scarring rate observed at FFS was significantly lower than that seen at Laysan ( $\chi^2 = 9.96$ ,  $P < 0.005$ ).

These data suggest that when the sex ratio becomes skewed in favor of adult males, the frequency of multi-male breeding encounters may increase, resulting in an increase in potentially fatal injuries to adult females.

This would lead to maintaining or increasing the disparate sex ratio to the detriment of the population. Further research is needed to ascertain the extent of this problem.

## Molt

Molt surveys were conducted between 14 May and 1 December. Molting seals were regularly seen during all of these months. Between 1 January and 30 April, 13 trips were made to Whale-Skate, Trig, and/or East Islands and daily observations were made at Tern Island. During these months, only two molting seals were seen, an unsexed juvenile on Tern (2 January) and an unsexed adult on East (9 April) indicating molting seals were rare before the start of the molt surveys. (Counts of molting seals are listed in Appendix G.) Molting seals were seen on all islands, but animals molting on Shark or Disappearing are not included in the following calculations.

Figure 6 presents the number of molting seals seen on molt survey counts. The majority of seals molted between July and November with the peak occurring in October. Figure 7 shows the molting season differed for the various age/sex classes. The molting season for adult females was longer than for the other age/sex classes, and the peak, in August (or July if estimated numbers from Table 7 are used), occurred earlier than the peak of the other age/sex classes. The greatest number of immature females molted in August and September. The immature male peak was in September. The peak of molting activity for the adult males was the latest, occurring in October.

Although the reliability of breaking down the immature age class into subadult and juvenile is questionable, it should be noted that all but one of the immature seals molting after September were classed as juvenile size.

These data agree closely with data from Laysan which show the long molting season for adult females (apparently due to the prolonged pupping season), the short and late molting period for adult males (presumably not beginning until after the breeding season ends), and the late molt for many yearlings. Compared to Laysan, the molting season at FFS appears to occur about 6 weeks later (Appendix D).

## Population Estimation

### Calculation of Estimate

Based on the 8-day interval counts of molting seals, a total of 426 animals (excluding pups) molted between 10 March and 1 December in 1980. In addition, one molting seal was seen on Tern Island in January and two were seen on Tern in mid-December. This total of 429 seals is clearly a conservative estimate of the number of seals using the molt survey islands for several reasons.

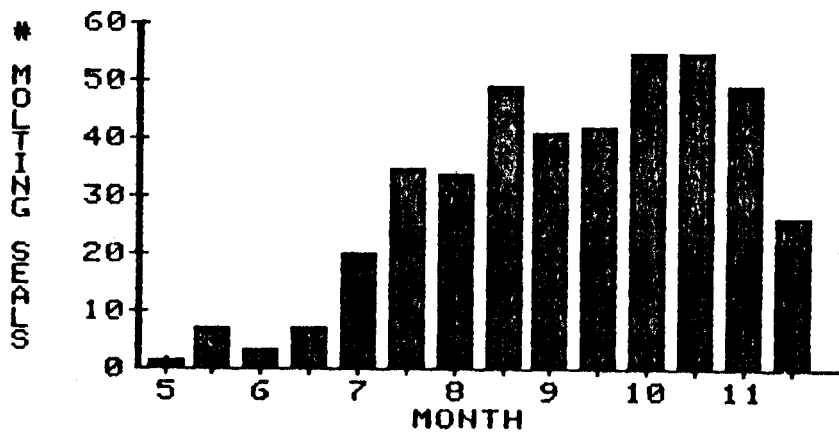


FIGURE 6 SEMIMONTHLY TOTAL OF MOLTING SEALS AT FRENCH FRIGATE, 1980.

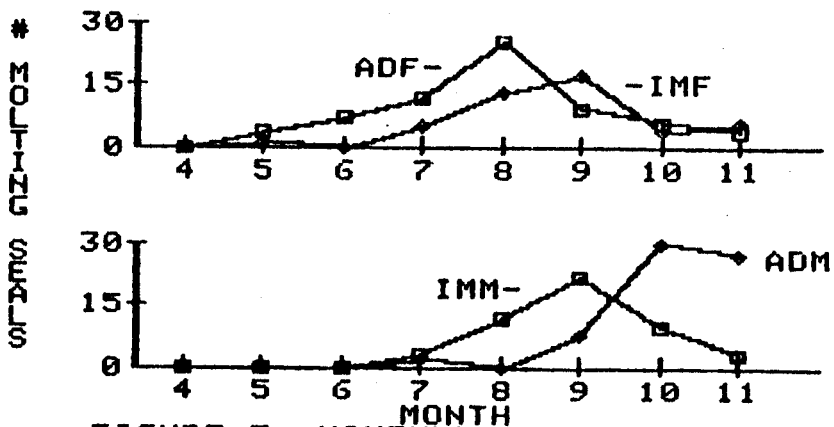


FIGURE 7 MONTHLY TOTAL OF MOLTING SEALS BY AGE CLASS, FROM 8-DAY COUNTS. FRENCH FRIGATE, 1980.

1. Some molters may have been missed before the start of the molt surveys in mid-May.
2. The molting season had not ended when the last molt survey was conducted (12 molting seals were seen on 1 December).
3. Gin and Little Gin were not visited during five of the molt surveys, thus seals molting on those islands would have been missed.
4. Some molting seals, particularly those just beginning or ending the molt, could have been missed on islands censused from offshore.

Adding in the estimated pup recruitment (births minus pre-weaning mortality) of 104 gives an estimate of 533 seals using the molt survey islands. Because Shark and Disappearing were excluded, this is a partial rather than a total atoll estimate.

Although seals were known to molt on both Shark and Disappearing during 1980, no counts of the actual number of molting seals were available. One indication of the use of these two areas by molting seals was obtained on 1 August 1981 when one of the authors (P. A. Johnson) visited all islands at FFS. Of the 21 molting seals seen on that date, 43% were on Shark and Disappearing, suggesting the importance of the two islands as molting areas.

A rough estimate of the number of seals which molted on Shark and Disappearing during 1980 can be calculated based on the mean percentage of seals using those areas for haul out from Table 4. An average of 23% of the seals ashore hauled out on Shark or Disappearing. If these islands were used by proportionately the same number of molting seals, then the 429 seals counted on molt surveys represent only 77% of a total non-pup population of 557 seals. Adding the estimated pup recruitment of 104 results in a total population estimate of 661 monk seals.

One method of testing whether the estimate of 557 seals is reasonable compares the population-estimate/mean-count ratio from FFS with those from other studies. Using the average of the monthly mean non-pup counts from the March through September period gives a ratio of 2.28 for Laysan during 1980 (mean count = 118, population estimate = 269), and a ratio from Stone (1984) for Lisianski of 2.19 (mean count = 98, population estimate = 215). The ratio for FFS was 2.46 (mean count = 226, population estimate = 557).

Factors such as differences in population age/sex structure and the timing of the molt and pupping seasons complicate comparisons. Comparison with other atolls indicate, however, that the non-pup estimate of 557 could be too high for the FFS population. (Assuming the ratios from Lisianski and Laysan are applicable to the FFS population, then the mean count of 226 would suggest a total non-pup population of 495 to 515 animals.)

In conclusion, the 8-day molt counts indicate at least 429 seals molted (excluding pups). Extrapolating from the ratio of seals using Shark and Disappearing Islands for haul out, an estimate for the total atoll

population of monk seals at FFS becomes 557 animals (or about 660 seals including pups). The ratio of estimate to mean count from Laysan and Lisianski indicate this number could be slightly high.

#### Discussion

The major objective of this study was to test the feasibility of using molt data to estimate the size of the FFS population. Because of the preliminary nature of the project and the need to keep disturbance to a minimum, we were unable to adequately test all assumptions of the estimate. Specifically:

1. A necessary assumption of the molt estimate is that seals shed hair for about 9 days and spend approximately 90% of the time hauled out (as at Laysan). While this seems likely, it needs to be tested. We were not able to collect any data on percent of time ashore for seals at FFS and did not get molt duration for more than a few seals (see Schulmeister 1984). If a significant difference in molt duration were found, the molt estimation methodology would need to be altered. Molt duration data are hard to collect as seals can freely move between haul-out areas at FFS. If duration of molt data for other areas, such as Necker, Nihoa or Kure, were found to be the same as Laysan, then it is likely that FFS seals follow the same pattern.

2. In the present study some molting seals were undoubtedly missed as counts were not made throughout the year, and it was sometimes hard to see molting seals on the islands which were censused from offshore. If seals were missed, the 8-day molt estimate would be low. While the observers did not feel this was a major problem, in the future it could be measured by observation of the small islands for long enough time periods to ascertain the degree to which molting seals were missed on censuses, and by counts made in January and December.

3. The percentage of the seals molting on Shark and Disappearing was unknown. As mentioned previously, Shark and Disappearing could not be visited regularly. If these islands could be visited during the molting season in future years, data collected on the number of molting seals could confirm or modify our assumption that roughly equal numbers use these islands to molt as used the molt survey islands.

In conclusion, this study has demonstrated that surface counts can be made at regular intervals throughout most of the year at FFS and that molting seals are readily distinguishable by trained observers. With care, censuses can be conducted which cause little disturbance yet yield valuable data. The aspects of the methodology which were not fully tested during 1980 would not be too difficult to test in the course of other monk seal observation which will undoubtedly be made on the FFS population in future years. With increased information on the degree to which the FFS population is directly comparable to the Laysan population of monk seals, the value of the molt estimate from 1980 will be improved.

It appears the molt estimation technique is feasible for FFS and makes crucial information on population size available to aid in monitoring change and making decisions concerning use of the atoll.

### Sex Ratio

There are problems in using data from ground counts to determine the sex ratio of any Hawaiian monk seal population. These problems affect the 1980 data from FFS as well. Three sources of error include: a large proportion of the seals ashore were not sexed during surveys; an unknown proportion of seals were not ashore for counts; and, all areas available for haul out were not visited during counts. Each of these problems introduces bias into determination of the sex ratio.

1. Unsexed seals. The time constraints and risk of disturbance to animals during censuses made sexing difficult. (During 1980 censuses, 50% of the adults and 57% of the immature seals were not sexed.) Of the animals sexed on censuses, the sex ratio may not be representative of the seals ashore. For example, it is possible that males are slightly easier to sex from a distance than females, due to the visibility of the penile opening and hair ridge lacking in females.

A more obvious bias exists during the pupping season. All adults accompanied by black pups are routinely sexed as female without the prerequisite ventral view required when sexing other animals. The effect of this bias can be seen by looking at a hypothetical adult population made up of 50 males and 50 females, 25 of which are accompanied by black pups. Two counts are made. On the first count all animals are sexed, resulting in a 1:1 sex ratio. On the second survey conditions are such that the probability of sexing each individual seal is only 20%, except all adults accompanied by pups are still sexed as female. The results of these counts show that the second count, where not all of the seals were sexed, will be strongly biased toward females.

|         | Males | Females |       |       | Unsexed | Male:Female<br>sex ratio |
|---------|-------|---------|-------|-------|---------|--------------------------|
|         |       | Alone   | w/Pup | Total |         |                          |
| Count 1 | 50    | (25)    | (25)  | 50    | 0       | 1:1                      |
| Count 2 | 10    | (5)     | (25)  | 30    | 60      | 1:3                      |

In theory, this bias can be corrected by estimating how many of the mothers would have been sexed as female by the normal method of sexing animals, based on the ratio of sexed adults to total adults.

$$A/B = X/M$$

or

$$X = (MA)/B$$

where:

- A = total adults sexed (excluding mothers)
- B = total adults (excluding mothers)
- M = females with pups (mothers)
- X = estimate of mothers which would have been classed as female without presence of pup.

In the above population where 20% of the non-mothers were sexed,  $X = (25)(15)/75 = 5$ , indicating that of the 25 mothers, only 5 would have been sexed using the normal sexing techniques. Added to the 5 females sexed using the normal methods, a total of 10 females result. When compared to the 10 seals sexed as male, the corrected sex ratio becomes 1:1.

In practice this correction factor will not eliminate all problems as other biases in both aging and sexing animals exist. It should, however, reduce the problem during the pupping season. It would be particularly useful when comparing counts from FFS with other populations where counts differ in percentage of seals sexed or include disproportionate numbers of mothers with pups.

2. Missing seals. A second major problem complicating the analysis of sex ratio data concerns the unknown percentage of seals that are not ashore during a count (often over two-thirds of the population at Laysan). Since the island use patterns of each age/sex class vary throughout the year, the sex ratio of animals ashore does not necessarily represent the sex ratio of the population. For example, most previous counts of monk seals at FFS have been made during the spring and summer months when females have outnumbered males. When counts from other times of the year are examined, such as those available for 1977 (Rauzon et al. 1978) and 1980, females outnumbered males from April through August, but males outnumbered females during the fall and winter months (Fig. 8).

3. Incomplete censuses. A third bias in the sex ratio data occurs when some haul-out areas are not included in a census. Data from long-term studies at Laysan and elsewhere have all shown that certain haul-out areas can be used predominately by one sex. To get accurate data on the sex ratio of seals hauled out at an atoll, all haul-out areas should be included in a census. Unfortunately, age/sex data were not collected on seals using Disappearing Island in 1980, and were rarely collected on Shark Island. Limited data from these two islands in previous years (Rauzon 1979; Rauzon et al. 1978) indicate they may be used by a larger percentage of adult males than other haul-out areas. If so, adult males would be underrepresented in the 1980 FFS count data.

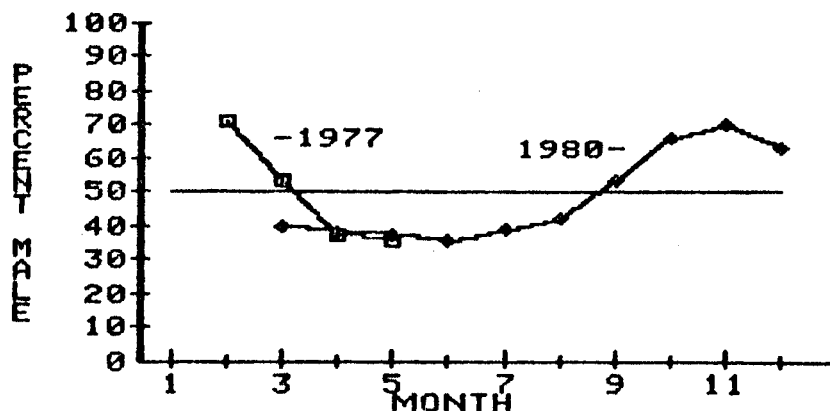


FIGURE 8 SEX RATIO FROM FFS COUNTS, EXCLUDING SHARK & DISAPPEARING, AND CORRECTED FOR FEMALE-WITH-PUP BIAS.

#### Comparative Data

Although sex ratio data from counts cannot be used directly to determine the population sex ratio, they can be compared to counts made at the same atoll in other years, or to counts made at other atolls. These comparisons must be between data collected in the same month or the same relative point in the pupping or molt seasons.

Table 7 presents the sex ratio data collected during the study for all censuses which included Gin and Little Gin Islands (N = 21). Because of problems to be discussed later (Age Structure section), no adult/immature breakdown is given. In general, however, the sex ratio of seals classed as immature was closer to 1:1 than the sex ratio of adults.

The best data available for comparison between years at FFS are from May of 1977 and May of 1980 (May is the only month when more than one count was made in two separate years). The comparison, corrected for the female-with-pup bias, indicates that 37% of the seals ashore were male in 1977, and 35% were male in 1980. Uncorrected for the female-with-pup bias, the numbers were 26% and 25%, respectively (all numbers exclude data from Disappearing and Shark). This indicates the sex ratio at FFS changed little between 1977 and 1980. Continued collection of sex ratio data could serve as an early indicator of problems in the FFS population by detecting any major increase in the proportion of adult males.

Counts of monk seals at areas which showed declines in the past 20 years (Kure, Lisianski, and Laysan) consistently report more males than females. (During 4 years of observations on Laysan, counts of males ranged from 60% to 77% of the yearly mean counts.) Counts from FFS, in contrast, typically report more females.



Table 7.--Mean monthly number of seals sexed on all censuses including Gin and Little Gin Island (N = 21).

| Month | Actual count |        |       | Corrected count |                     |                    |
|-------|--------------|--------|-------|-----------------|---------------------|--------------------|
|       | Male         | Female | Ratio | Male            | Female <sup>1</sup> | Ratio <sup>2</sup> |
| Mar.  | 42           | 46     | 10:11 | 42              | 46                  | 10:11              |
| Apr.  | --           | --     |       | --              | --                  |                    |
| May   | 19           | 58     | 10:31 | 19              | 35                  | 10:18              |
| June  | 22           | 61     | 10:31 | 22              | 42                  | 10:19              |
| July  | 24           | 49     | 10:20 | 24              | 36                  | 10:15              |
| Aug.  | 27           | 48     | 10:18 | 27              | 45                  | 10:17              |
| Sept. | 34           | 32     | 10:9  | 34              | 31                  | 10:9               |
| Oct.  | 44           | 22     | 10:5  | 44              | 22                  | 10:5               |
| Nov.  | 39           | 14     | 10:4  | 39              | 14                  | 10:4               |

<sup>1</sup>Totals corrected for female-with-pup bias.

<sup>2</sup>Ratio per 10 males.

#### Population Sex Ratio

Data previously presented in Fig. 8 show that when counts are made in all months of the year, the sex ratio is approximately equal, but that month-to-month patterns vary.

An estimate of the true sex ratio for the population can be derived from data used for the molt estimate. As shown in Table 8, nearly equal numbers of molting males and females were counted but many molting seals were not sexed. The sex of unsexed animals seen on counts was estimated, based on the male to female ratio of molting animals sexed on each survey. The estimated totals again show the sex ratios for both adults and immatures to be near 1:1.

Like the pattern seen at FFS, data from Laysan show no particular time of year when the sex ratio seen on counts can be expected to represent the true sex structure of the population (Johnson and Johnson 1984). It is possible that count data may roughly approximate the population sex ratio if counts are made throughout the year.

Table 8.--Age/sex classification of molting seals seen on molt surveys.

| Month | Total molting | Actual count <sup>1</sup> |        |          |        | Estimated count <sup>2</sup> |        |          |        |
|-------|---------------|---------------------------|--------|----------|--------|------------------------------|--------|----------|--------|
|       |               | Adult                     |        | Immature |        | Adult                        |        | Immature |        |
|       |               | Male                      | Female | Male     | Female | Male                         | Female | Male     | Female |
| Apr.  | 1             | 0                         | 0      | 0        | 0      | 0                            | 1      | 0        | 0      |
| May   | 8             | 0                         | 4      | 0        | 1      | 0                            | 7      | 0        | 1      |
| June  | 10            | 0                         | 7      | 0        | 0      | 0                            | 9      | 0        | 1      |
| July  | 56            | 2                         | 12     | 3        | 5      | 0                            | 41     | 7        | 7      |
| Aug.  | 83            | 0                         | 25     | 12       | 13     | 0                            | 32     | 24       | 27     |
| Sept. | 83            | 8                         | 9      | 22       | 17     | 13                           | 14     | 32       | 25     |
| Oct.  | 110           | 30                        | 6      | 10       | 4      | 65                           | 11     | 22       | 12     |
| Nov.  | 75            | 27                        | 4      | 3        | 6      | 53                           | 9      | 4        | 9      |
| Total | 426           | 67                        | 67     | 50       | 46     | 131                          | 124    | 89       | 82     |
|       | +3            |                           |        |          |        |                              |        |          | +2     |
|       | 429           |                           |        |          |        |                              |        |          | 84     |

<sup>1</sup>Excludes unsexed animals.

<sup>2</sup>Assigns a sex to unsexed animals based on the sex ratio of the sexed seals of that age class. (Assumes the two "adult" males molting in early July were actually immature males.)

#### Estimated age/sex ratios

Adult/immature ratio = 255/174 = 59% adult

Male/female ratio = 220/208 = 51% male

#### Age Structure

As mentioned in the Sex Ratio section, using data from ground counts to determine sex ratio or age structure has built-in biases. In addition to the problems of an unknown proportion of the population being at sea during counts and seals hauling out on places not included in the counts, there is a third difficulty with determination of age structure. This concerns the subjective nature of assigning an age to an animal.

Unless animals were recognizable individuals, pups, or mothers with pups, age categories were based primarily on the observers' subjective estimate of size. (Other factors, such as pelage color and behavior were sometimes useful.) The lack of a photographic inventory of well-identified seals to help calibrate observers size classifications, inexperience of observers, and infrequent chances to compare ageing criteria may have resulted in inconsistencies in age classification between observers. On

Laysan, where two observers worked closely together with numerous identified seals as reference animals, observer differences were minimal. Data collection at FFS was more limited in scope and was not optimally designed to determine age/sex structure. The two contracted observers were rarely able to conduct joint censuses to compare age classification because they were seldom in the field at the same time.

Figure 9 presents data on counts of adults and immatures during the study. These data appear to show dramatic reversals in age ratio occurred between July and August and again between September and October. While this could represent an actual change, it could also be the result of observer bias, as both of the shifts in age structure corresponded with shifts in observers.

The data presented in Fig. 10 support the idea that the change was primarily due to observer differences. Age ratio data collected in 1980 are compared with data from 1976 through 1979 (DeLong et al. 1976; Balazs 1977, personal communication; Rauzon et al. 1978; FWS 1977, 1978, unpublished reports; Fiscus et al. 1978; Rauzon 1979). Except for the July 1977 count, the data show similar patterns through August, when the 1980 data show an increase not seen in other years. Unfortunately, no September counts are available for the other years. These data indicate observer bias could be responsible for the dramatic increase in the percentage of immatures, but it is also possible that observer bias merely accentuated an actual change in age specific haul-out patterns not seen in the other years.

Although only single counts are available for most months in the 1976 to 1979 period, the data from all years indicate the ratio of adults to immatures was near equal in March, and that adults outnumbered immatures by 2:1 in April, May, and June.

The molt data provide a different approach to determining age structure. Summing the number of adult and immature seals that molted gives the age structure of the population using the molt survey islands, rather than a measure of seasonal change in haul-out frequency. While the same problem of reliably ageing seals exists, more time was spent observing and classifying molting seals. Table 8 presented data which showed that 59% of the molting seals were aged as adults and 41% as immatures.

Overall, the proportion of immatures in the FFS population was similar to that reported for Laysan, where the mean percent immature was 51% in 1977, 38% in 1978, and 45% in both 1979 and 1980 (Johnson and Johnson 1984). Age data for FFS are presented in Appendix H.

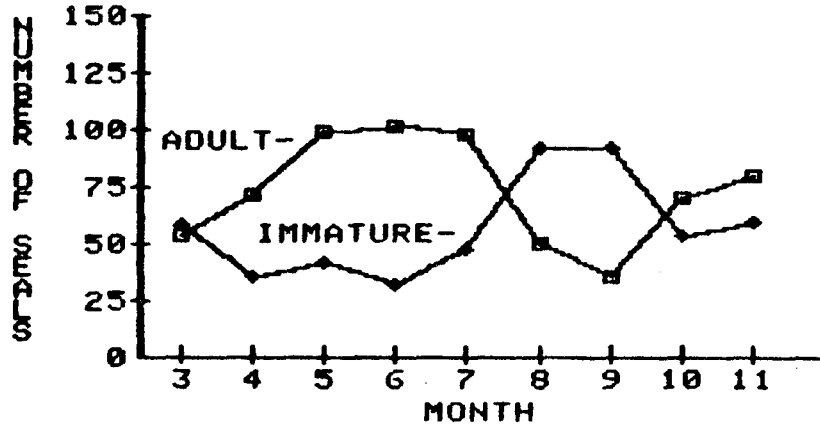


FIGURE 9 MEAN MONTHLY COUNT OF ADULTS AND IMMATURES, FFS, 1980.

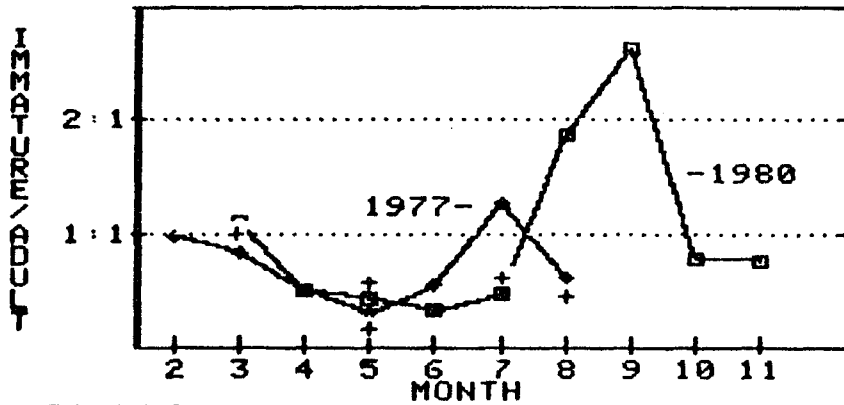


FIGURE 10 IMMATURE:ADULT RATIO FROM COUNTS AT FFS, 1976-1980. ("+" = DATA FROM SINGLE COUNTS, 1976, '78, OR '79.)

## SUMMARY

1. Objectives. The major objective was to determine if regular counts of molting seals could be used to estimate the population size at FFS. Secondary objectives included the collection of data on distribution, natality, and mortality.

2. Methods. Counts were made of all islands regularly used by monk seals (except Shark and Disappearing) at 8-day intervals throughout the molting season (May to December). Observations were made with binoculars and, in the case of several small islands, from offshore. Disturbance to seals was carefully avoided.

3. Maximum Count. The maximum total atoll count of 258 seals occurred on 30 May. The maximum count of seals on the regularly surveyed islands (excluding Shark and Disappearing) was 228 in late July (no count was made of both Shark and Disappearing in July or October). These counts fall within the range of highest counts made during the previous 5 years (195-274).

4. Distribution. The largest number of seals hauled out on Whale-Skate followed by Disappearing, East, and Trig. Most of the pupping occurred on three islands, with approximately 34% of the pups born on East, 30% born on Round, and 27% born on Whale-Skate. The greatest number of molting seals used Whale-Skate, followed by Trig. (Data for molting seals exclude Shark and Disappearing where molt data were not collected.)

5. Pupping Season. Pups were born from March through October, with the peak number of births occurring in May. The maximum count of mother-pup pairs was in June. The pupping season at FFS was 6 to 7 weeks later than at Laysan or Kure.

6. Pup Production. An estimated 114 pups were born on FFS in 1980. Data from 1977 and 1981 indicate over 100 pups were born in each of those years as well.

7. Molting Season. Molting seals were seen in all months except February and March, but the majority molted between 1 July and 30 November. The molting season for adult males was clearly later than for the other age/sex classes. The peak of the molting season was August for non-adult males, and October for adult males. The molting season occurred about 5 to 6 weeks later at FFS than at Laysan.

8. Population Estimate. The 8-day molt surveys counted 429 seals (excluding pups) but this is a conservative population estimate because molt counts were not made on Shark or Disappearing Islands. Adding in an estimate of molting seals on Shark and Disappearing (extrapolated from the percentage hauled out on those two islands) results in a total atoll population of around 557 seals. Adding the estimated pup production gives an estimated atoll population of over 660 seals. The study demonstrated the molt technique is feasible for a population like FFS, but the results should be considered tentative until additional data become available on

the mean molt duration and the proportion of seals which molt on Shark and Disappearing.

9. Sex ratio. The collection of sex ratio data is subject to several biases. The most obvious, and easily corrected is the female-with-pup bias, which should always be corrected before comparing sex ratios within and between atolls. The best available data indicate the sex ratio at FFS is near 1:1. This is considerably different from atolls to the northwest where males clearly outnumber females.

10. Age Structure. Because of possible differences in the age classification criteria used by the two contracted observers, data on age structure are even more difficult to interpret than data on sex ratio. A rough idea of the number of immatures in the population can be taken from the percentage of molting seals aged as immatures (about 41%), which is similar to the proportion of immatures reported for Laysan.

11. Breeding. Only one breeding encounter was observed, involving a single male/female pair. Multi-male breeding encounters, like those seen at Laysan resulting in serious injury to the female, were not observed. A comparison of the frequency of adult female dorsal scars, possibly breeding related, showed dorsal midline scars were significantly more common on Laysan than FFS.

#### ACKNOWLEDGMENTS

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## REFERENCES

- Amerson, A.B., Jr. 1971. The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Research Bulletin 150.
- Balazs, G.H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-7.
- DeLong, R.L., C.H. Fiscus, and K.W. Kenyon. 1976. Survey of monk seal (Monachus schauinslandi) populations of the Northwestern (Leeward) Hawaiian Islands. Preliminary report. Northwest Fisheries Center, Marine Mammals Division, NMFS Processed Report, 36 p.
- Fiscus, C.H., A.M. Johnson, and K.W. Kenyon. 1978. Hawaiian monk seal (Monachus schauinslandi) survey of the Northwestern Hawaiian Islands, July, 1978. NMFS Processed Report, 26 p.
- Johnson, A.M., R.L. DeLong, C.H. Fiscus, and K.W. Kenyon. 1982. Population status of the Hawaiian monk seal (Monachus schauinslandi), 1978. Journal of Mammalogy 63:415-421.
- Johnson, B.W., and P.A. Johnson. 1981a. Estimating the Hawaiian monk seal population on Laysan Island. National Technical Information Service No. PB82-106113, 29 p.
- Johnson, B.W., and P.A. Johnson. 1981b. The Hawaiian monk seal on Laysan Island: 1978. National Technical Information Service No. PB-82-109661, 17 p.
- Johnson, B.W., and P.A. Johnson. 1984. Observations of the Hawaiian monk seal on Laysan Island from 1977 through 1980. Unpublished NMFS Report, Contract 80-ABC-00124, 79 p.
- Kenyon, K.W., and D.W. Rice. 1959. Life history of the Hawaiian monk seal. Pacific Science 13:215-252.
- Rauzon, M.J. 1979. Survey of Hawaiian monk seal (Monachus schauinslandi), Northwestern Hawaiian Islands, 9-25 May, 1979. Unpublished Report. U.S. Fish and Wildlife Service, Anchorage, Alaska.
- Rauzon, M.J., K.W. Kenyon, and A.M. Johnson. 1978. Observations of monk seals, French Frigate Shoals, 17 February to 27 May 1977. Unpublished Report. U.S. Fish and Wildlife Service, Anchorage, Alaska, 34 p.
- Rice, D.W. 1960. Population dynamics of the Hawaiian monk seal. Journal of Mammalogy 41:376-385.
- Schulmeister, S. 1981. Hawaiian monk seal numbers increase on Tern Island. 'Elepaio 41(7):62-63..

- Schulmeister, S. 1984. Summary of Hawaiian monk seal (Monachus schauinslandi) data collected at French Frigate Shoals from July 1979 through December 1981. Unpublished Report. National Marine Fisheries Service, Honolulu, Hawaii.
- Stone, H.S. 1984. Hawaiian monk seal population research, Lisianski Island, 1982. Report to NMFS (draft), Honolulu, Hawaii.
- Taylor, L.R., and G. Naftel. 1978. Preliminary investigations of shark predation on the Hawaiian monk seal at Pearl and Hermes Reef and French Frigate Shoals. National Technical Information Service No. PB-285626, 34 p.
- Wirtz, W.O., II. 1968. Reproduction, growth and development, and juvenile mortality in the Hawaiian monk seal. *Journal of Mammalogy* 49:229-238.



APPENDIXES A - H

Appendix A.—Island breakdown of seals on molt surveys.

Table A-1.

Total number of seals (T), mothers with pups (MP), and weaned pups (WP) seen on molt surveys. First date is planned date of survey, the second date is actual date survey conducted. Spits include sand spits near Gin, Little Gin, and between Trig and Tern Islands.

| Plan date | Actual date | Tern |    | Trig |    | Whale-Skate |    | East |    | Bare |    | Mallet |    | Round |    | Gin |    | Little Gin |    | Spits |    |    |    |   |   |   |   |
|-----------|-------------|------|----|------|----|-------------|----|------|----|------|----|--------|----|-------|----|-----|----|------------|----|-------|----|----|----|---|---|---|---|
|           |             | T    | MP | WP   | T  | MP          | WP | T    | MP | WP   | T  | MP     | WP | T     | MP | WP  | T  | MP         | WP | T     | MP | WP | M  | F | U |   |   |
| 3/03      | 3/05*       | 17   | 0  | 0    | 37 | —           | —  | —    | —  | —    | —  | —      | —  | —     | —  | —   | —  | —          | —  | —     | —  | —  | —  | — |   |   |   |
| 3/11      | 3/10        | 16   | 0  | 0    | 25 | 0           | 0  | 0    | 0  | 0    | 0  | 0      | 0  | 0     | 0  | 0   | 0  | 0          | 0  | 0     | 0  | 0  | 0  | 0 |   |   |   |
| 3/27      | 3/28        | 19   | 0  | 0    | 17 | 0           | 0  | 15   | 1  | 0    | 2  | 0      | 0  | 0     | 2  | 1   | 0  | —          | —  | —     | —  | —  | —  | — |   |   |   |
| 4/20      | 4/17*       | 14   | 0  | 0    | 16 | —           | —  | 23   | —  | —    | 0  | —      | —  | 6     | —  | —   | —  | —          | —  | —     | —  | —  | —  | — |   |   |   |
| 4/28      | 4/28*       | 15   | 0  | 0    | 16 | 0           | 0  | 34   | 11 | 0    | 2  | 0      | 0  | 6     | 0  | 0   | 14 | 6          | 0  | 13    | —  | —  | —  | — |   |   |   |
| 5/14      | 5/14        | 15   | 0  | 0    | 13 | 0           | 0  | 46   | 10 | 3    | 3  | 0      | 0  | 2     | 0  | 0   | 25 | 11         | 0  | 10    | 1  | 1  | 11 | 0 | 0 | 0 |   |
| 5/30      | 5/30        | 15   | 0  | 0    | 11 | 0           | 0  | 58   | 13 | 3    | 57 | 17     | 4  | 2     | 0  | 0   | 36 | 16         | 3  | 9     | 1  | 1  | 8  | 0 | 0 | 0 |   |
| 6/07      | 6/07        | 15   | 0  | 0    | 14 | 0           | 0  | 61   | 15 | 6    | 50 | 15     | 10 | 3     | 0  | 0   | 40 | 18         | 4  | 8     | 0  | 1  | 8  | 1 | 0 | 1 |   |
| 6/15      | 6/18        | 12   | 0  | 0    | 27 | 1           | 0  | 56   | 10 | 6    | 47 | 10     | 14 | 1     | 0  | 0   | 36 | 12         | 8  | 10    | 0  | 2  | 9  | 1 | 0 | 0 |   |
| 6/23      | 6/23        | 15   | 0  | 0    | 10 | 1           | 0  | 66   | 10 | 8    | 44 | 11     | 11 | 2     | 0  | 0   | 39 | 13         | 12 | 6     | 0  | 1  | 10 | 1 | 0 | 0 |   |
| 7/01      | 7/02        | 15   | 0  | 1    | 15 | 1           | 0  | 59   | 5  | 11   | 55 | 10     | 14 | 4     | 0  | 0   | 37 | 15         | 5  | 7     | 0  | 1  | 7  | 1 | 0 | 0 |   |
| 7/09      | 7/09        | 14   | 0  | 0    | 23 | 1           | 1  | 70   | 6  | 11   | 49 | 5      | 19 | 5     | 0  | 0   | 33 | 7          | 18 | 2     | 0  | 0  | 7  | 1 | 0 | 0 |   |
| 7/17      | 7/19        | 17   | 0  | 0    | 15 | 1           | 1  | 88   | 4  | 14   | 47 | 4      | 19 | 6     | 0  | 0   | 28 | 3          | 9  | 8     | 0  | 1  | 10 | 1 | 0 | 0 |   |
| 7/25      | 7/25        | 11   | 0  | 0    | 18 | 0           | 1  | 79   | 4  | 18   | 50 | 5      | 18 | 3     | 0  | 0   | 29 | 3          | 14 | 9     | 0  | 0  | 10 | 1 | 1 | 3 |   |
| 8/02      | 8/04        | 22   | 0  | 0    | 24 | 0           | 4  | 75   | 4  | 11   | 36 | 4      | 18 | 1     | 0  | 0   | 29 | 2          | 16 | 14    | 0  | 0  | 12 | 2 | 2 | 0 |   |
| 8/10      | 8/10        | 25   | 0  | 0    | 27 | 0           | 2  | 62   | 2  | 12   | 38 | 6      | 9  | 6     | 0  | 0   | 15 | 1          | 10 | 0     | 0  | 0  | 11 | 2 | 1 | 4 |   |
| 8/18      | 8/19        | 32   | 0  | 3    | 28 | 0           | 3  | 69   | 1  | 15   | 29 | 3      | 12 | 1     | 0  | 0   | 9  | 0          | 6  | —     | —  | —  | —  | — | — | — |   |
| 8/26      | 8/27        | 24   | 0  | 3    | 25 | 0           | 5  | 67   | 0  | 10   | 36 | 3      | 11 | 5     | 0  | 2   | 3  | 10         | 0  | 3     | 8  | 0  | 1  | 4 | 0 | 0 |   |
| 9/03      | 9/04        | 22   | 0  | 4    | 36 | 0           | 8  | 66   | 0  | 17   | 35 | 2      | 17 | 3     | 0  | 1   | 0  | 0          | 0  | 12    | 0  | 8  | 0  | 0 | 0 | 0 |   |
| 9/11      | 9/10        | 14   | 0  | 1    | 29 | 0           | 8  | 67   | 0  | 23   | 27 | 2      | 10 | 1     | 0  | 0   | 0  | 0          | 0  | 6     | 0  | 3  | 4  | 0 | 0 | 1 |   |
| 9/19      | 9/18        | 13   | 0  | 3    | 15 | 0           | 1  | 84   | 0  | 23   | 29 | 0      | 15 | 3     | 0  | 0   | 1  | 6          | 1  | 3     | 2  | 0  | 1  | 5 | 0 | 1 |   |
| 9/27      | 9/27        | 22   | 0  | 6    | 36 | 0           | 3  | 70   | 0  | 20   | 25 | 0      | 6  | 2     | 0  | 0   | 0  | 0          | 0  | 2     | 0  | 8  | 0  | 4 | 9 | 0 | 0 |
| 10/05     | 10/05       | 21   | 0  | 0    | 36 | 0           | 2  | 61   | 0  | 14   | 27 | 0      | 8  | 0     | 0  | 0   | 2  | 1          | 0  | —     | —  | —  | —  | — | — | — |   |
| 10/13     | 10/14       | 17   | 0  | 6    | 40 | 0           | 9  | 56   | 0  | 13   | 22 | 1      | 6  | 2     | 0  | 0   | 2  | 1          | 0  | 8     | 0  | 3  | 0  | 1 | 0 | 0 |   |
| 10/21     | 10/21**     | 18   | 0  | 1    | ?  | 0           | ?  | ?    | 0  | ?    | 17 | 1      | 6  | 1     | 0  | 0   | 1  | 0          | 1  | 4     | 0  | 0  | 5  | 0 | 2 | 0 |   |
| 10/29     | 10/30       | 23   | 0  | 3    | 51 | 0           | 5  | 54   | 0  | 12   | 16 | 1      | 3  | 3     | 0  | 0   | 0  | 0          | 0  | 11    | 0  | 4  | 11 | 0 | 1 | 0 |   |
| 11/06     | 11/06       | 23   | 0  | 5    | 52 | 0           | 5  | 52   | 0  | 7    | 14 | 1      | 7  | 1     | 0  | 0   | 3  | 0          | 1  | 2     | 0  | 0  | 3  | 0 | 0 | 0 |   |
| 11/14     | 11/18       | 24   | 0  | 0    | 52 | 0           | 2  | 52   | 0  | 10   | 19 | 1      | 4  | 1     | 0  | 0   | 0  | 0          | 0  | —     | —  | —  | —  | — | — | — |   |
| 11/22     | 11/22       | 24   | 0  | 3    | 45 | 0           | 2  | 64   | 0  | 6    | 25 | 1      | 3  | 3     | 0  | 1   | 0  | 0          | 0  | —     | —  | —  | —  | — | — | — |   |
| 11/30     | 12/01       | 34   | 0  | 0    | 48 | 0           | 0  | 52   | 0  | 3    | 15 | 0      | 3  | 0     | 0  | 1   | 0  | 0          | —  | —     | —  | —  | —  | — | — | — |   |

\*Includes data from aerial count.

\*\* No distinction was made between animals on Trig and Whale-Skate during the census. A total of 101 seals were seen on the two islands, with 20 weaned pups.

## Appendix B.--Counts of Shark and Disappearing Islands.

Table B-1.--Aerial and ground counts of seals on Shark and Disappearing Islands (Schulmeister 1984).

| Disappearing Island |       |        | Shark Island |       |          |
|---------------------|-------|--------|--------------|-------|----------|
| Date                | Count | Method | Date         | Count | Method   |
| 3/05                | 27    | Aerial | 3/05         | 10    | Aerial   |
|                     |       |        | 3/08         | 34    | Ground   |
| 4/02                | 33    | Aerial |              |       |          |
| 4/17                | 23    | Aerial | 4/17         | 24    | Aerial   |
| 4/29                | 43    | Aerial |              |       |          |
| 5/07                | 31    | Aerial |              |       |          |
|                     |       |        | 5/15         | 9     | Offshore |
| 5/21                | 23    | Ground |              |       |          |
| 6/02                | 44    | Ground |              |       |          |
|                     |       |        | 6/18         | 6     | Offshore |
|                     |       |        | 6/27         | 16    | Ground   |
|                     |       |        | 7/09         | 5     | Ground   |
|                     |       |        | 7/19         | 7     | Ground   |
|                     |       |        | 7/25         | 14    | Offshore |
|                     |       |        | 8/10         | 6     | Ground   |
| 8/29                | 25    | Ground |              |       |          |
| 9/08                | 40    | Ground |              |       |          |
|                     |       |        | 9/10         | 13    | Ground   |
| 11/18               | 54    | Aerial | 11/18        | 31    | Aerial   |

## Appendix C.--Counts of small pups.

Table C-1.--Estimated births at French Frigate Shoals during 1980 based on size of pups. Sm = pups classed as small (probably less than 8 days old); Add = the minimum number of births necessary to account for increase in number of pups over last census for each haul-out area (used when observers did not record the size of pups).

| Planned date | Actual date | Increased pup count | Source |     |
|--------------|-------------|---------------------|--------|-----|
|              |             |                     | Sm     | Add |
| 3/03         | 3/06        | 1                   | 1      |     |
| 3/11         | --          | --                  |        |     |
| 3/19         | --          | --                  |        |     |
| 3/27         | 3/28        | 2                   | 2      |     |
| 4/04         | 4/02        | 1                   | 1      |     |
| 4/12         | 4/09        | 2                   | 1      | 1   |
| 4/20         | 4/17        | 3                   | 3      |     |
| 4/28         | 4/28        | 19                  |        | 19  |
| 5/06         | --          | --                  |        |     |
| 5/14         | 5/14        | 12                  | 7      | 5   |
| 5/22         | 5/25        | 3                   | 1      | 2   |
| 5/30         | 5/30        | 14                  | 8      | 6   |
| 6/07         | 6/07        | 15                  | 15     |     |
| 6/15         | 6/18        | 2                   | 2      |     |
| 6/23         | 6/23        | 4                   | 2      | 2   |
| 7/01         | 7/02        | 3                   | 1      | 2   |
| 7/09         | 7/09        | 3                   | 2      | 1   |
| 7/17         | 7/19        | 7                   | 7      |     |
| 7/25         | 7/25        | 4                   | 4      |     |
| 8/02         | 8/04        | 4                   | 4      |     |
| 8/10         | 8/10        | 2                   |        | 2   |
| 8/18         | 8/19        | 1                   | 1      |     |
| 8/26         | 8/27        | 0                   |        |     |
| 9/03         | 9/04        | 0                   |        |     |
| 9/11         | 9/10        | 2                   | 1      | 1   |
| 9/19         | 9/18        | 0                   |        |     |
| 9/27         | 9/27        | 0                   |        |     |
| 10/05        | 10/04       | 0                   |        |     |
| 10/13        | 10/10       | 1                   | 1      |     |
| 10/21        | 10/21       | 0                   |        |     |
| 10/29        | 10/30       | 0                   |        |     |

## Appendix D.--Variation between atolls in the pupping and molt season.

## Pupping Season

Table D-1 includes data on the pupping season, based on known birth dates, for Laysan and Kure Atoll. These data are compared to data from FFS, which include an estimate of the median birth date calculated from counts of small pups (Appendix C).

The pupping seasons for Laysan (1977-1980, from Johnson and Johnson 1984) and Kure (1964-1965, from Wirtz 1968) show similar patterns, with the mean and median pupping dates falling in mid-April. Data from Kure collected in 1981 and 1982 (N = 15) show a mean pupping date of 23 April and a median pupping date of 10 April (W. G. Gilmartin, personal communication). The range of births in 1981 and 1982 on Kure was 18 February to 13 August. Limited data from 1958 at Midway Atoll (Rice 1960) indicate a similar pattern, with the mean pupping date on 7 April, and the median date on 8 April (N = 10, including only full-term births).

The data in Table D-1 show a different pattern for FFS, with mid-range and median pupping dates occurring 6 to 7 weeks later than at Laysan or Kure. Figure D-1 presents semi-monthly birth frequency data for Laysan (known) and FFS (estimated). These data also indicate that the pupping season is later at FFS, with the modal peak occurring about 1-1/2 months later.

Table D-1.--Pupping season dates for Kure (1964 and 1965), Laysan (1977 to 1980), and French Frigate Shoals (1980).

|           | Kure (N = 57) | Laysan (N = 136) | FFS (N = 104) |
|-----------|---------------|------------------|---------------|
| Range     | 3/14-7/27     | 1/15-8/22        | 3/06-10/09    |
| Mid-range | 5/07          | 5/05             | 6/24          |
| Median    | 4/11          | 4/13             | 5/22          |
| Mean      | 4/11          | 4/17             | --            |

The above comparisons are based on estimates of birth dates for FFS. Actual counts of attended pups at Laysan and FFS are more directly comparable. Figure D-2 presents data on the mean semi-monthly counts of attended pups at both areas, and again shows the modal peak occurs about 6 weeks later at FFS.

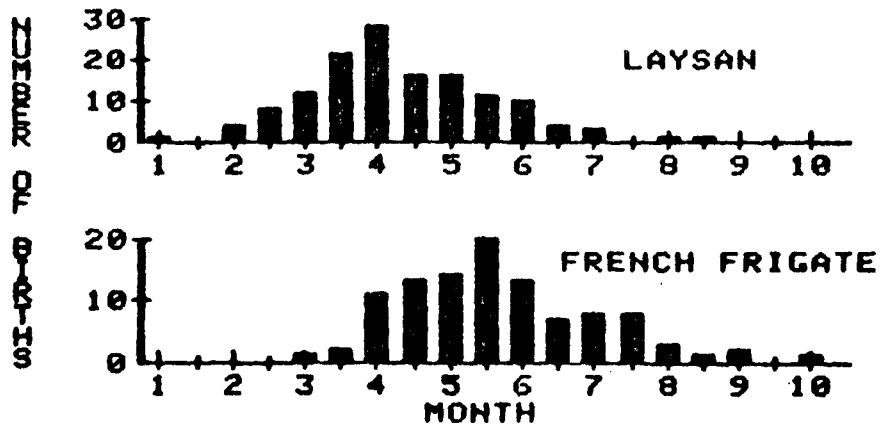


FIGURE D-1 SEMIMONTHLY BIRTHS, LAYSAN 1977-1980 AND FRENCH FRIGATE 1980.

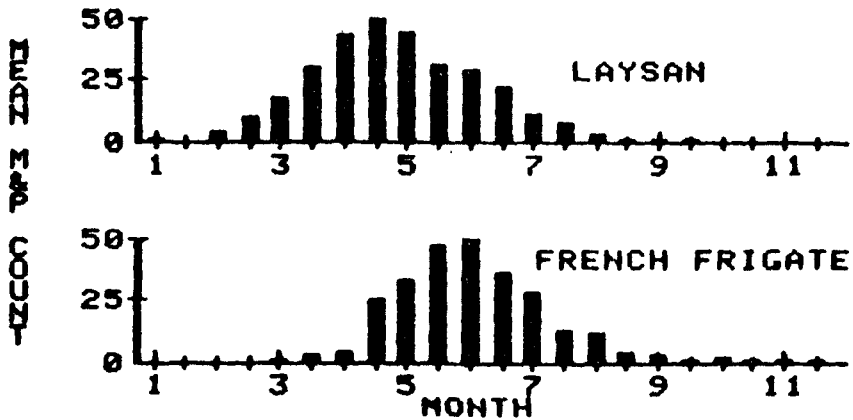


FIGURE D-2 MEAN SEMI-MONTHLY MOTHER/PUP COUNT, LAYSAN '77-80 AND FFS '80.

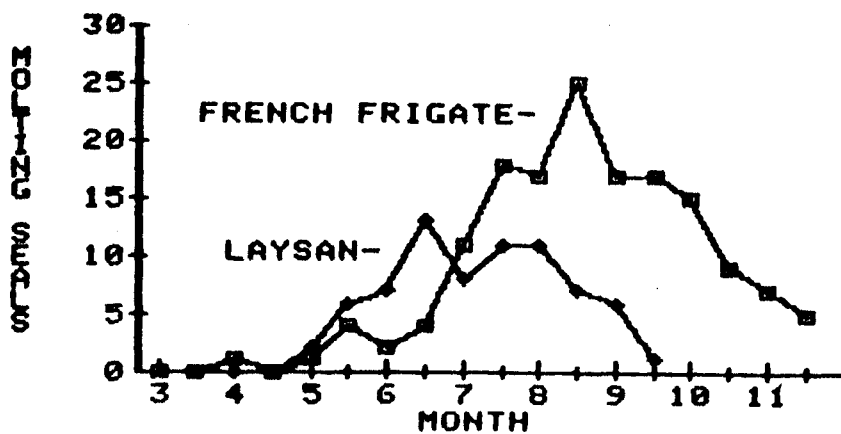


FIGURE D-3 MEAN SEMIMONTHLY MOLTING SEALS, EXCLUDING ADULT MALES, 1980.

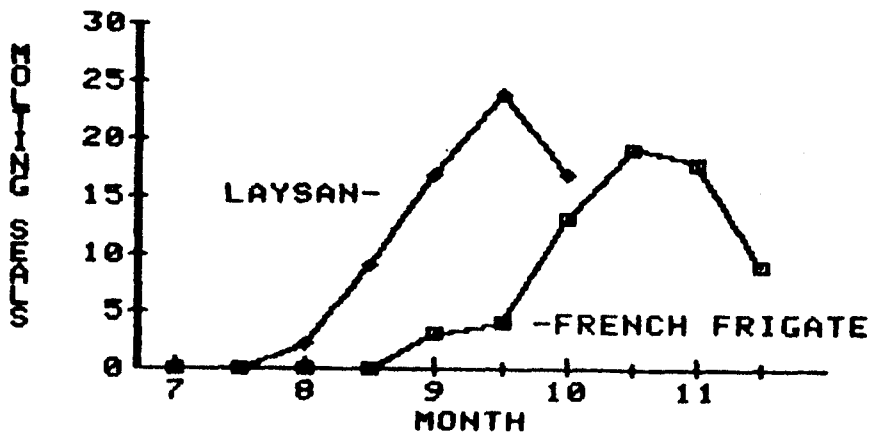


FIGURE D-4 MEAN SEMIMONTHLY MOLTING ADULT MALES, LAYSAN '78 AND FFS '80.

## Molting Season

Figure D-3 compares the mean number of molting seals (excluding adult males) seen on counts at Laysan and FFS in 1980 (FFS data are based on estimates from Table 8). Although the peak molting period on Laysan is not as clearly defined, the molting season at FFS seems to occur 1 to 2 months later than at Laysan.

Figure D-4 compares the average 1980 monthly count of molting adult males at FFS (from estimates in Table 8) with the 1978 data from Laysan (the only year for which data were collected throughout the peak of the adult male molting season). These data also show the FFS peak occurs at least 1 month later than at Laysan.

## Conclusion

Based on the above data, it appears the timing of the pupping and molting seasons occur about 1-1/2 months later at FFS than at the other monk seal haul-out areas to the northwest. Data from haul-out areas southeast of FFS (Necker and Nihoa) need to be examined.

## Appendix E.--Pup production estimates based on 36-day interval counts.

Kenyon and Rice (1959) proposed that an estimate of Hawaiian monk seal pup production could be obtained by summing counts of attended pups at intervals approximating the mean weaning age. It is possible to examine the reliability of this technique on pup production data from Laysan, and to identify sources of variability when applying the technique to other populations. The effects of two sources of variability will be discussed: mean weaning age and early mortality of pups.

Counts were made every fourth day throughout four pupping seasons on Laysan Island. During these 4 years, the mean age at weaning ranged from 35.7 to 36.6 days (for pups surviving until weaning), with an overall mean of 36.2 days. Estimates from nine series of counts, with 36 days between counts, can be calculated from the data for each year except 1978 (an absence from Laysan of 10 days during the pupping season resulted in the loss of two series for that year). Table E-1 presents the results of the 34 estimates. The mean estimate was 91.2% of the actual pup production (SD = 8.32). The estimates were consistently low, with only two of the 34 overestimating the known births.



Table E-1.--Estimated pup production on Laysan Island from 1977 to 1980 based on counts of attended pups at 36-day intervals.

| Series                  | 1977 | 1978 | 1979 | 1980 |
|-------------------------|------|------|------|------|
| 1                       | 45   | 27   | 28   | 32   |
| 2                       | 39   | 28   | 30   | 26   |
| 3                       | 42   | 27   | 27   | 26   |
| 4                       | 39   | 29   | 21   | 27   |
| 5                       | 38   | 29   | 32   | 26   |
| 6                       | 41   | 30   | 31   | 28   |
| 7                       | 39   | 26   | 29   | 30   |
| 8                       | 38   |      | 30   | 28   |
| 9                       | 40   |      | 29   | 28   |
| Mean                    | 40   | 28   | 29   | 28   |
| Known pup<br>production | 42   | 29   | 32   | 33   |
| Early deaths            | 2    | 1    | 3    | 5    |

In using the 36-day interval to estimate pup production at other areas, it must be assumed that monk seal females normally nurse pups for 36 days. This is difficult to determine without observing a large sample of identifiable mothers throughout the pupping season. Examination of the data currently available suggests that using a 36-day interval at other populations may be reasonable. Kenyon and Rice (1959) proposed using a 35-day estimate after observations at Kure and Midway during the 1950's. During the 4 years of the Laysan study presented here, the mean weaning age for pups remained at or very near 36 days despite a major population decline during 1978 when up to one quarter of the population died (Johnson and Johnson 1981b). Lastly, newly weaned pups seen at FFS and Lisianski appear similar in size and appearance to recently weaned pups at Laysan.

A second source of variability was identified in comparing actual births on Laysan with the results of the 36-day counts. In all 4 years, the estimate was less than the known pup production. Some pups died prior to weaning each year. As Table E-1 shows, adding the number of early deaths to the estimated production equals the actual number of births in each of the 4 years.

On Laysan, the 36-day interval gave an accurate estimate of pup recruitment rather than the number of births. Applying the 36-day interval to other populations will likely also underestimate the actual number of births, with the degree of underestimation dependent on the rate of early mortality.

On Laysan it was found that a 33-day interval (the average time between birth and death, disappearance, or weaning of pups) would have more accurately estimated the number of births. However, early mortality of pups is known to vary considerably between atolls (Johnson and Johnson 1984). Without accurate determination of mortality for the population under study, it seems reasonable to use the 36-day interval and risk underestimation of births. Any unnaturally high degree of mortality would probably be discovered in the process of collecting the 36-day interval counts.

We, therefore, suggest that 36-day intervals be used to estimate pup recruitment (or as a conservative estimate of pup production) at atolls where more frequent censusing is either impossible or undesirable. This estimate can be improved by the collection of additional data on the degree of early pup mortality and on the average weaning age of pups.

## Appendix F.--Pup Production in 1977 and 1981.

Pup recruitment (births minus pre-weaning mortality) was estimated at 104 pups for FFS in 1980. Using the same technique, an estimate of the number of pups born in 1977 and 1981 can be calculated from count data.

Counts were made by various observers in 1977. These counts are listed in Table F-1. The counts marked with "\*" had three weaned pups that had been seen before the series began added, resulting in a total count of 80 pups. This series was selected because of all possible series with counts at least 36 days apart, it had the lowest mean interval between counts (45.5 days). If the mean weaning age was 36 days, as at Laysan, and pup mortality negligible, then pup production would be underestimated by 21%. Correcting the count of 80 pups gives a pup production estimate of 101 for 1977. (The estimate would be low if appreciable pre-weaning mortality occurred.)

Table F-1.--Counts of attended pups (MP) and weaned pups (WP) with the source of the counts for French Frigate Shoals, 1977.

| Date  | MP | WP | Source                               |
|-------|----|----|--------------------------------------|
| 3/09  | 4  | 3  | Rauzon et al. 1978                   |
| 3/28* | 6  | 2  | Rauzon et al. 1978                   |
| 4/09  | 26 | 2  | Rauzon et al. 1978                   |
| 4/24  | 28 | 4  | Rauzon et al. 1978                   |
| 5/11* | 35 | 6  | Rauzon et al. 1978                   |
| 5/25  | 22 | 24 | Rauzon et al. 1978                   |
| 6/24* | 25 | -- | G. H. Balazs, personal communication |
| 7/09  | 22 | 0  | Geizantanner, unpublished FWS report |
| 8/12* | 10 | 0  | Coleman, unpublished FWS report      |
| 9/26* | 1  | -- | G. H. Balazs, personal communication |

\* Counts used to estimate minimum pup production.

Counts of mothers attending pups were made every 36 days in 1981 (Schulmeister 1984). Summing the counts shown in Table F-2 for Whale-Skate, Round and East, and adding the 7 pups that were known to be born on Disappearing and Little Gin gives an estimated pup production of 112 pups in 1981. (Again, this estimate would be low if appreciable pre-weaning mortality of pups occurred.)

From these estimates, it appears that over 100 pups are normally born at FFS each year.

Table F-2.--Counts of attended pups at French Frigate Shoals in 1981.

| Date       | Count | Date        | Count |
|------------|-------|-------------|-------|
| 11 January | 1     | 1 August    | 9     |
| 6 March    | 3     | 6 September | 6     |
| 7 April    | 16    | 24 October  | 0     |
| 21 May     | 32    | 15 November | 1     |
| 26 June    | 37    |             |       |

## Appendix G.--Age/sex breakdown of molting seals seen on all molt surveys.

Table G-1.--Counts of male (M), female (F), and unsexed (U) seals seen at French Frigate Shoals in 1980.

| Date   | Adult |    |     | Immature |    |    | Total |
|--------|-------|----|-----|----------|----|----|-------|
|        | M     | F  | U   | M        | F  | U  |       |
| 3/10   | 0     | 0  | 0   | 0        | 0  | 0  | 0     |
| 3/28*  | 0     | 0  | 0   | 0        | 0  | 0  | 0     |
| 4/09   | 0     | 0  | 1   | 0        | 0  | 0  | 1     |
| 4/28*  | 0     | 0  | 0   | 0        | 0  | 0  | 0     |
| 5/14   | 0     | 1  | 1   | 0        | 0  | 0  | 2     |
| 5/30   | 0     | 3  | 2   | 0        | 1  | 0  | 6     |
| 6/07   | 0     | 1  | 1   | 0        | 0  | 1  | 3     |
| 6/18   | 0     | 3  | 1   | 0        | 0  | 0  | 4     |
| 6/23   | 0     | 3  | 0   | 0        | 0  | 0  | 3     |
| 7/02   | 2     | 0  | 3   | 0        | 0  | 1  | 6     |
| 7/09   | 0     | 4  | 6   | 0        | 4  | 1  | 15    |
| 7/19   | 0     | 4  | 10  | 3        | 0  | 3  | 20    |
| 7/25   | 0     | 4  | 10  | 0        | 1  | 0  | 15    |
| 8/04   | 0     | 6  | 1   | 1        | 2  | 3  | 13    |
| 8/10   | 0     | 4  | 2   | 3        | 3  | 9  | 21    |
| 8/19*  | 0     | 10 | 3   | 7        | 3  | 6  | 29    |
| 8/27   | 0     | 5  | 1   | 1        | 5  | 8  | 20    |
| 9/04   | 1     | 2  | 1   | 5        | 5  | 5  | 19    |
| 9/10   | 3     | 3  | 1   | 5        | 3  | 7  | 22    |
| 9/18   | 0     | 2  | 3   | 8        | 3  | 3  | 19    |
| 9/27   | 4     | 2  | 4   | 4        | 6  | 3  | 23    |
| 10/05* | 5     | 1  | 10  | 2        | 1  | 4  | 23    |
| 10/14  | 9     | 4  | 6   | 8        | 2  | 3  | 32    |
| 10/21  | 5     | 1  | 11  | 0        | 0  | 9  | 26    |
| 10/30  | 11    | 0  | 13  | 0        | 1  | 4  | 29    |
| 11/06  | 12    | 1  | 18  | 1        | 1  | 0  | 33    |
| 11/18* | 4     | 2  | 6   | 1        | 1  | 2  | 16    |
| 11/22* | 7     | 1  | 3   | 1        | 1  | 1  | 14    |
| 12/01* | 4     | 0  | 4   | 0        | 3  | 1  | 12    |
| Total  | 67    | 67 | 122 | 50       | 46 | 74 | 426   |

\*Gin and Little Gin Islands not visited.

Appendix H.--Age/sex breakdown of count data for all molt surveys conducted during 1980. The following describes the headings used on Table H-1.

---

DATE: Date of count  
ADM : Number of adult males counted  
ADF : Number of adult females counted  
AD? : Number of unsexed adults  
SAM : Number of subadult males  
SAF : Number of subadult females  
SA? : Number of unsexed subadults  
JM : Number of juvenile males  
JF : Number of juvenile females  
J? : Number of unsexed juveniles  
WP : Number of weaned pups  
MP : Number of pups still attended by a female  
TOT : Total of all seals counted  
STOT: Total excluding WP and MP counts  
%UNK: Percentage of STOT count that were not sexed  
AM/C: Corrected adult male count corrected for mother with pup bias with  
a sex assigned to the unsexed adults based on the resulting sex  
ratio  
AF/C: Corrected adult female count (same as AM/C)  
IM/C: Corrected immature male count (includes subadult and juvenile males,  
with sexes assigned to unsexed animals on the basis of sex ratio  
of sexed immatures  
IF/C: Corrected immature female count (same as IM/C)  
%AD : Percentage of STOT that were classified as adults  
%FEM: Percentage of STOT that were sexed as female (based on the AF/C and  
IF/C totals)

Table H-1.—Counts of Hawaiian monk seals at French Frigate Shoals in 1980. Counts include only the molt survey islands (i.e., they exclude Shark and Disappearing islands). Data on age structure are probably biased and should be used only with caution (see Age Structure section). Monthly summaries include only censuses which covered all the molt survey islands.

| DATE  | ADM | ADF | AD? | SAH | SAF | SA? | JH | JF | J? | WP | MP | NOTE | TOI | STOI | ZUNK | AM/C | AF/C | IM/C | IF/C | ZAD | ZPEM |
|-------|-----|-----|-----|-----|-----|-----|----|----|----|----|----|------|-----|------|------|------|------|------|------|-----|------|
| 3/07  | 27  | 28  | 12  | 1   | 5   | 12  | 11 | 22 | 18 | 0  | 1  | (1)  | 137 | 136  | 31   | 33   | 34   | 21   | 48   | 49  | 60   |
| 3/28  | 12  | 19  | 14  | 0   | 0   | 0   | 7  | 11 | 21 | 0  | 3  | (2)  | 87  | 84   | 42   | 18   | 27   | 15   | 24   | 54  | 61   |
| 4/28  | 8   | 36  | 28  | 0   | 1   | 6   | 13 | 8  | 7  | 0  | 26 | (2)  | 133 | 107  | 38   | 20   | 52   | 21   | 14   | 67  | 62   |
| 5/14  | 10  | 40  | 40  | 0   | 0   | 0   | 4  | 4  | 30 | 6  | 33 |      | 167 | 128  | 55   | 34   | 56   | 19   | 19   | 70  | 59   |
| 5/30  | 15  | 63  | 30  | 2   | 3   | 12  | 7  | 6  | 14 | 11 | 47 |      | 210 | 152  | 37   | 30   | 78   | 22   | 22   | 71  | 66   |
| 6/07  | 14  | 60  | 35  | 2   | 0   | 6   | 1  | 3  | 12 | 22 | 49 |      | 204 | 133  | 40   | 34   | 75   | 12   | 12   | 82  | 66   |
| 6/18  | 16  | 50  | 36  | 0   | 3   | 17  | 6  | 2  | 11 | 30 | 34 |      | 205 | 141  | 45   | 34   | 68   | 21   | 18   | 72  | 61   |
| 6/23  | 20  | 58  | 17  | 3   | 1   | 8   | 4  | 6  | 11 | 32 | 36 |      | 196 | 128  | 28   | 28   | 67   | 17   | 17   | 74  | 65   |
| 7/02  | 11  | 43  | 46  | 3   | 1   | 23  | 2  | 0  | 8  | 32 | 32 |      | 201 | 137  | 56   | 34   | 66   | 31   | 6    | 73  | 53   |
| 7/09  | 9   | 41  | 33  | 5   | 11  | 15  | 10 | 2  | 10 | 49 | 20 |      | 205 | 136  | 43   | 19   | 64   | 28   | 25   | 61  | 65   |
| 7/19  | 20  | 32  | 52  | 8   | 9   | 16  | 11 | 5  | 11 | 44 | 13 |      | 221 | 164  | 48   | 47   | 57   | 35   | 25   | 63  | 50   |
| 7/25  | 11  | 41  | 53  | 4   | 5   | 15  | 2  | 5  | 12 | 53 | 13 |      | 214 | 148  | 54   | 26   | 79   | 16   | 27   | 71  | 72   |
| 8/04  | 6   | 36  | 14  | 6   | 5   | 32  | 9  | 12 | 30 | 51 | 12 |      | 194 | 144  | 48   | 12   | 41   | 66   | 25   | 37  | 45   |
| 8/10  | 8   | 30  | 15  | 16  | 3   | 29  | 11 | 7  | 25 | 39 | 11 | (2)  | 177 | 125  | 30   | 12   | 38   | 43   | 32   | 40  | 56   |
| 8/19  | 9   | 30  | 11  | 11  | 7   | 12  | 17 | 14 | 14 | 48 | 4  |      | 190 | 148  | 49   | 7    | 35   | 47   | 59   | 28  | 64   |
| 8/27  | 6   | 29  | 7   | 7   | 10  | 28  | 11 | 13 | 37 | 39 | 3  |      | 193 | 132  | 44   | 7    | 21   | 63   | 41   | 21  | 47   |
| 9/04  | 5   | 16  | 7   | 19  | 10  | 16  | 13 | 11 | 35 | 59 | 2  |      | 174 | 120  | 46   | 12   | 17   | 56   | 35   | 24  | 44   |
| 9/10  | 8   | 13  | 8   | 11  | 7   | 21  | 16 | 10 | 26 | 51 | 3  |      | 169 | 118  | 42   | 8    | 16   | 56   | 38   | 20  | 45   |
| 9/18  | 6   | 12  | 6   | 18  | 8   | 19  | 12 | 12 | 25 | 50 | 1  |      | 179 | 136  | 58   | 30   | 29   | 37   | 40   | 43  | 50   |
| 9/27  | 13  | 13  | 33  | 5   | 3   | 16  | 10 | 13 | 30 | 42 | 1  | (2)  | 149 | 124  | 56   | 43   | 22   | 36   | 23   | 52  | 36   |
| 10/05 | 18  | 10  | 37  | 6   | 3   | 10  | 10 | 7  | 23 | 24 | 1  |      | 151 | 111  | 32   | 45   | 11   | 36   | 19   | 50  | 28   |
| 10/14 | 33  | 9   | 14  | 7   | 3   | 4   | 15 | 9  | 17 | 38 | 2  |      | 172 | 121  | 59   | 51   | 22   | 19   | 29   | 60  | 42   |
| 10/21 | 24  | 11  | 38  | 4   | 2   | 8   | 2  | 7  | 25 | 30 | 1  |      | 171 | 141  | 49   | 70   | 16   | 26   | 29   | 61  | 32   |
| 10/30 | 34  | 8   | 44  | 3   | 3   | 4   | 11 | 13 | 21 | 29 | 1  |      | 155 | 129  | 59   | 68   | 19   | 29   | 14   | 67  | 25   |
| 11/06 | 27  | 8   | 51  | 3   | 1   | 5   | 9  | 5  | 20 | 25 | 1  |      | 153 | 135  | 50   | 55   | 15   | 39   | 26   | 52  | 31   |
| 11/18 | 28  | 8   | 34  | 5   | 1   | 1   | 14 | 12 | 32 | 17 | 1  | (2)  | 169 | 153  | 50   | 58   | 21   | 44   | 30   | 52  | 34   |
| 11/22 | 31  | 12  | 36  | 8   | 4   | 11  | 12 | 10 | 29 | 15 | 1  | (2)  | 150 | 144  | 51   | 59   | 26   | 32   | 27   | 59  | 37   |
| 12/01 | 31  | 14  | 40  | 4   | 2   | 13  | 10 | 10 | 20 | 6  | 0  | (2)  |     |      |      |      |      |      |      |     |      |

SUMMARY

| ADM   | ADF | AD? | SAH | SAF | SA? | JH | JF | J? | WP | MP | NOTE | TOI | STOI | ZUNK | AM/C | AF/C | IM/C | IF/C | ZAD | ZPEM |    |
|-------|-----|-----|-----|-----|-----|----|----|----|----|----|------|-----|------|------|------|------|------|------|-----|------|----|
| MEAN  | 15  | 31  | 28  | 6   | 4   | 15 | 8  | 8  | 20 | 35 | 15   |     | 186  | 136  | 46   | 29   | 45   | 33   | 28  | 55   | 54 |
| Mar.  | 27  | 28  | 12  | 1   | 5   | 12 | 11 | 22 | 18 | 0  | 1    |     | 137  | 136  | 31   | 33   | 34   | 21   | 48  | 49   | 60 |
| Apr.  |     |     |     |     |     |    |    |    |    |    |      |     |      |      |      |      |      |      |     |      |    |
| May   | 13  | 52  | 35  | 1   | 2   | 6  | 6  | 5  | 22 | 9  | 40   |     | 189  | 140  | 45   | 31   | 68   | 21   | 21  | 71   | 63 |
| June  | 17  | 56  | 29  | 2   | 1   | 10 | 4  | 4  | 11 | 28 | 40   |     | 202  | 134  | 38   | 31   | 71   | 17   | 15  | 76   | 64 |
| July  | 13  | 39  | 46  | 5   | 7   | 17 | 6  | 3  | 10 | 45 | 20   |     | 210  | 146  | 50   | 31   | 67   | 26   | 22  | 67   | 61 |
| Aug.  | 7   | 32  | 12  | 10  | 6   | 30 | 10 | 11 | 31 | 43 | 9    |     | 199  | 147  | 49   | 9    | 41   | 53   | 44  | 34   | 58 |
| Sept. | 8   | 14  | 14  | 13  | 7   | 18 | 13 | 12 | 29 | 51 | 2    |     | 179  | 127  | 48   | 13   | 22   | 53   | 38  | 28   | 47 |
| Oct.  | 30  | 9   | 32  | 5   | 3   | 5  | 9  | 10 | 21 | 32 | 1    |     | 158  | 124  | 47   | 56   | 16   | 28   | 25  | 58   | 33 |
| Nov.  | 27  | 8   | 51  | 3   | 1   | 5  | 9  | 5  | 20 | 25 | 1    |     | 155  | 129  | 59   | 68   | 19   | 29   | 14  | 67   | 25 |
| Dec.  |     |     |     |     |     |    |    |    |    |    |      |     |      |      |      |      |      |      |     |      |    |

1. Count conducted over a 4-day period.
2. Count did not include Gin, Little Gin, or the Gin Spits.

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