Hawaiian Monk Seal Population Summary 2024

Hawaiian Monk Seal Research Program, Pacific Islands Fisheries Science Center

INTRODUCTION

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The Hawaiian Monk Seal Research Program (HMSRP) recognizes the importance of using culturally significant names for places in Papahānaumokuākea Marine National Monument which overlays the Northwestern Hawaiian Islands (NWHI). For consistency, we retain the naming conventions of preceding annual reports but note culturally significant names in parentheses.

EXECUTIVE SUMMARY

This document provides preliminary information on Hawaiian monk seal population status, selected recovery activities in 2024, and population trajectories evaluated in the context of long-term trends (Johanos 2024a-e). Contrary to previous years, data analysis for this report was conducted prior to the end of the calendar year. Thus, events that occurred in mid to late December 2024 are not included in this report. Graphical and tabular information make up most of this report, with some explanatory text and commentary on notable findings.

The majority of endangered Hawaiian monk seals reside within the remote NWHI. Field surveys in this geographic region are conducted for population monitoring, stock assessment, and other conservation activities to aid in the recovery of this endangered species (U.S. NMFS 2007). This work has produced a long-term dataset on the Hawaiian monk seal spanning over 40 years. Historically, field surveys were conducted in seasonally established camps at most breeding sites for a period of 3-6 months or more. Presently, field camps are deployed for approximately 3 months every other year (i.e., 2022, 2024,...), with abbreviated efforts (lasting a few days to about 3 weeks) at all sites except French Frigate Shoals (Lalo) in the intervening years (i.e., 2023, 2025,...). Also, for several years, data collection at Midway (Kuaihelani) and Kure (Hōlanikū) atolls has been primarily collected by U.S. Fish and Wildlife and State of Hawaii Department of Land and Natural Resources/Kure Atoll Conservancy staff, respectively. Additional partners participating in monk seal research and recovery efforts include The Marine

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Mammal Center, Papahānaumokuākea Marine Debris Project, Hawaii Marine Animal Response, and the U.S. Coast Guard.

We did not estimate range-wide abundance for the species in 2023 because of limited field effort at Laysan Island (Kamole), Lisianski Island (Kapou), and Pearl and Hermes Reef (Manawai). We use data obtained in 2024 to assess the abbreviated field surveillance in 2023 and if resulting information deficits were restored in 2024. We also evaluate the adequacy of increased reliance on population monitoring provided by our conservation partners at Midway and Kure Atolls.

Total range-wide abundance (and 95% confidence interval) of Hawaiian monk seals in 2024 is estimated to be 1580 (1504, 1685), which is slightly lower than the total abundance estimated in 2022 (1605, 1512 to 1743). These abundance estimates are not significantly different because their confidence intervals almost entirely overlap. However, analyzing abundance trends from 2013-2024, there has been a significant positive trend in abundance for the NWHI, main Hawaiian Islands (MHI), and range-wide over this time period, although the population remains well below historic levels. A total of 169 pups were counted at the six NWHI subpopulations from Kure to French Frigate Shoals in 2024, compared to 168 in 2023. Notably, a record high number of births (55) was documented in the MHI in 2024.

Lifetable analysis indicates that vital rates (fecundity and survival) are conducive to population growth at all subpopulations with the exception of Pearl and Hermes Reef. There are, however, factors at several NWHI subpopulations that may limit population growth. These concerns are summarized below.

French Frigate Shoals—The depleted population at French Frigate Shoals continues to show signs of recovery. Continued favorable survival of all age classes from weaning through adulthood were observed again this past year. French Frigate Shoals abundance has been increasing slowly since 2014 as a consequence of improved survival. However, dependent pups at French Frigate Shoals have suffered significantly higher early mortality compared to all other sites due to higher early mortality due to shark predation, as well as young pups being washed away by waves or drowned.

Laysan Island, Lisianski Island, and Pearl and Hermes Reef – At Laysan, the reasons for low weaned pup (age 0) survival in recent years is unknown, and the estimate from 2023 to 2024 was the second lowest ever observed. At Lisianski, survival of (age 0) weaned pups from 2023 to 2024 was just under 0.5, one of the lowest rates estimated for several years. And, at Pearl and Hermes Reef, survival of weaned pups (age 0) and yearling seals declined during 2023 to 2024 compared to recent years. Otherwise, survival rates of older age classes were quite high at these locations.

Midway and Kure Atolls— The apparent decline in adult survival over the past three years at these locations likely reflects a failure to identify adults due to loss of easily identifiable marks and reliance on survey data collected by partners as an ancillary duty.

Finally, fifty-seven life-saving interventions were conducted range-wide in 2024. These included removing marine debris from entangled seals, removing fish hooks from seals, rehabilitating undersized seals, translocating pups away from areas of high shark predation risk, vaccinating seals against morbillivirus, and more. These actions and other activities, such as removing entangling debris from beaches, continue to contribute significantly to recovery at both the individual seal and population levels (Harting et al. 2014, Baker et al. 2024).

Field Effort in the NWHI

The 2024 field seasons at Laysan (LAY; Kamole), Lisianski (LIS; Kapou), and Pearl and Hermes Reef (PHR; Manawai) were considerably longer in duration than in 2023 but still somewhat shorter than typical historical seasons (Figure 1). At French Frigate Shoals (FFS; Lalo) the field season duration was typical. At Midway Atoll (MDY; Kuaihelani) and Kure Atoll (KUR; Hōlanikū), survey effort was conducted by U.S. Fish and Wildlife Service (USFWS) and State of Hawaii Department of Land and Natural Resources (DLNR) staff, respectively, with varying frequency throughout most the year. There was no NMFS presence at Midway Atoll in 2024 and HMSRP staff conducted surveys during just two days at Kure Atoll. Necker Island (NEC; Mokumanamana) was surveyed twice and Nihoa Island (NIH) was surveyed four times.

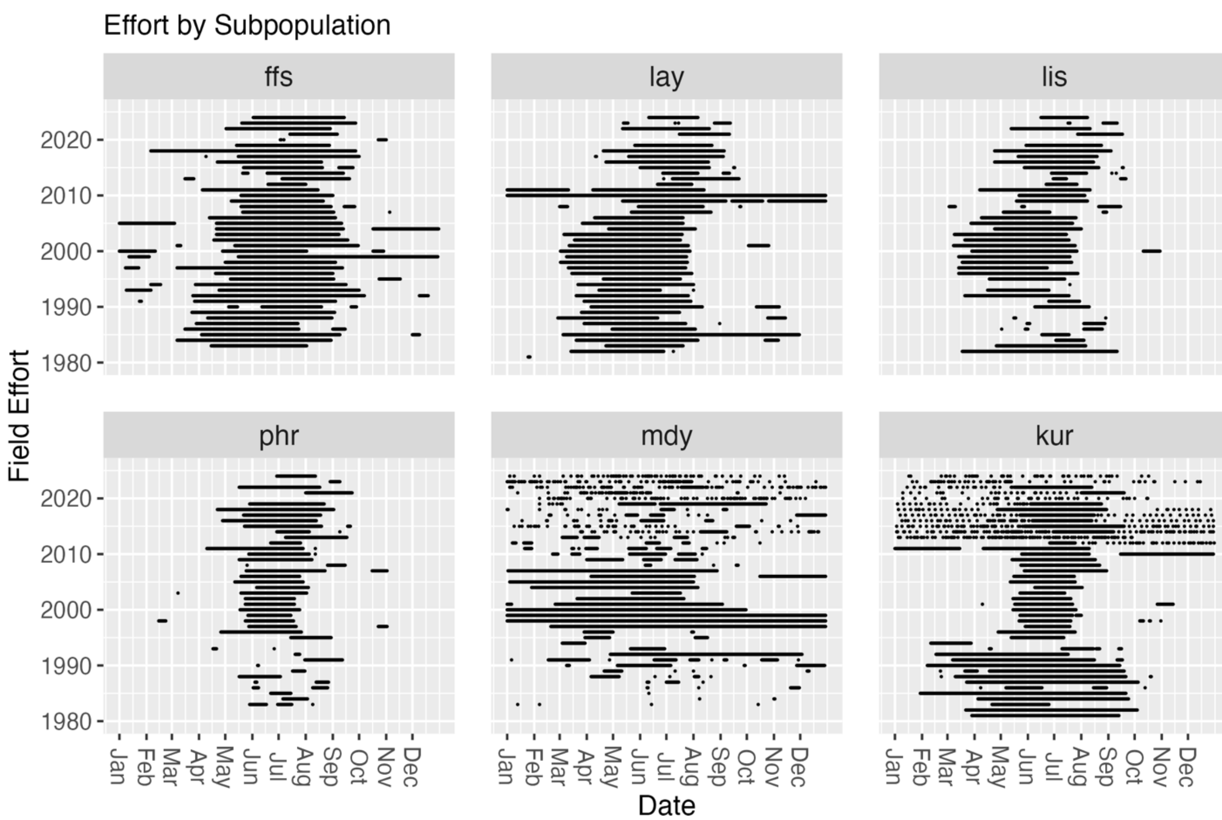

Figure 1. Historic field effort (solid lines and dots) at 6 NWHI sites by month and year. State of Hawaiʻi (DLNR) effort at Kure Atoll is included and U.S. Fish and Wildlife effort is shown at Midway Atoll.

The following three figures provide some additional insight into patterns in survey effort from Kure Atoll to French Frigate Shoals over time. Figure 2 shows the total number of survey effort hours expended at each subpopulation each year. At Midway and Kure Atolls after approximately 2010, surveys were conducted both by HMSRP staff and partners (USFWS and DLNR). In some years, especially at Kure, all or nearly all the survey effort was carried out by these partners. Because partner effort is more sporadic than during concentrated HMSRP field seasons, the pattern across years is less comparable at Midway and Kure than at other sites.

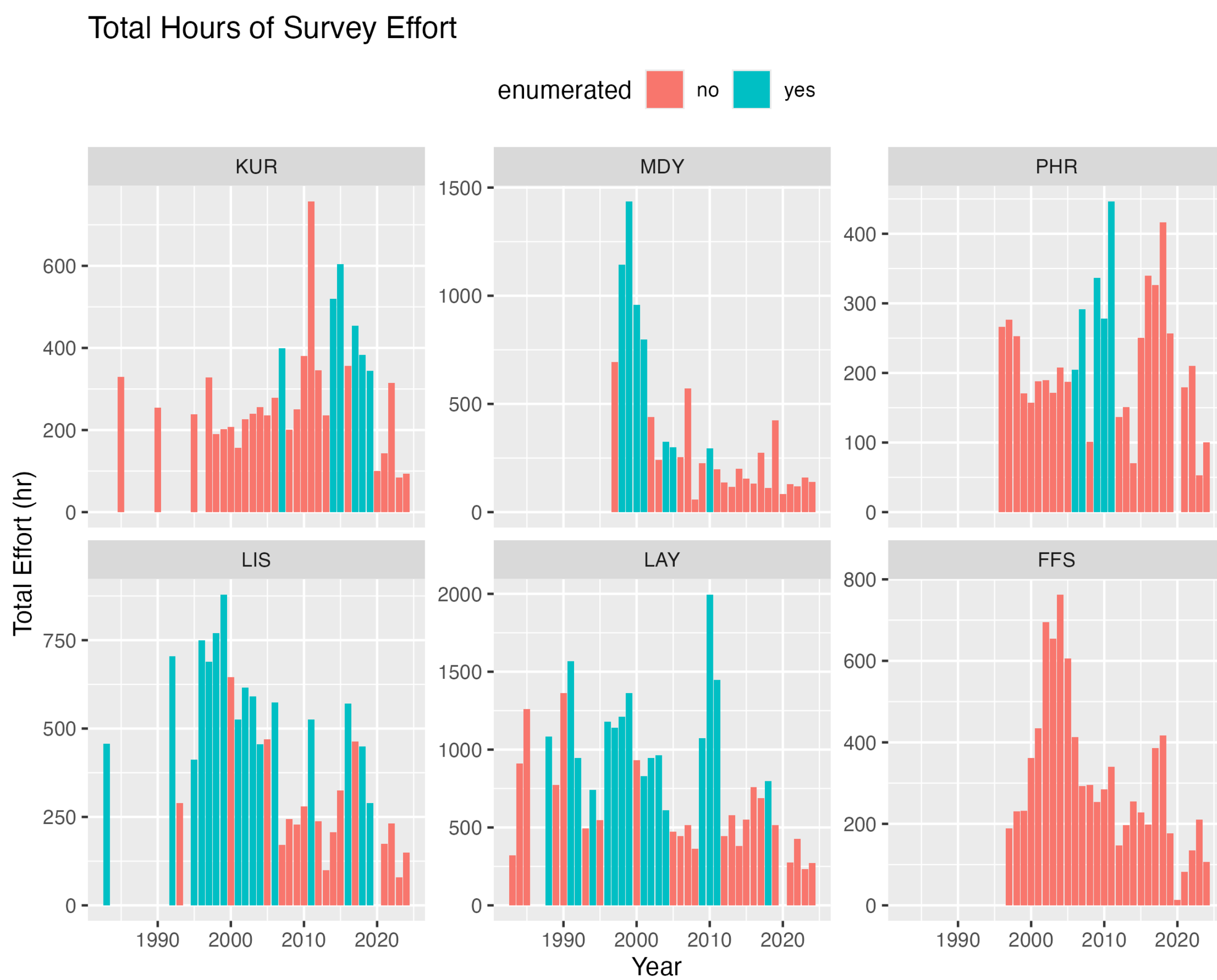

Figure 2. Number of hours of survey effort expended by year at six NWHI subpopulations. Colors indicate if full population enumeration was achieved. Note that the y-axis scales vary among subpopulations to help visualize trends within locations.

Figure 3 shows the durations of field camps in days. With the exception of Midway and Kure Atolls since about 2010, days in the field is calculated from the time camps are deployed until they are picked up. In some years at certain sites, more than one camp was deployed in a year. In these cases, the days-in-the-field calculation excludes the time between camps when teams were absent. Days in the field at Midway and Kure Atoll are tallies of just the days when data were collected because surveillance was typically infrequent at these sites (see also the dots and dashes at Midway and Kure in Figure 1).

Although the 2024 field seasons at Laysan I., Lisianski I., and Pearl and Hermes Reef were much longer in duration than the 2023 seasons, the number of effort hours in 2024 did not increase proportionately. At FFS, the 2024 field season was 20% shorter compared to 2023 whereas the number of effort hours expended declined by 50%.

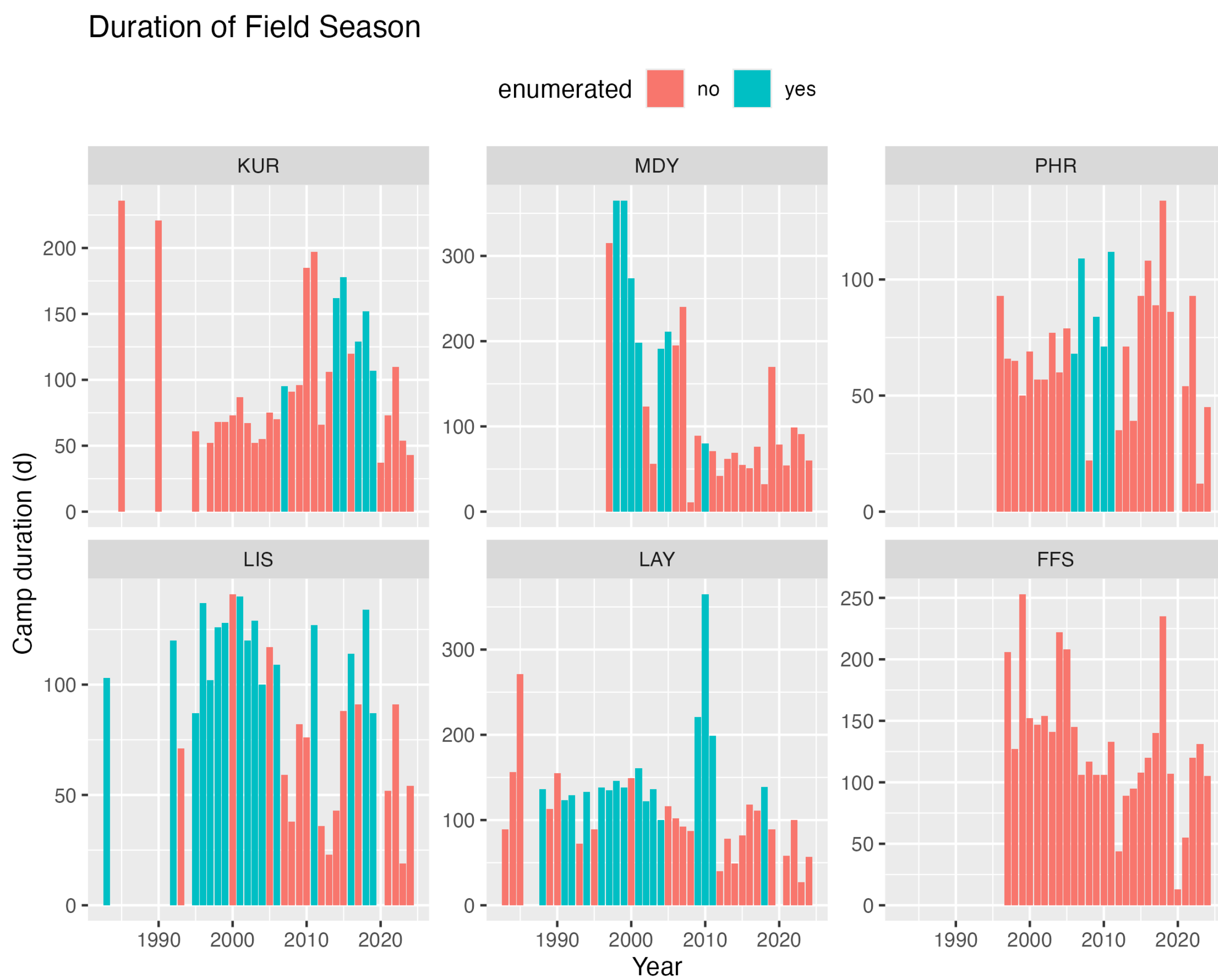

Figure 3. Field season durations in days. Values shown by year at six NWHI subpopulations. Note that the y-axis scale varies among subpopulations.

Finally, Figure 4 combines information from the previous two figures and depicts trends in the number of hours of survey effort expended per day in the field. In 2023, this metric increased at French Frigate Shoals, Laysan I., Lisianski I., and Pearl and Hermes Reef. Because the 2023 season was very short, effort was intensified at Laysan I., Lisianski I., and Pearl and Hermes Reef that year, so it is not surprising that effort per day declined during 2024. Still, the 2024 rate of field effort hours per day remained lower at French Frigate Shoals, Laysan I., and Lisianski I. compared to typical field seasons up until the 2010s. The reason for these trends should be determined, and may have to do with a dramatic increase in photo identification image collection during surveys which results in lengthy post-survey processing, as well as in changing field culture and workload expectations

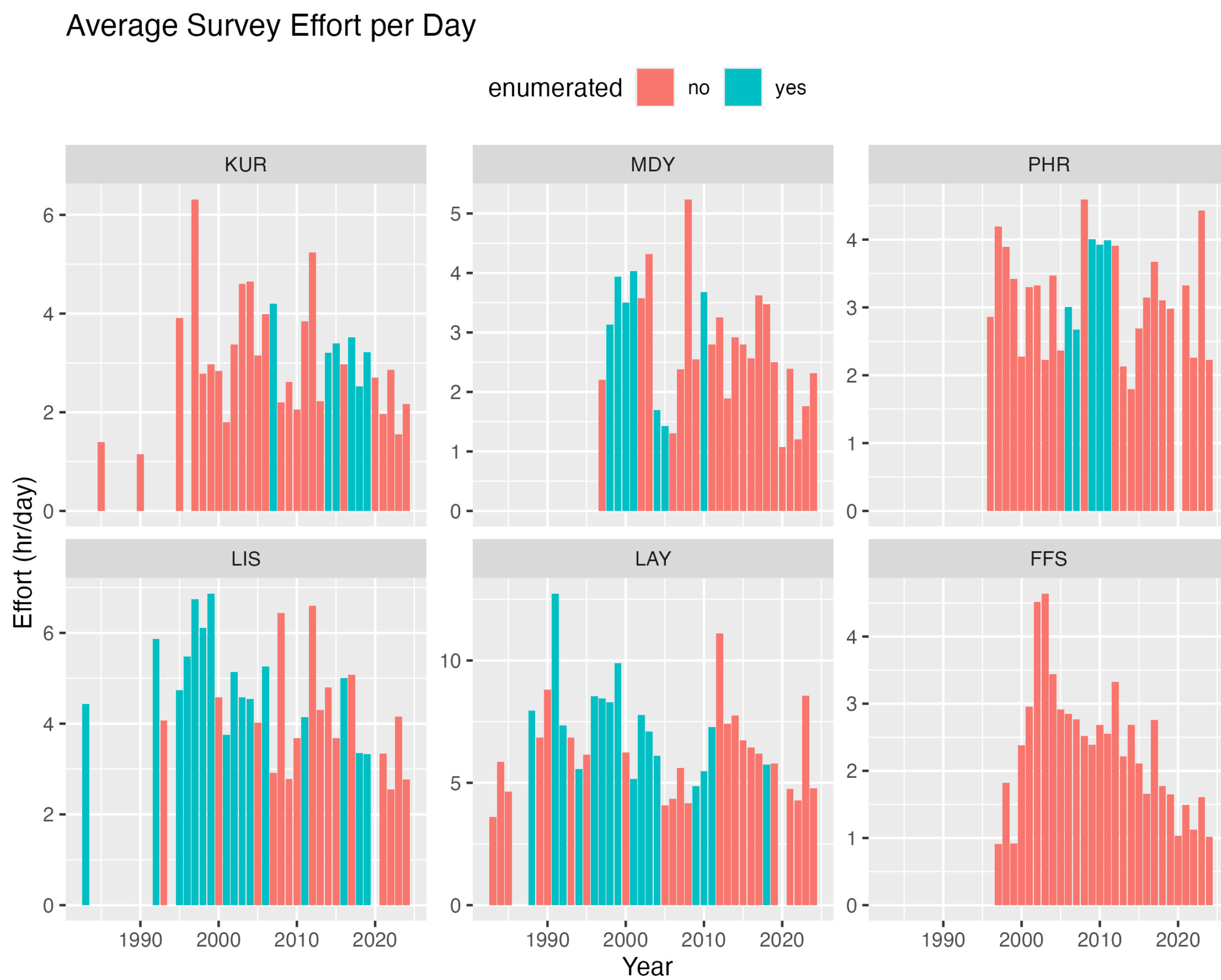

Figure 4. Average number of survey effort hours expended per day in the field. Values shown by year at six NWHI subpopulations. Note that the y-axis scales vary among subpopulations.

Survey Effort in the main Hawaiian Islands (MHI)

The majority of MHI monk seal monitoring was conducted through the public, volunteer, and agency partner sighting network from Kauaʻi to Hawaiʻi Island. Two complete island-wide monk seal surveys were conducted at Niʻihau in 2024. These surveys were funded by the U.S. Navy and carried out by staff from Naval Facilities Engineering Command Hawaiʻi (NAVFAC), State of Hawaiʻi Division of Aquatic Resources (DAR), and Niʻihau Ranch following HMSRP survey protocols. A survey of Niʻihau was conducted on 1 July 2024 and a survey of Niʻihau and Lehua Rock was conducted on 19 August 2024 which included HMSRP staff. The two surveys yielded total counts of 70 and 73 seals, respectively, including seals seen in the water.

Interventions to Improve Survival

A total of 26 seals were subject to 26 interventions in the NWHI during 2024 with the intention of improving their survival prospects (Table 1).

Table 1. Summary of interventions conducted in 2024. Size classes are abbreviated as follows (A-Adult, S-Subadult, J-Juvenile, W-Weaned pup, P-Nursing pup.

Intervention Type	**Number (by size class)**
NWHI	
Translocation	14 (W[1])
Disentanglement from marine debris	4 (W-3, J-1)
Medical treatment *in situ*	1 (J-1[2])
Rehabilitation	3 (W)
Pup reunite with birth mother	4 (P)
Subtotal NWHI	26
MHI	
Translocation	2 (W-2)
Displacement for seal safety	8 (A-4, S-1, J-3)
De-hooking/trim attached gear	7 (S-3, J-2, W-2)
Disentanglement from marine debris	2 (A-1, W-1)
Medical treatment *in situ*	6 (A-1, J-5[3])
Rehabilitation	3 (S-1, J-2)
Pup reunite with birth mother	1 (P)
Umbilical snip	2 (P)
Subtotal MHI	31
GRAND TOTAL	57

[1]All NWHI translocations were conducted to mitigate shark predation.
[2]Treatment of an injured juvenile with a fore flipper amputation with antibiotics.
[3]Number includes five treatments with antibiotics a juvenile female received for the same injury.

Seventeen of the NWHI interventions occurred at French Frigate Shoals. These included the translocation of 14 weaned pups from historically high shark predation risk areas to a lower risk site within the atoll, the treatment of an injured juvenile female with antibiotics, and the reunification of two pups with their birth mothers. Translocations to mitigate shark predation were suspended in late August 2021 due to a lack of evidence of predatory shark activity but were reinstated in 2022-2024 due to a resumption of shark activity targeting nursing and newly weaned pups. Interventions at other NWHI subpopulations included disentangling four immature seals entangled in marine debris at Laysan and Lisianski Islands, and Midway and Kure Atolls, reuniting two nursing pups with their birth mothers at Kure Atoll, and capturing three compromised weaned pups at Pearl and Hermes Reef and transporting them to the Marine Mammal Center's monk seal hospital, Ke Kai Ola, in Kona, for rehabilitation. One weaned female pup was released at Midway Atoll in December and the other two seals remain in care at Ke Kai Ola as of December 10, 2024. In addition to these interventions to increase survival, an adult male was captured in the MHI and transported to Laysan Island and released to mitigate concerning interactions with members of the public.

A total of 31 interventions were conducted to benefit 23 seals in the MHI in 2024 (Table 1). Interventions included hook removal, trimming trailing gear from hooked seals, removal of entangling marine debris, treatment with antibiotics, displacement for seal safety, translocation, rehabilitation and interventions to help newborn pups. A total of 14 hookings were documented in the MHI in 2024. Hooks were removed from four seals. Trailing line and gear were trimmed from three hooked seals whose hooks eventually pulled out on their own over time. Seven additional hooked seals were monitored without direct intervention; of those, three lost the gear on their own, one seal remained hooked at the end of 2024, and the outcome is unknown for the other three cases. Entangling debris (plastic ring, nylon strap) was removed from two seals. Two seals were treated with antibiotics for shark inflicted and suspected dog inflicted wounds. Eight seals were displaced away from areas for seal safety. These included busy roads and parking lots. A one-day old pup was reunited with its birth mother and the placenta was cut from the umbilicus of two newborn pups. Two weaned pups were translocated within their natal island to prevent habituation to humans and for overall seal safety. Three seals were taken into rehabilitative care at Ke Kai Ola monk seal hospital. All three were brought in because they were in poor body condition and two of the seals had additional injuries. The juvenile male from Kauai was successfully released back into the wild after just over four months in rehabilitation. The other two seals remain in care at Ke Kai Ola as of December 10, 2024.

Vaccination of seals against morbillivirus was also conducted in 2024. A total of 16 seals received at least one full dose of the vaccine, and 9 seals received 2 doses within the appropriate timeframe and are considered fully vaccinated; all vaccinations occurred in the MHI in 2024.

Abundance and Trends

Abundance estimates were obtained for all subpopulations in 2024 (Table 2). Capture-recapture estimates were obtained for Laysan and Pearl and Hermes Reef, whereas discovery curve extrapolation was used to estimate abundance of non-pups at French Frigate Shoals, Lisianski Island, and at Midway and Kure Atolls.

Table 2. Estimates of Hawaiian monk seal abundance for sites where estimates were obtained in 2024. Methods used to generate abundance estimates are abbreviated as follows: CR—capture-recapture, DC—discovery curve extrapolation, CC—corrected beach counts, Min—minimum tally. Median values are presented with (in parentheses) 95% confidence limits of 30,000 random draws from abundance distributions where estimates of error are available. Note that the median range-wide abundance is not equal to the total of the individual sites' medians, because the median of sums may differ from the sum of medians for non-symmetrical distributions. Pup production at Necker and Nihoa Islands is estimated as the mean of the total pups observed in the past 5 years, excluding counts occurring early in the pupping season when most have yet to be born.

	Non-pups			Pups	Total			
Location	**Median**	**LCL**	**UCL**		**Median**	**LCL**	**UCL**	**Method**
French Frigate Shoals	216	208	230	50	266	258	280	DC
Laysan	192	188	203	43	235	231	246	CR
Lisianski	148	141	172	19	167	160	191	DC
Pearl & Hermes Reef	121	115	131	24	145	139	155	CR
Midway	71	69	109	12	83	81	121	DC
Kure	91	80	119	21	112	101	140	DC
Necker	80	52	142	6	86	58	148	CC
Nihoa	73	48	131	2	75	50	133	CC
Subtotal NWHI	***1008***	***954***	***1104***	***177***	***1185***	***1131***	***1281***	**---**
MHI Kauai to Hawaii	204	204	204	34	238	238	238	Min
Ni'hau/Lehua	134	84	183	21	155	105	204	CC
Subtotal MHI	***338***	***288***	***387***	***55***	***393***	***343***	***442***	**---**
Range-wide total	***1348***	***1272***	***1453***	***232***	***1580***	***1504***	***1685***	**---**

Discovery curve extrapolation is likely becoming a less reliable method for estimating non-pup abundance than it once was. This method likely worked well when field effort was conducted quite consistently from year to year and when new reference curves (from years with total enumeration) were obtained every few years at most sites. However, as described above (Figures 2 and 4), survey effort patterns have changed in NMFS field camps in recent years, whereas reference discovery curves primarily date from longer field seasons with more intensive daily survey effort. Midway and Kure effort patterns now reflect partners conducting less regular surveys than in prior years when NMFS or other staff were primarily focused on monk seal population monitoring. The reference discovery curves for Midway and Kure may not be representative of the current accrual of new individual identifications. Finally, at French Frigate Shoals, total enumeration has never been achieved, so reference curves are borrowed from Pearl and Hermes Reef, the subpopulation location with the most similar physiography. For all these reasons, the viability of the discovery curve extrapolation method for estimating current abundance should be re-examined.

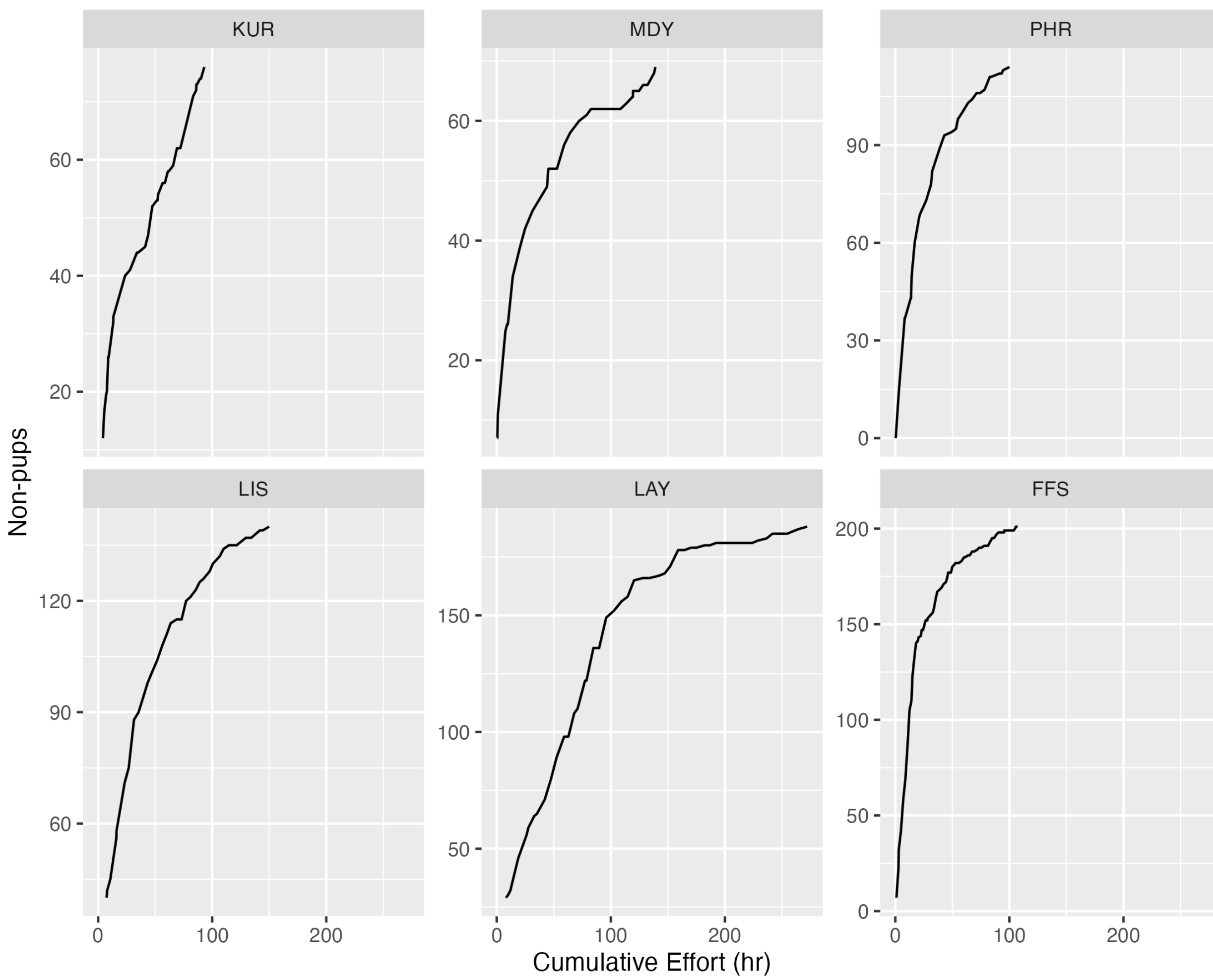

Figure 5. Discovery curves showing the accumulation of new non-pup identifications at each of the six most-studied NWHI subpopulations in 2024. Note that x-axis scales are the same for all panels, whereas the y-axis scales differ.

Total enumeration (generally defined as 100 hours of survey effort without identification of a new non-pup) was not achieved at any location. Figure 5 shows that discovery curves for non-pups did not reach a sustained asymptote at any of the sites from Kure Atoll to French Frigate Shoals.

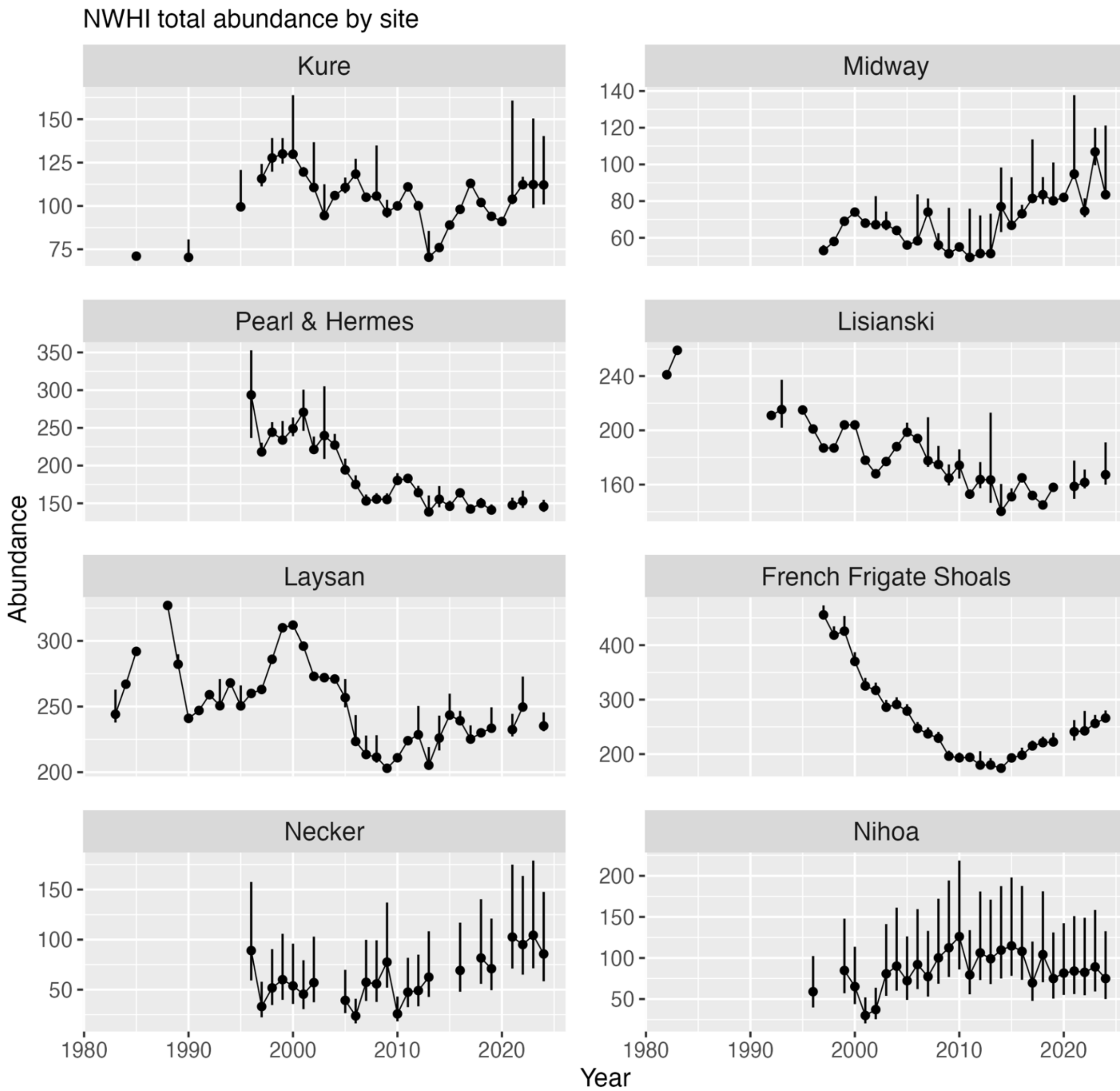

Figure 6. Estimated total abundance trends at eight Northwestern Hawaiian Islands subpopulations. Medians and 95% confidence intervals are shown.

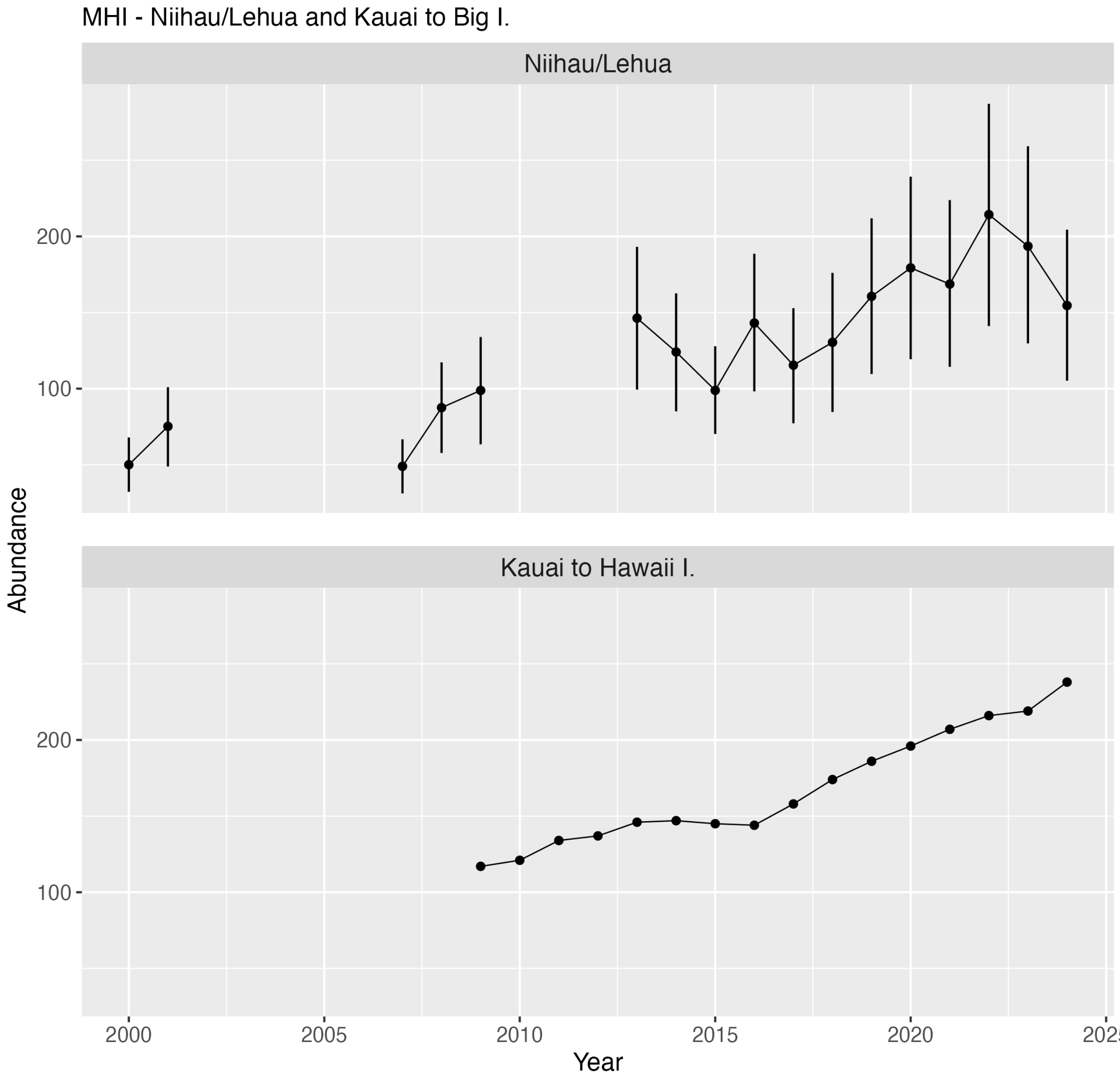

Figure 7. Estimated total abundance trends at Niʻihau/Lehua and from Kauaʻi to Hawaiʻi I. Note that Lehua Rock was not surveyed on one of the two days in 2024 when Niʻihau was surveyed.

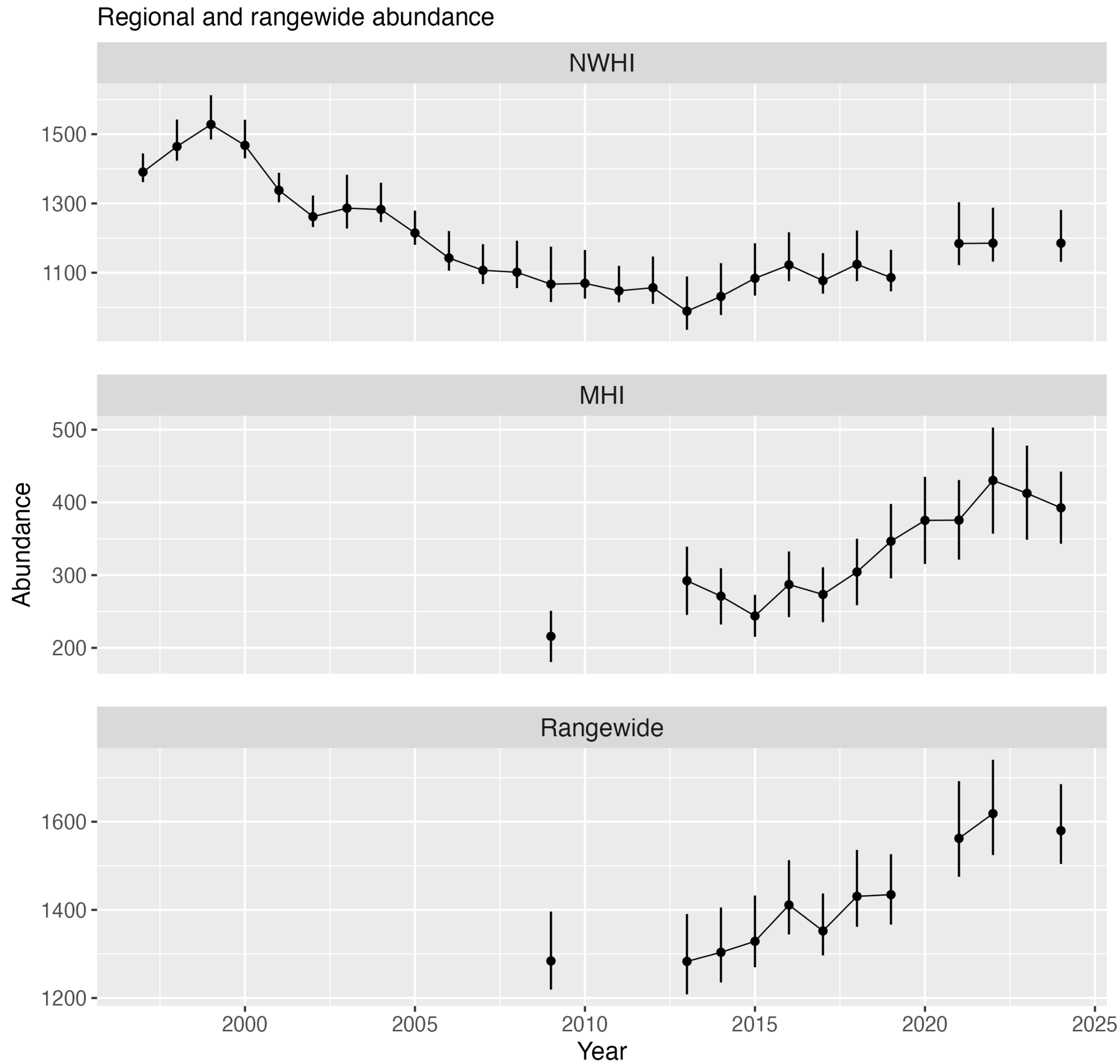

Figure 8. Estimate total abundance trends in the NWHI, MHI, and range-wide. Note that for 2023 only the MHI abundance estimate was obtained.

We analyzed abundance trends from 2013 through 2024, though no NWHI nor range-wide estimates were available for 2020 and 2023. A Monte Carlo approximation of the annual multiplicative rate of realized population growth ($\lambda_{realized}$) during 2013–2024 was generated by fitting 10,000 log-linear regressions to randomly selected values from each year's abundance distributions (Table 3). The lower confidence limits of the growth rate distributions for the NWHI, MHI, and range-wide since 2013 are all above 1.0, indicating significant positive trends.

Table 3. Median realized population growth rates with lower and upper 95% confidence limits for the NWHI, MHI, and range-wide from 2013 to 2024.

Location	Median	LCL	UCL
NWHI	1.015	1.009	1.022
MHI	1.048	1.035	1.061
Range-wide	1.022	1.016	1.028

Age-Sex Structure

Age and sex structures of various monk seal subpopulations are represented using data on known individuals identified in a given year (Figures 9 and 10). True total abundance is usually only slightly higher than the tally of known individuals, so that the age-sex structures are nearly complete. The exceptions are Necker, Nihoa, Niʻihau, and Lehua Islands, where most individuals are not identified. We present an age-sex structure for MHI seals observed from Kauaʻi to Hawaiʻi Island, where we believe a majority of the seals are identified each year. However, approximately half the MHI seals reside at Niʻihau and Lehua (and the very rarely surveyed Kaʻula Rock). Thus, the age and sex composition of seals identified from Kauaʻi to Hawaiʻi Island may not be representative of the entire MHI.

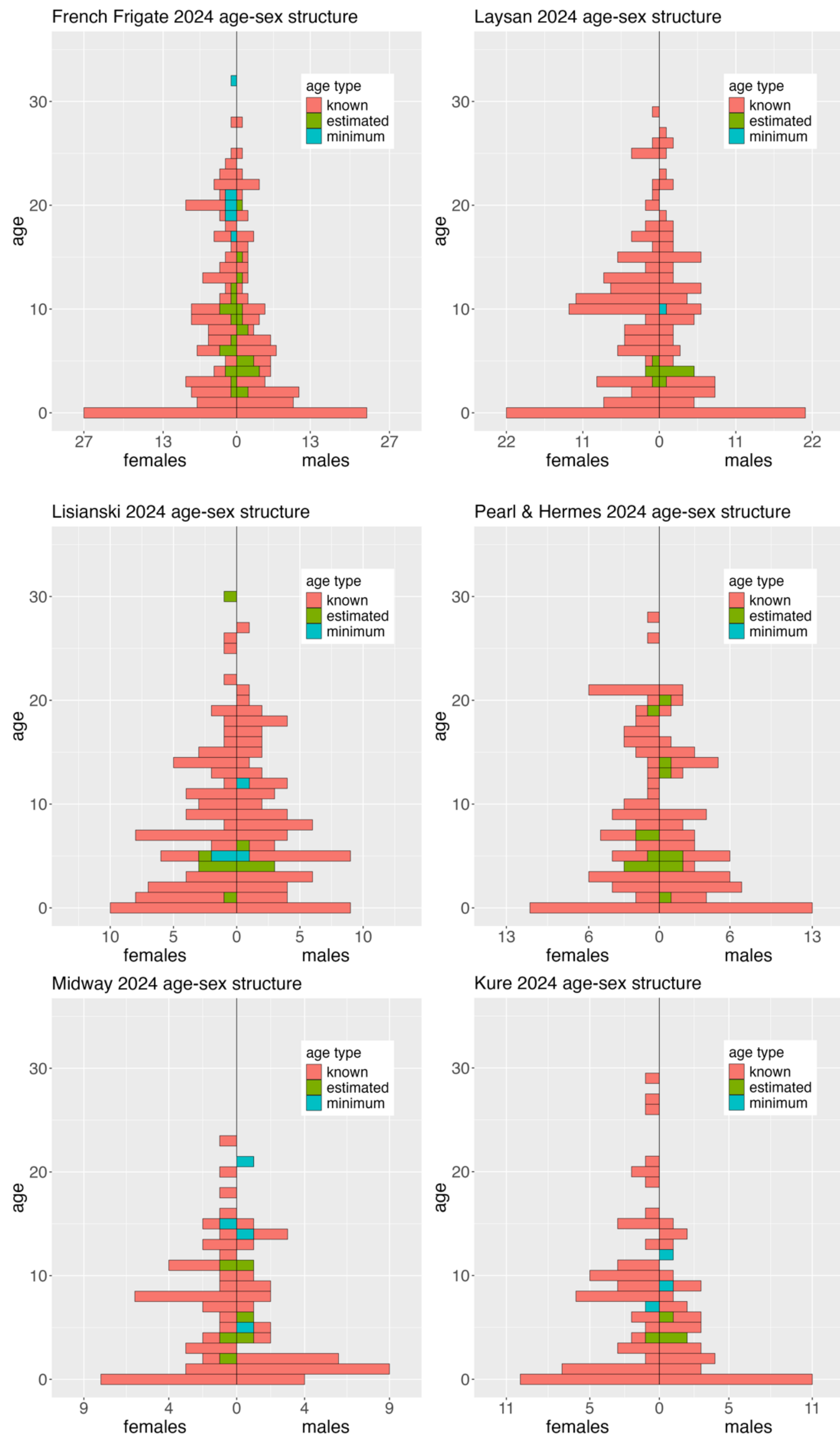

Figure 9. Age-sex structures of six NWHI subpopulations in 2024.

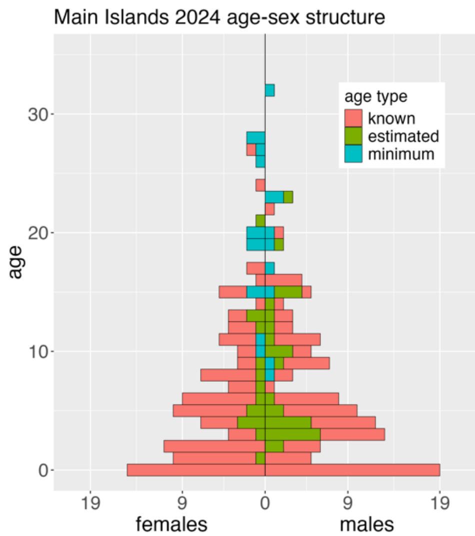

Figure 10. Age-sex structure in the MHI from Kaua'i to Hawai'i Island in 2024.

Pup Production[1]

A total of 169 pups were counted at the six NWHI subpopulations from Kure to French Frigate Shoals in 2024, compared to 168 in 2023 (Figure 11).

[1] Since 2022, pup tallies were extracted from the Master ID file (ALLMID.new), whereas prior to 2021, a spreadsheet with numbers drawn from published annual reports or field camp leaders' summary tables was simply updated. The new method is preferred because it is not subject to transcriptions errors, and any corrections to historic data will be reflected in newly extracted tallies. Some tallies differ between the old and new methods, and these should be examined to determine which data source is in error.

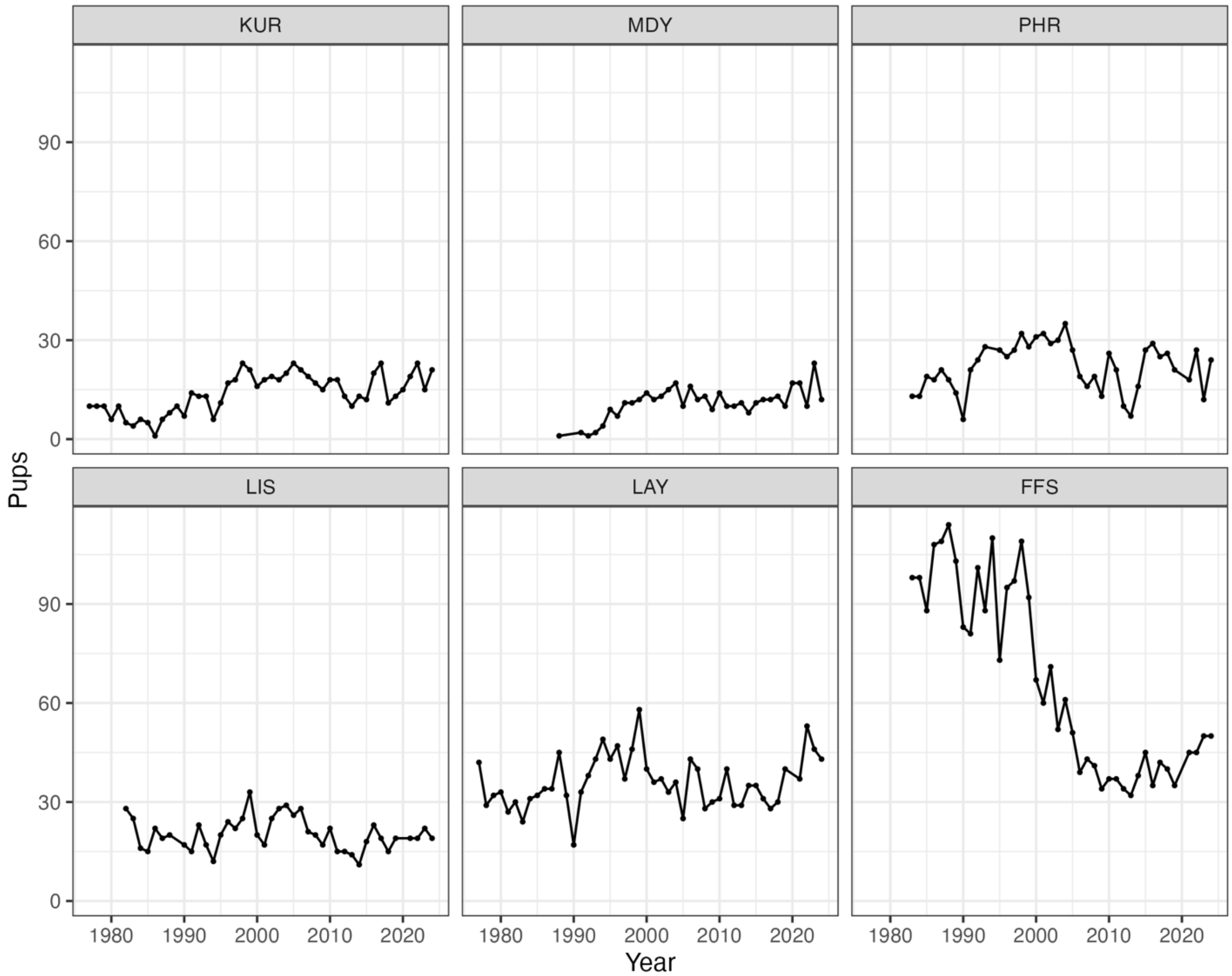

Figure 11. Number of pups born at six NWHI subpopulations.

Because surveys of Necker and Nihoa Islands are typically brief and occur only a few days per year at most, pup production cannot be reliably assessed. In 2024, a minimum of four pups was born at Necker Island and a minimum of one was born at Nihoa Island.

French Frigate Shoals terrestrial habitat has been greatly impacted by climate-change. All the islands have been reduced in size over the past 50 years, and the formerly second, third, and fourth largest islands have either been greatly reduced in size (East) or have entirely disappeared (Whaleskate and Trig). Whaleskate was mostly gone by the late 1990s and in 2018 Trig disappeared and East was mostly destroyed by Hurricane *Walaka*. Distribution of pupping has changed dramatically in response to terrestrial habitat loss, as depicted in Figure 12.

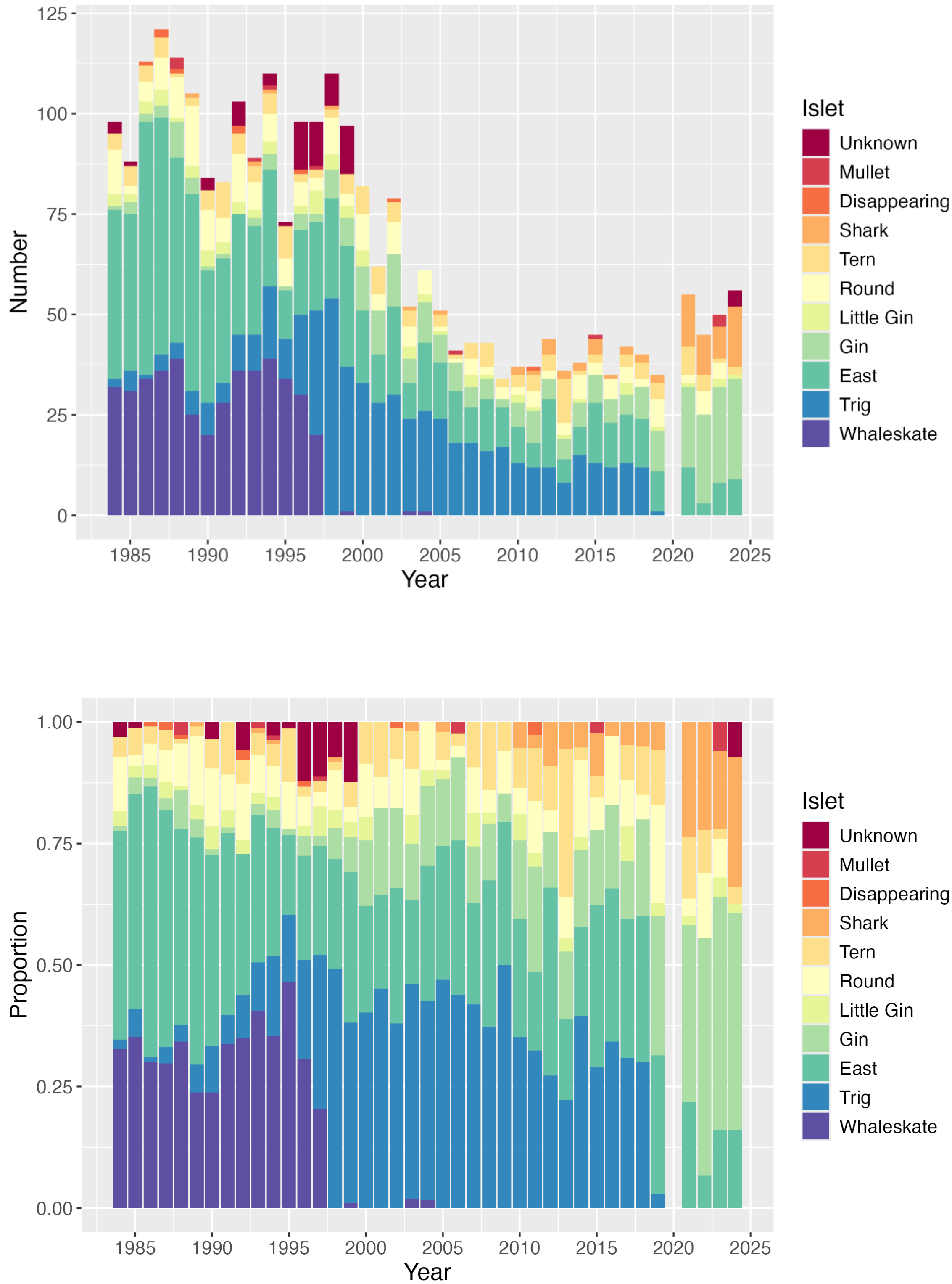

Figure 12. Number (top panel) and proportion (bottom panel) of pups born at French Frigate Shoals islands. Pup births with insufficient geographical data to resolve them to a particular islet are categorized as unknown.

A record high 55 pups were counted in the MHI in 2024 (Figure 13).

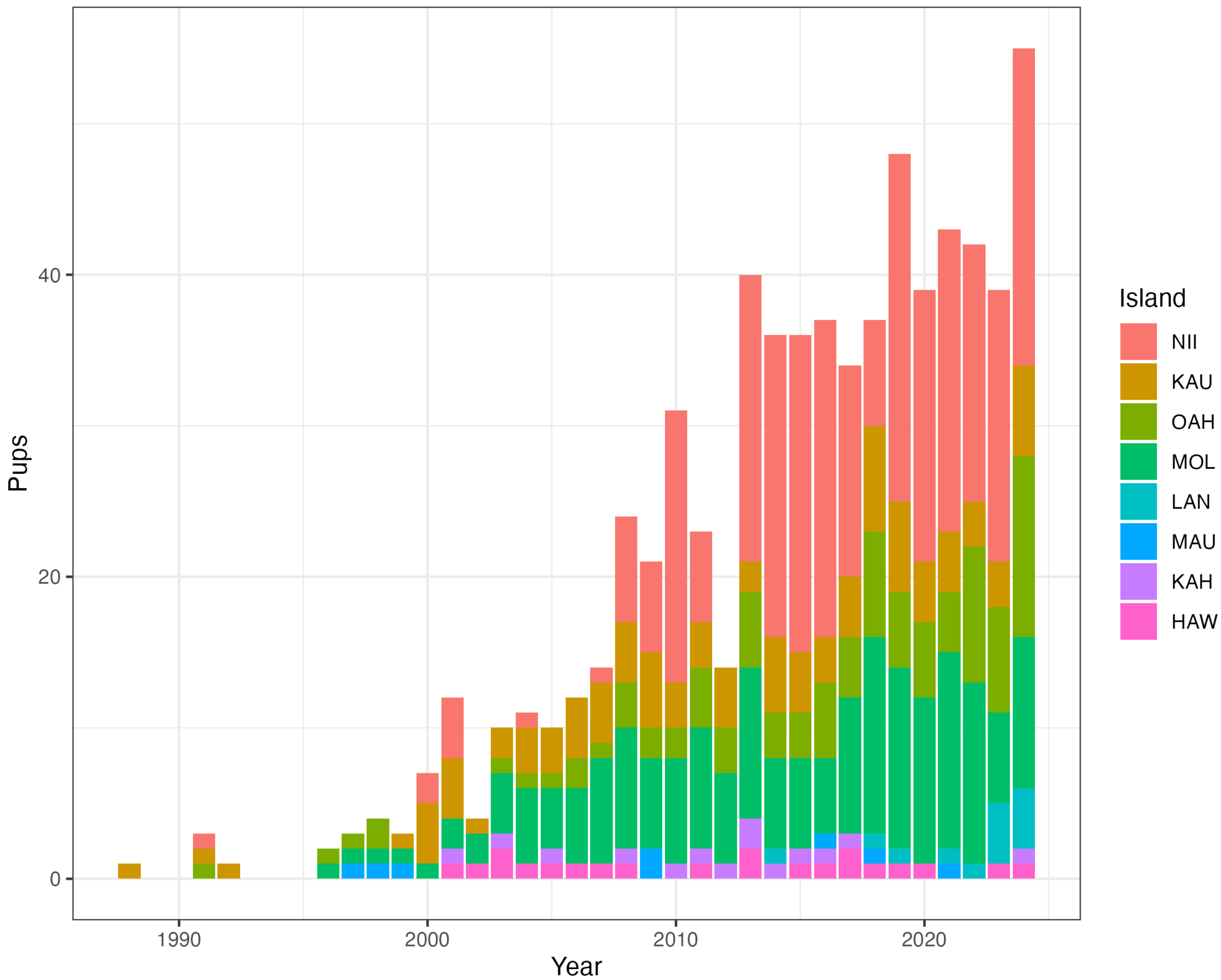

Figure 13. Number of pups counted in the MHI; colors indicate birth islands. NII – Niʻihau, KAU – Kauaʻi, OAH - Oahu, MOL - Molokai, LAN - Lanai, MAU - Maui, KAH – Kahoʻolawe, HAW – Hawaiʻi.

Reproductive Rates

Age-specific reproductive curves for four subpopulations (MHI, FFS, LAY, and LIS) have typically been fitted to data pooled from 2000 to the present. The reproductive curves have not been updated to 2024. The curve-fitting method used to date requires considerable manipulation to obtain convergence. There are also several adjustments made to account for unknown aged females and undetected births. In recent years, HMSRP has endeavored, to the extent practicable, to automate annual data analysis processes. Our methods for fitting reproductive curves requires an overhaul to achieve this.

Survival

Birth to Weaning

Until 2021, survival of pups from birth to weaning was calculated by dividing the number of pups known to have weaned by the total observed number of pups. Pups that were still nursing at the end of a field season were excluded from this calculation, whereas pups already weaned when field teams arrived were included. This *status quo* approach tends to be positively biased because any pups that die prior to the beginning of the field season are not counted unless their carcasses are discovered. To obtain less-biased estimates of survival to weaning, we developed a new approach in 2021. The new calculation only includes pups born after field teams arrived and that either died or weaned prior to the end of field observations. The estimates are presented in Figure 14 along with those calculated using the *status quo* method for comparison. The differences in the two approaches to calculating survival to weaning are especially apparent when field seasons are very short.

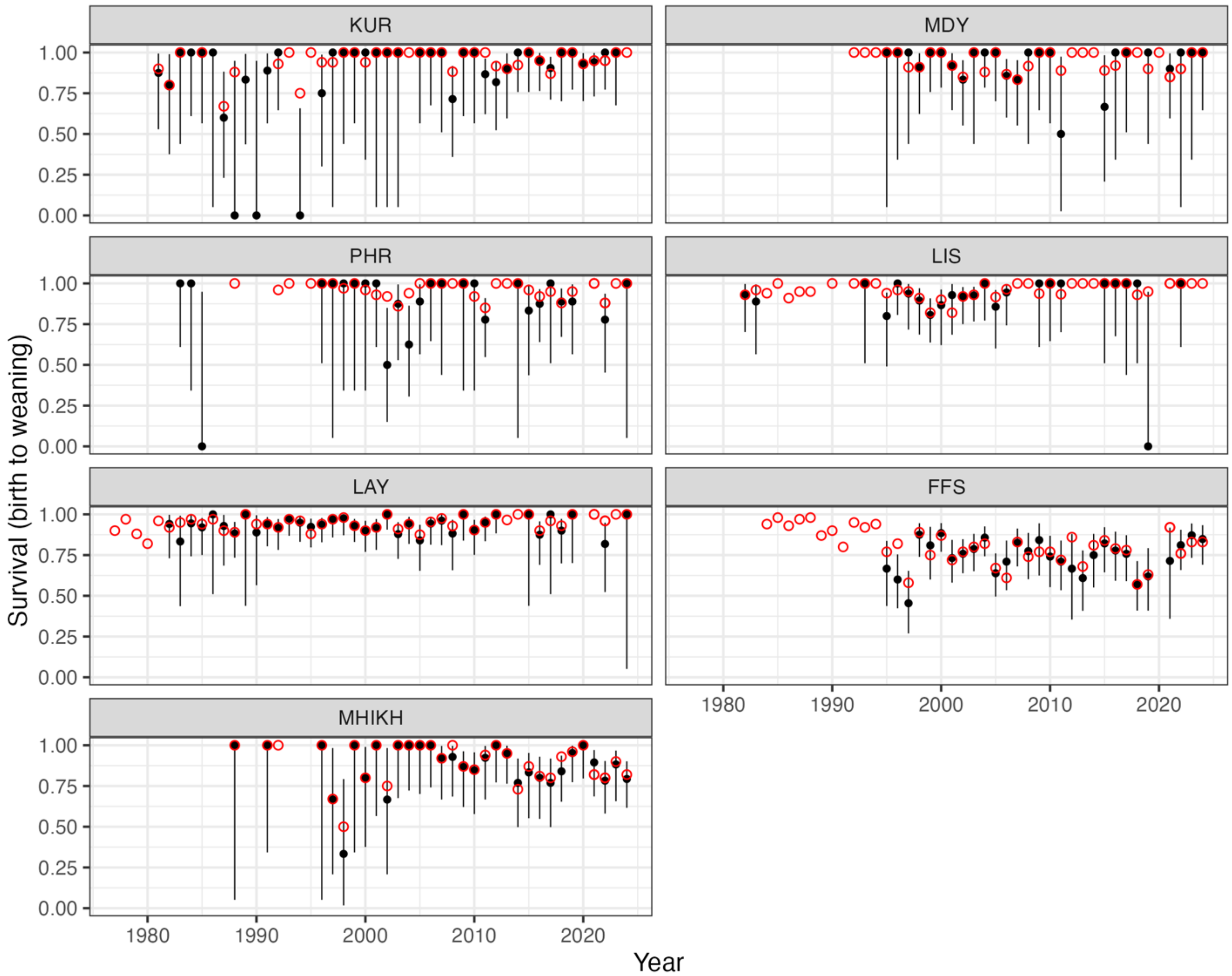

Figure 14. Estimated survival rates from birth to weaning at six NWHI subpopulations (KUR, MDY, PHR, LIS, LAY, FFS) and the MHI from Kauaʻi to Hawaiʻi Island (MHIKH). Solid black circles are estimates derived using the new method with black lines indicating 95% binomial confidence intervals. Open red circles are estimates derived using the status quo method.

Figure 15 shows estimated survival from birth to weaning using the new method with all years combined, providing a comparison among subpopulations. Pups at French Frigate Shoals clearly have suffered significantly higher early mortality compared to all other sites due to historically high shark predation targeting pupping areas within this site.

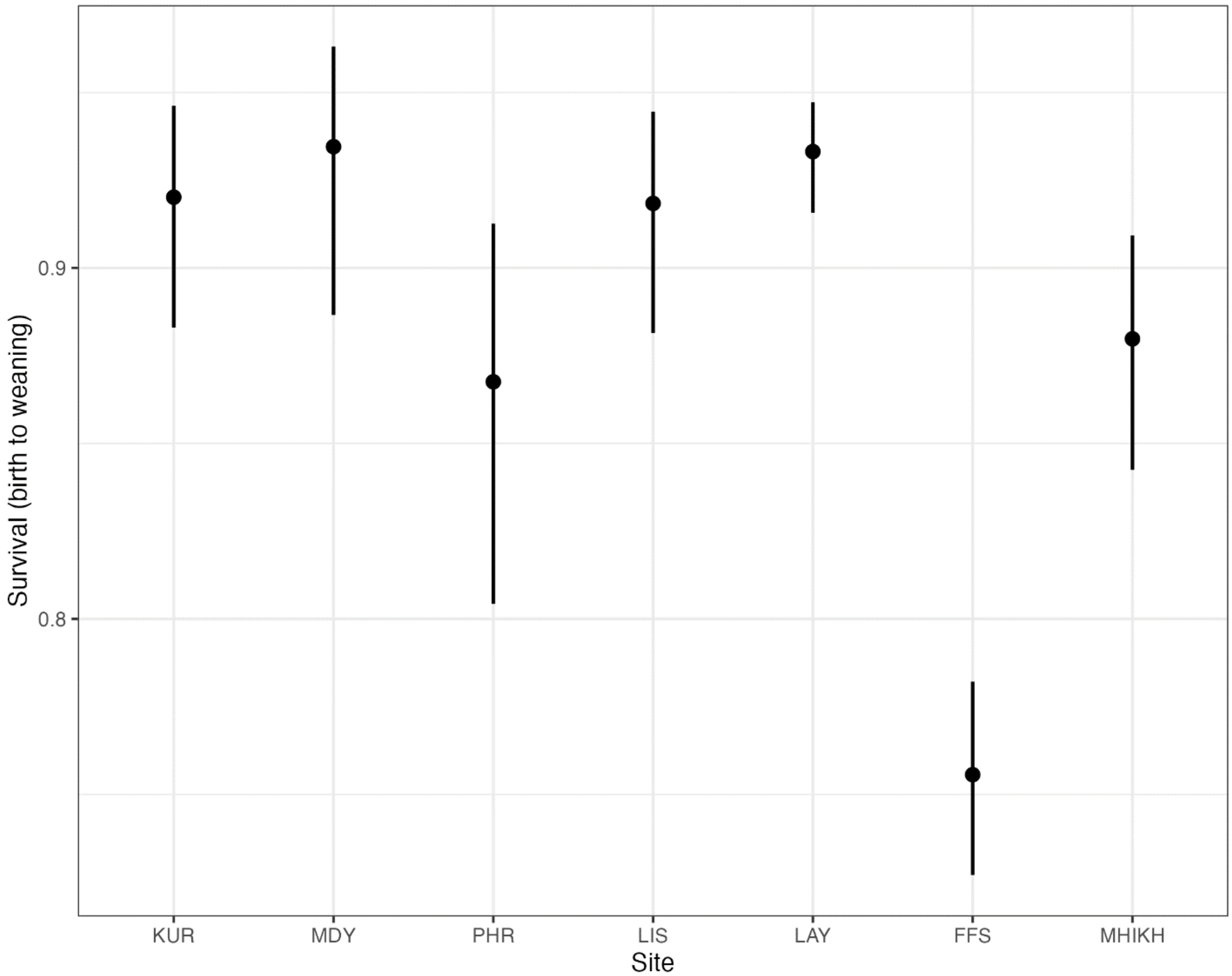

Figure 15. Estimated survival rates from birth to weaning at six NWHI subpopulations (KUR, MDY, PHR, LIS, LAY, FFS) and the MHI from Kauaʻi to Hawaiʻi Island (MHIKH). Solid black circles are estimates with black lines indicating 95% binomial confidence intervals. All years were combined.

Post-weaning Survival

Figures 16–23 present capture-mark-recapture (CMR) survival estimates for 6 age classes: weaning to 1 yr, 1 to 2 yr, 2 to 3 yr, 3 to 4 yr, adult (4 to 17 yr), and senescent (18+ yr). Highlights appear below each figure.

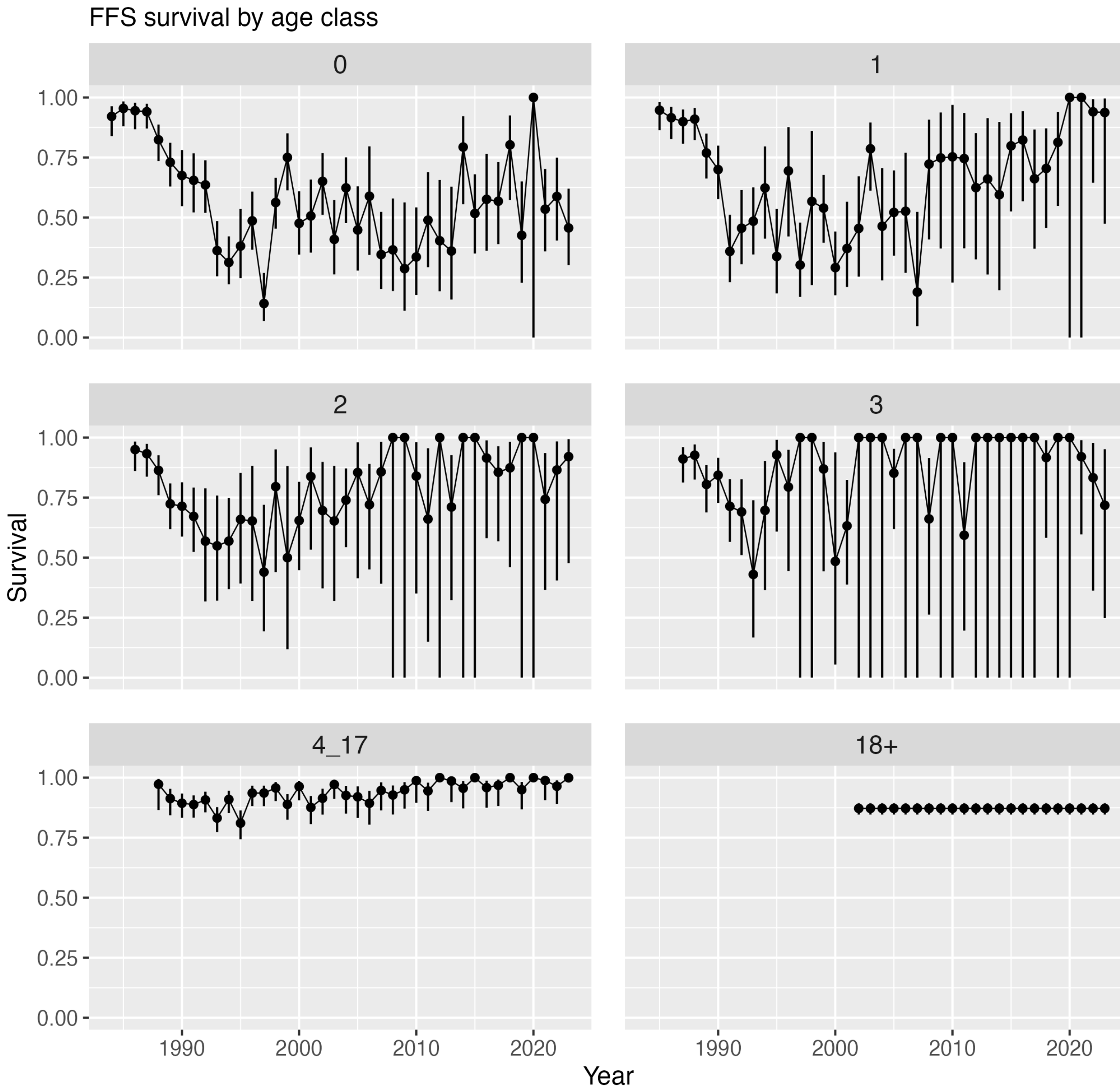

Figure 16. Age-specific post-weaning survival estimates at French Frigate Shoals.

Weaned pup survival at French Frigate Shoals from 2023 to 2024 was similar to recent years, though perhaps somewhat lower. Note that survival of the 2020-born weaned pups was estimated to be 100%, but was based only on six tagged pups. Age 1 and 2 yr survival to 2024 remained quite high, whereas age 3 survival has declined the past several years, although these estimates have rather broad and overlapping confidence intervals. Adult survival (ages 4 to 17 years) remained very high.

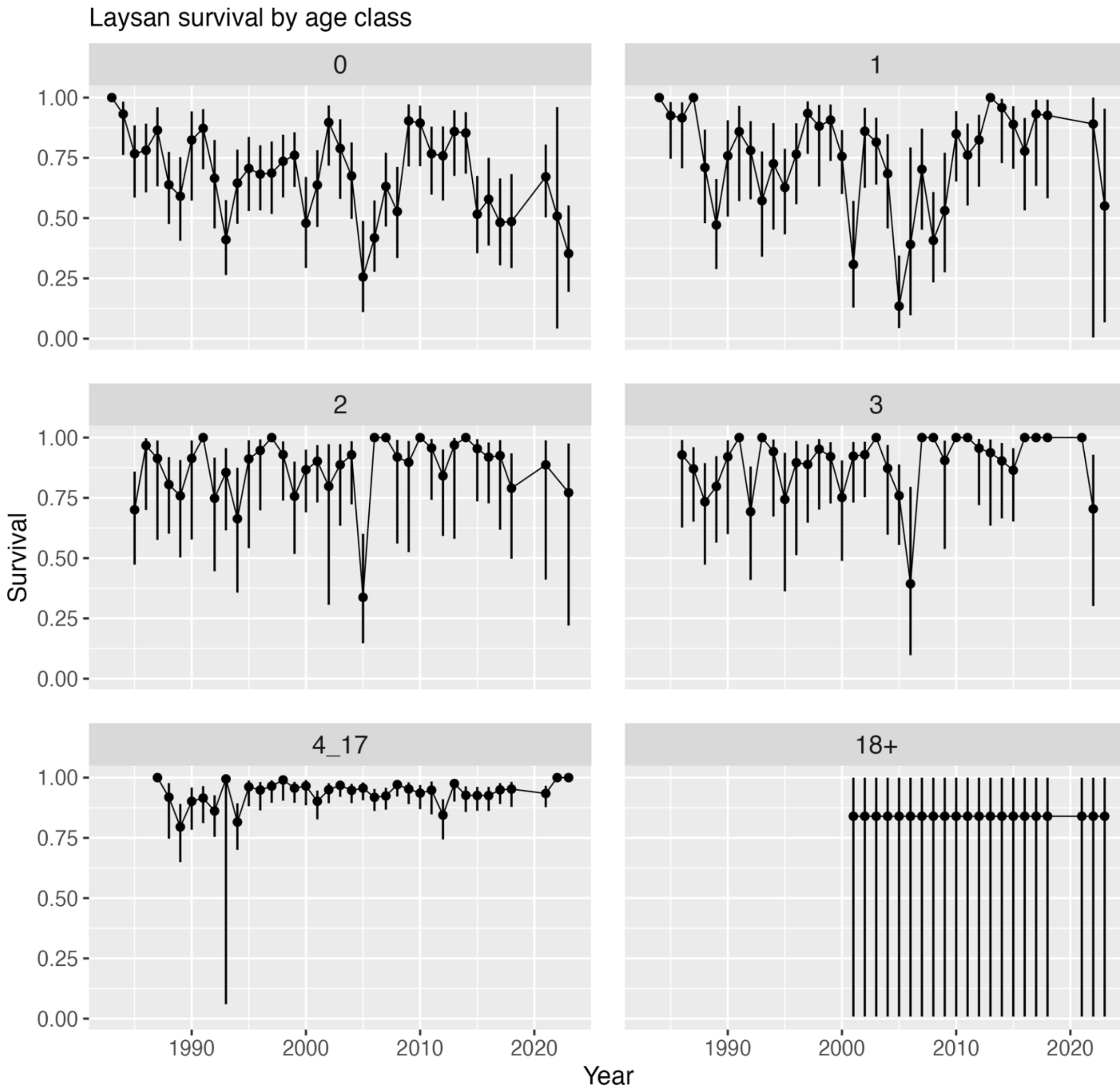

Figure 17. Age-specific post-weaning survival estimates at Laysan Island.

The reasons for low weaned pup (age 0) survival at Laysan in recent years is unknown, and the estimate from 2023 to 2024 was the second lowest ever observed. Estimates for years 2019 and 2020 are missing because there was no resighting effort nor tagging in 2020. The same gaps appear in Figures 18 and 19 for Lisianski Island and Pearl and Hermes Reef. The single parameter estimate for 18+ yr survival had confidence intervals ranging from 0 to 1. It is unclear why the estimation procedure yielded this result.

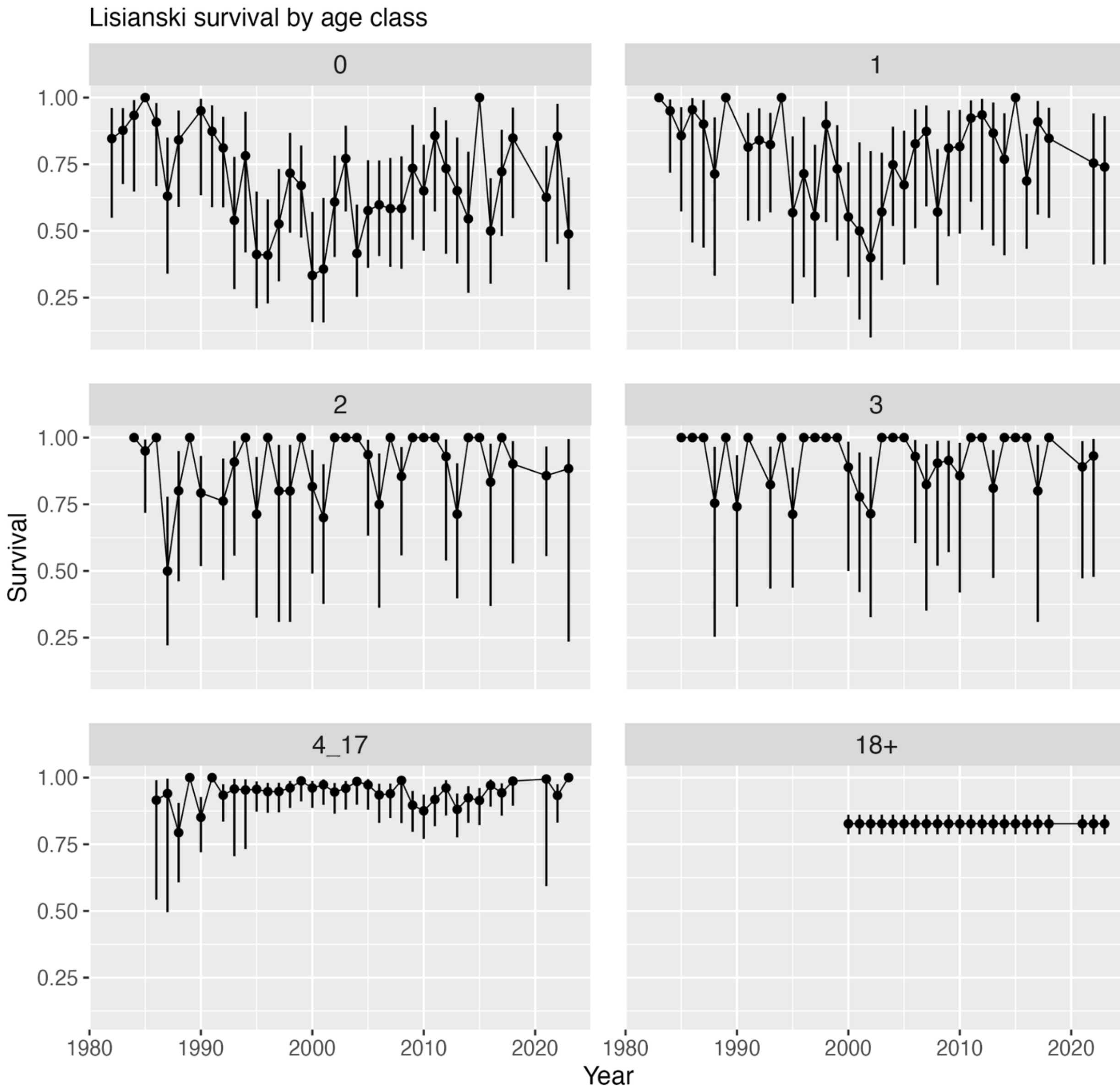

Figure 18. Age-specific post-weaning survival estimates at Lisianski Island.

Survival of (age 0) weaned pups from 2023 to 2024 was just under 0.5, one of the lowest rates estimated at Lisianski for several years. Survival rates for older age classes remained quite high.

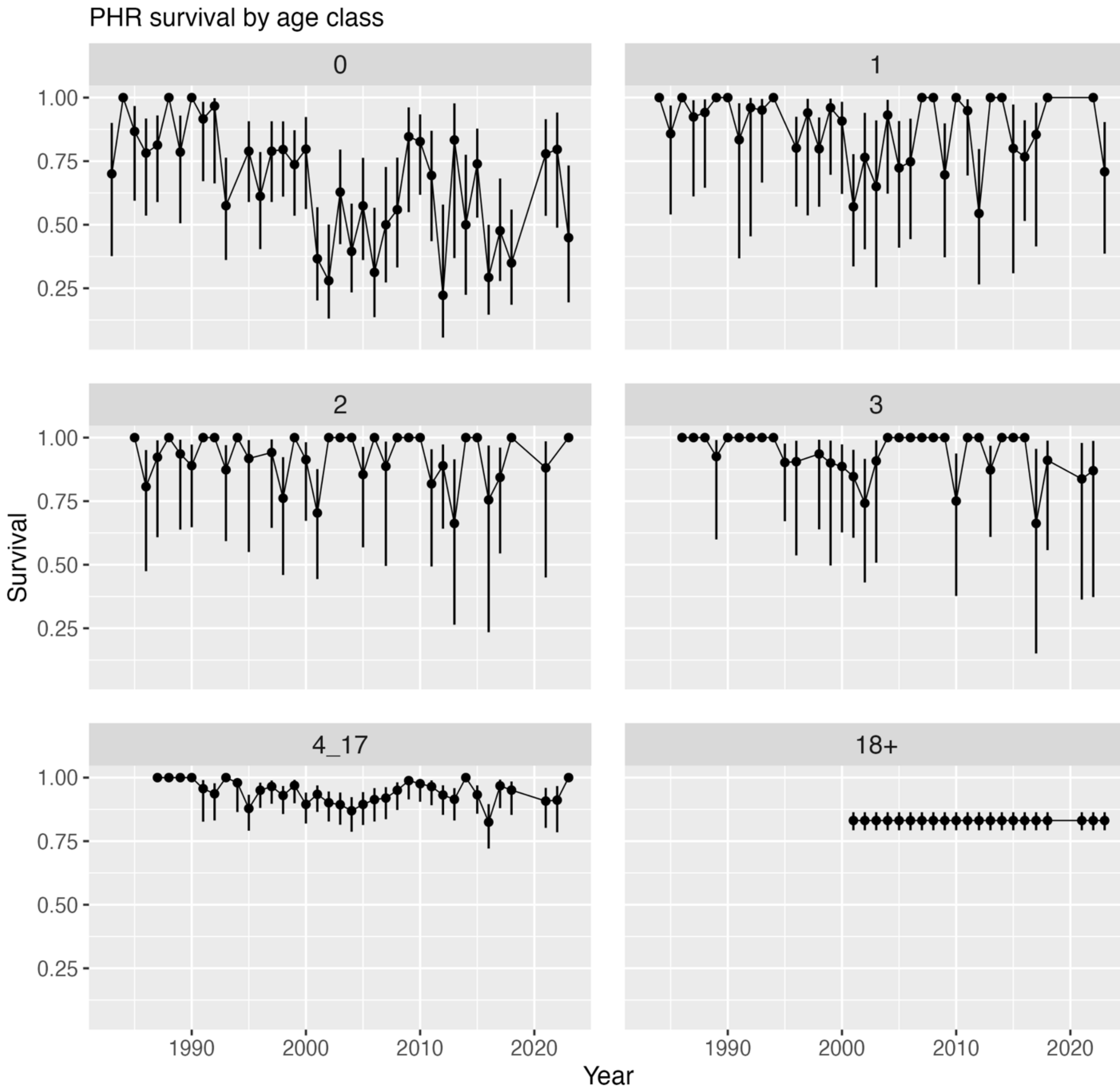

Figure 19. Age-specific post-weaning survival estimates at Pearl and Hermes Reef.

Survival of weaned pup (age 0) and yearling seals at Pearl and Hermes Reef declined during 2023 to 2024 compared to recent years. Otherwise, survival rates of older age classes were quite high.

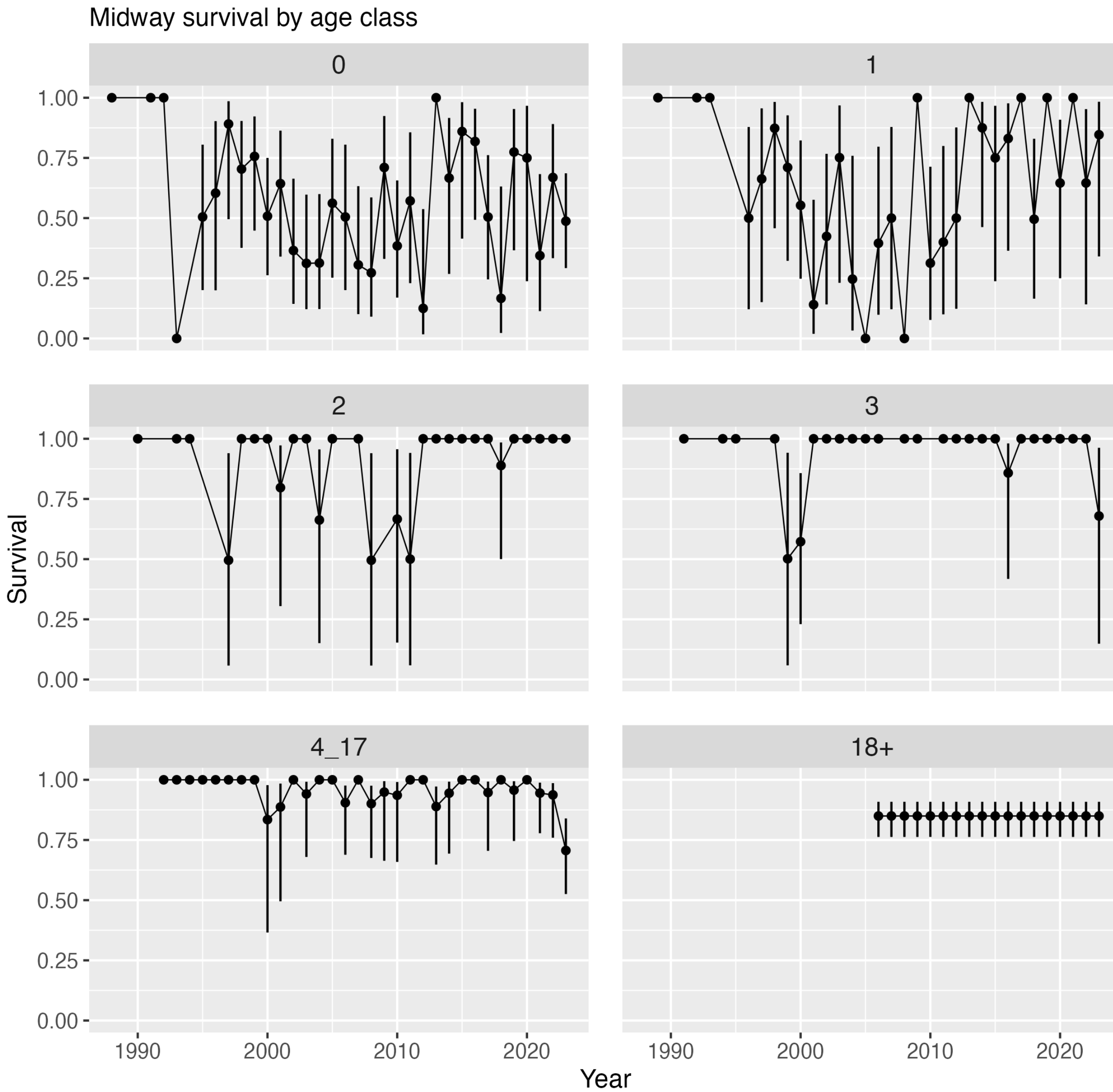

Figure 20. Age-specific post-weaning survival estimates at Midway Atoll.

Survival rate estimates of non-adults at Midway Atoll exhibits considerable variability from year to year as well as much uncertainty, the latter due to small cohort sizes. The lower estimated survival of adults (ages 4 to 17 yr) may be due to incomplete photo-identification of individuals that are not well marked (tagged). See similar comment on Figure 21 below.

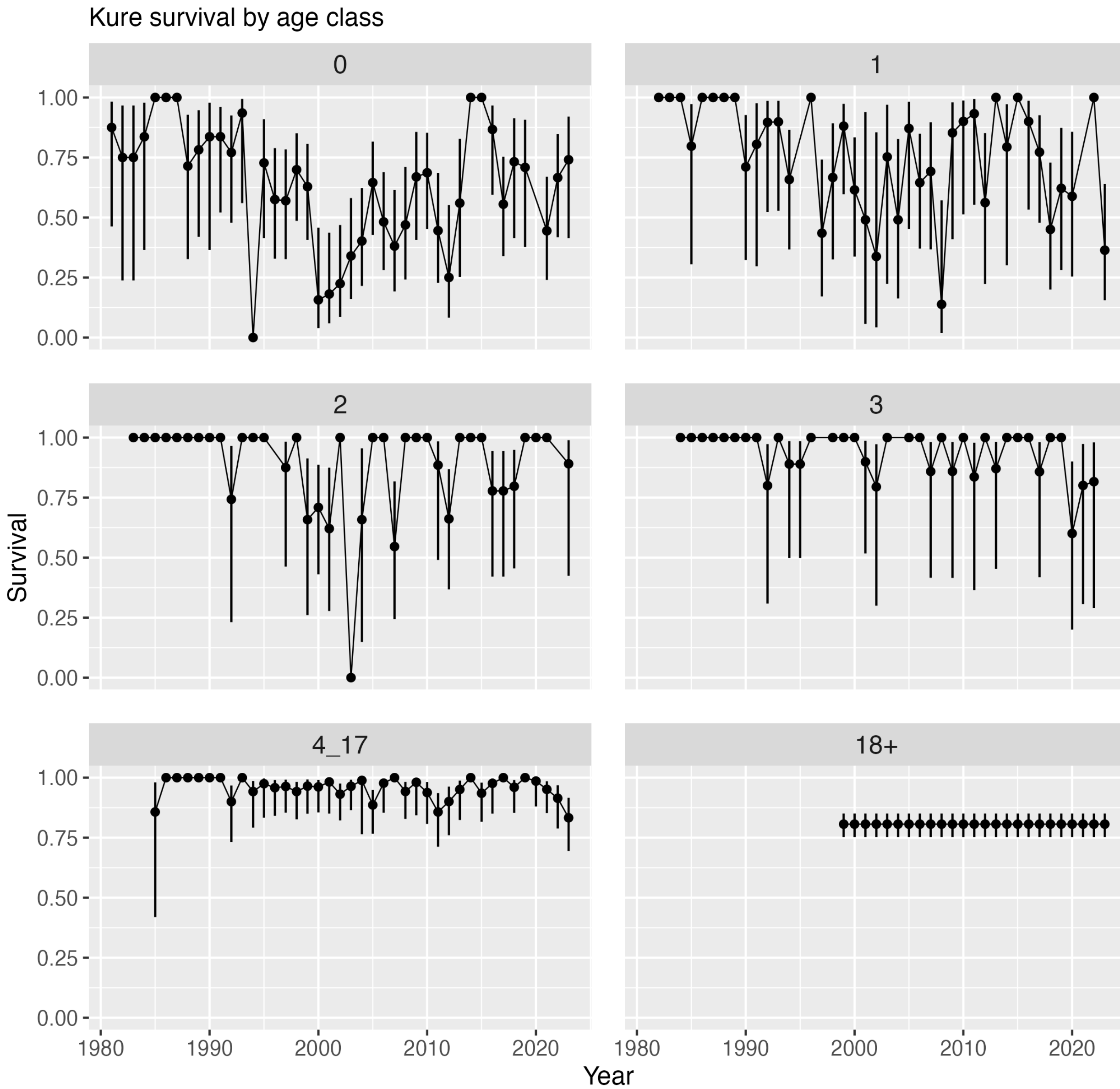

Figure 21. Age-specific post-weaning survival estimates at Kure Atoll.

The apparent decline in adult survival over the past three years might be cause for concern. However, it may reflect a failure to identify surviving adults. Because nearly all survey data were collected by DLNR partners as an ancillary duty, maintenance and scrutiny of the Kure photographic identification catalog may have been incomplete. In the past, similar apparent declines in adult survival have been attributed to a combination of short field seasons, less experienced field staff, and the presence of adult seals that are not readily identifiable from tags.

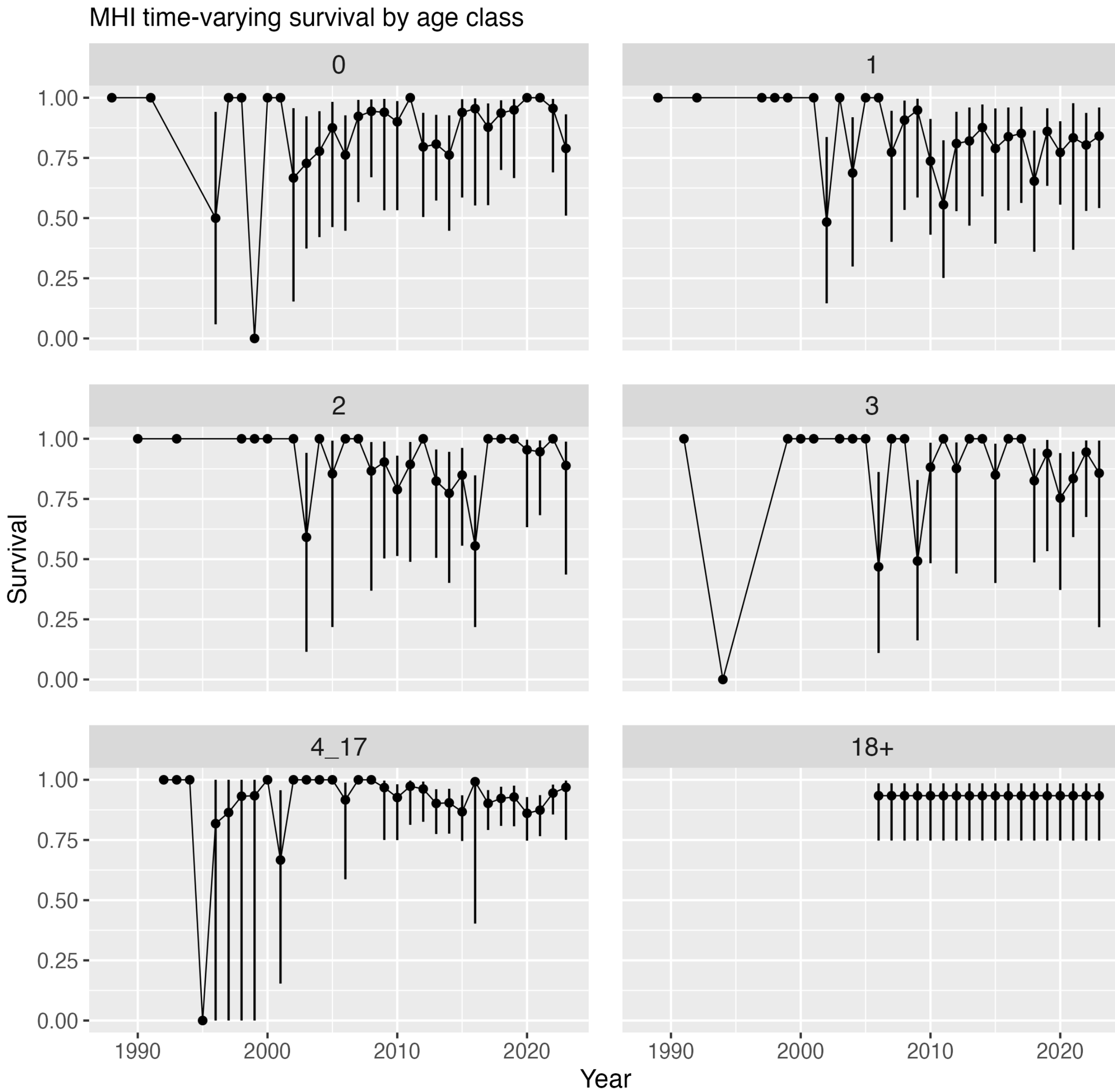

Figure 22. Age-specific post-weaning survival estimates in the main Hawaiian Islands. A time-varying survival model is shown.

A time-varying survival model is shown for the MHI to facilitate detecting any suggestion of changing trends, though the model has virtually no statistical support compared to one with constant survival (Figure 23). No notable temporal trends are evident.

Figure 23. Age-specific post-weaning survival estimates in the main Hawaiian Islands. Best fit model with no time variation.

Recapture probabilities—Evaluating recapture probabilities provides some insight into the short duration field seasons at Laysan I., Lisianski I., and Pearl and Hermes Reef in 2023. For each graph in Figure 24, the *x-axis* labels indicate groups of years and demographic groups (age and sex), which are constrained to share recapture probability parameters in CJS models. For the Laysan I., Lisianski I., and Pearl and Hermes Reef models, recapture probabilities in 2023 were fitted separately to evaluate the proportion of cohort seals that were identified. The point estimates varied by subpopulation somewhat (Laysan females = 0.82, Laysan males = 0.58, Lisianski (both sexes) = 0.66, Pearl and Hermes Reef (both sexes) = 0.70. Thus, roughly 30% of cohort seals were likely not identified at these subpopulations in 2023, whereas typically more than 90% are identified during longer status quo field season. If, in future years, seals are resighted which had been identified in 2023 or 2024, these recapture rate estimates may decline somewhat.

Note that all Laysan Island recapture estimates have confidence intervals spanning 0 to 1. Since 2023, the CJS models fitted with the R “marked” package have had similar issues with estimating variance and confidence intervals. The source of this issue has not been identified and requires further analysis. However, the survival rate estimates and confidence intervals appear to be well-estimated (with the exception of the age 18+ yr as noted above), and the current recapture estimates are similar to those estimated in previous years. Consequently, the problem seems to be related to variance estimation.

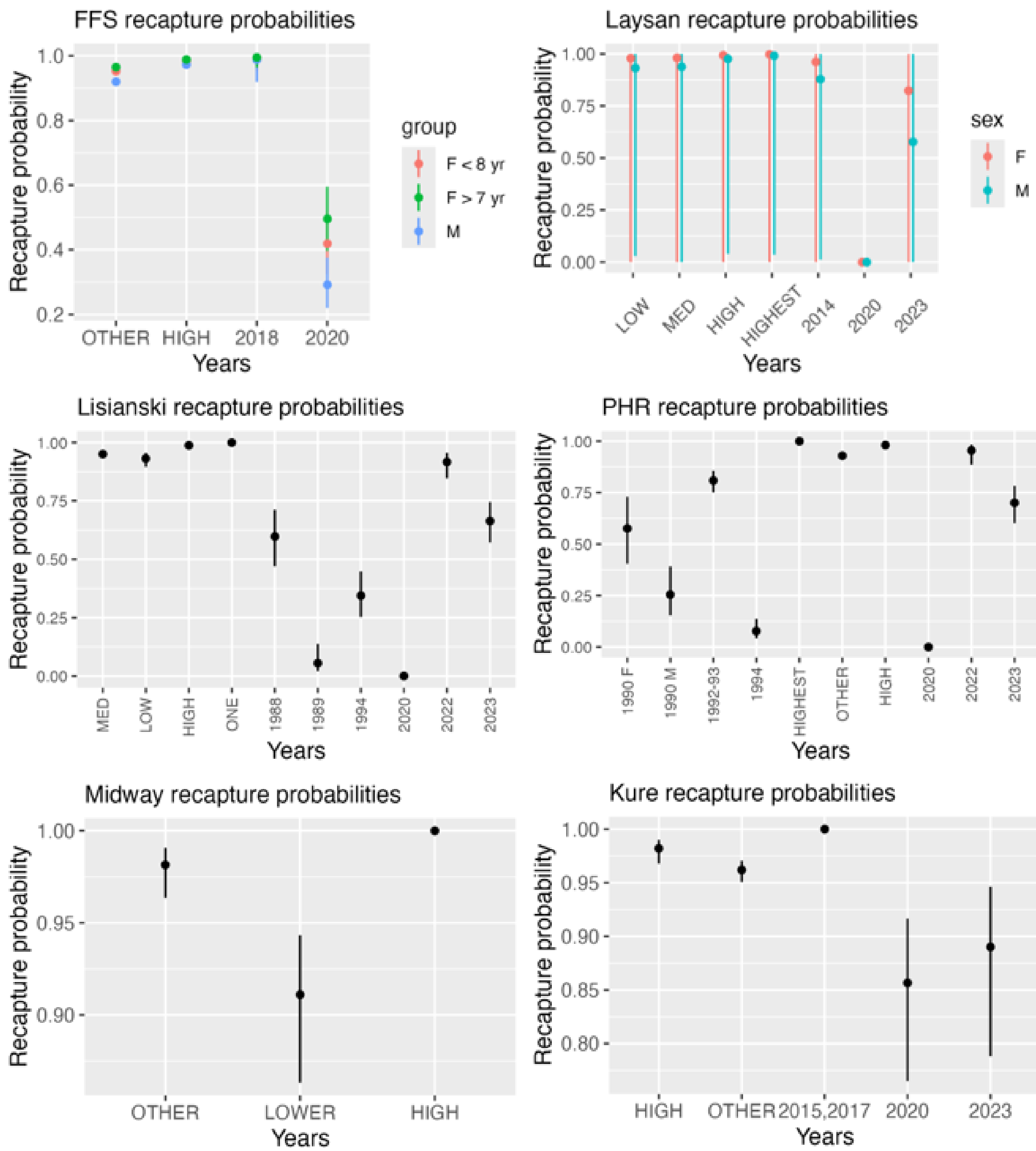

Figure 24. Estimated recapture probabilities at six NWHI subpopulations. Labels on x-axis indicate individual or groups of years constrained to have the same recapture probability.

Weaned Pup Girths

Figures 25 and 26 present box plots of weaned pup girths (corrected for the time between weaning and measurement) for all years combined and by year, respectively.

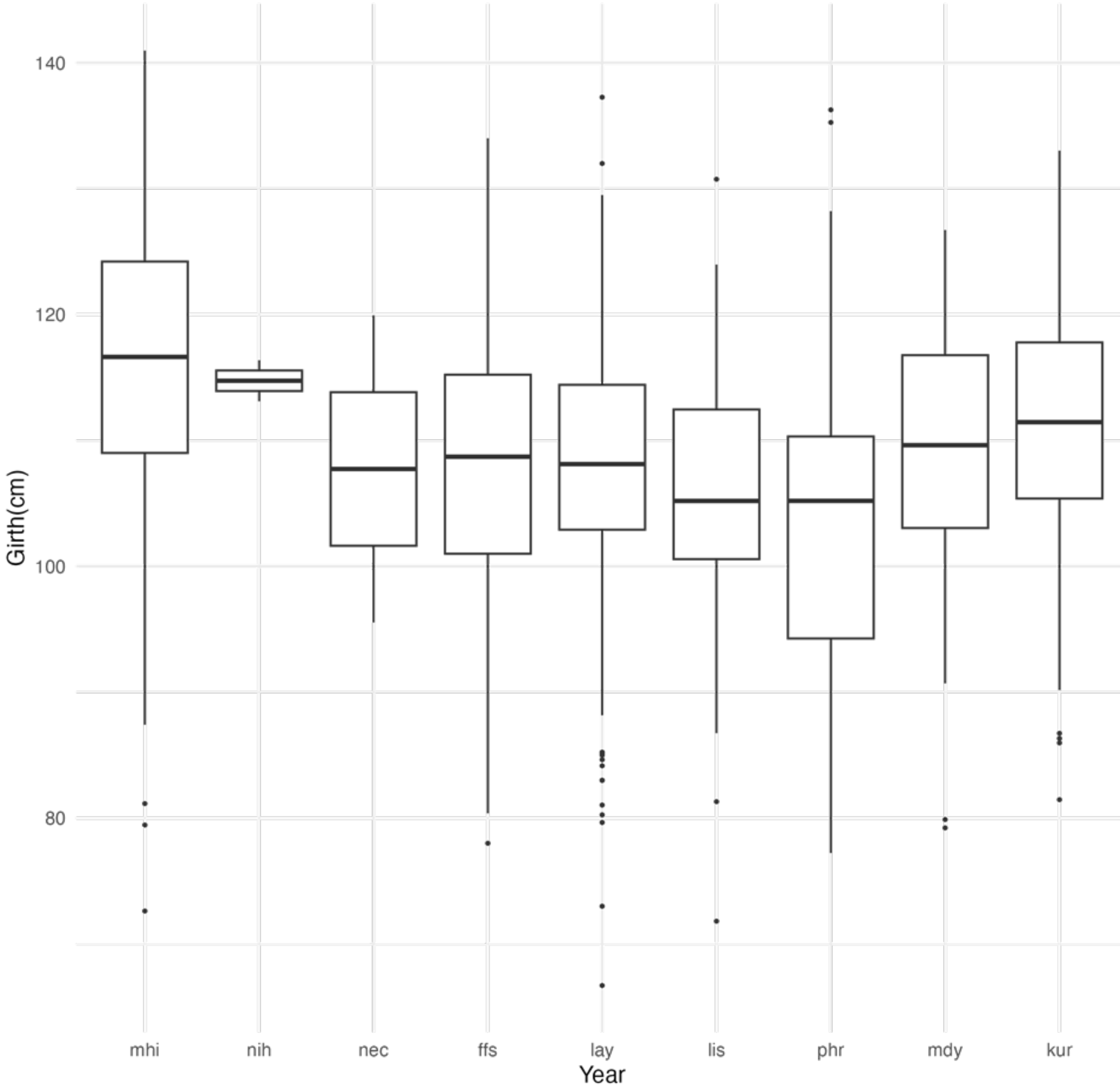

Figure 25. Boxplots of axillary girth at weaning distributions for all subpopulations, all years combined. The bold horizontal line in each box is the median, the boxes encompass the interquartile range (center 50% of the distribution), and the vertical lines extend to 1.5 times the interquartile range. The dots are observations beyond 1.5 times the interquartile range.

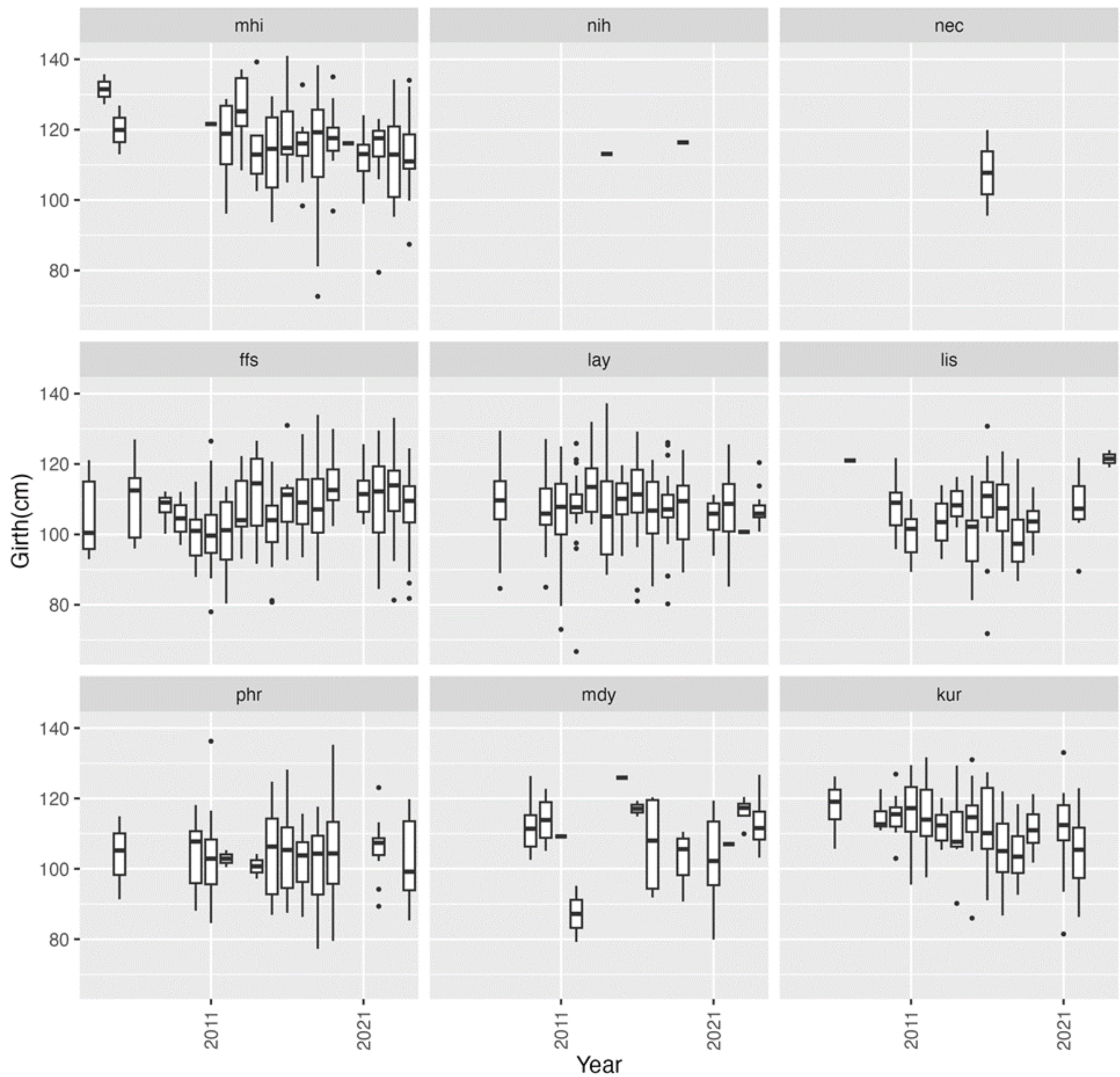

Figure 26. Boxplots of axillary girth at weaning distributions for all subpopulations by year. The bold horizontal line in each box is the median, the boxes encompass the interquartile range (center 50% of the distribution), and the vertical lines extend to 1.5 times the interquartile range. The dots are observations beyond 1.5 times the interquartile range.

Lifetable Analysis

This section integrates many of the demographic results presented above to obtain key lifetable metrics and population projections.

Age-structure anomalies—To quantify age structure anomalies, we calculate the discrepancy between the observed number of females up to age 12 yr and the same measure for a theoretical reference population at stable age distribution and with demographic rates that result in an intrinsic growth rate of 1.09. The reference age structure provides a consistent reference for comparing current age structures with one that would be robustly growing.

Figure 27 depicts the results of the observed cumulative female age structures along with that of the cumulative reference age structure. The proportion of females up to age 12 yr in the reference age distribution is 0.82. The current age distributions for French Frigate Shoals and Pearl and Hermes Reef have notably fewer proportions of females within this age range.

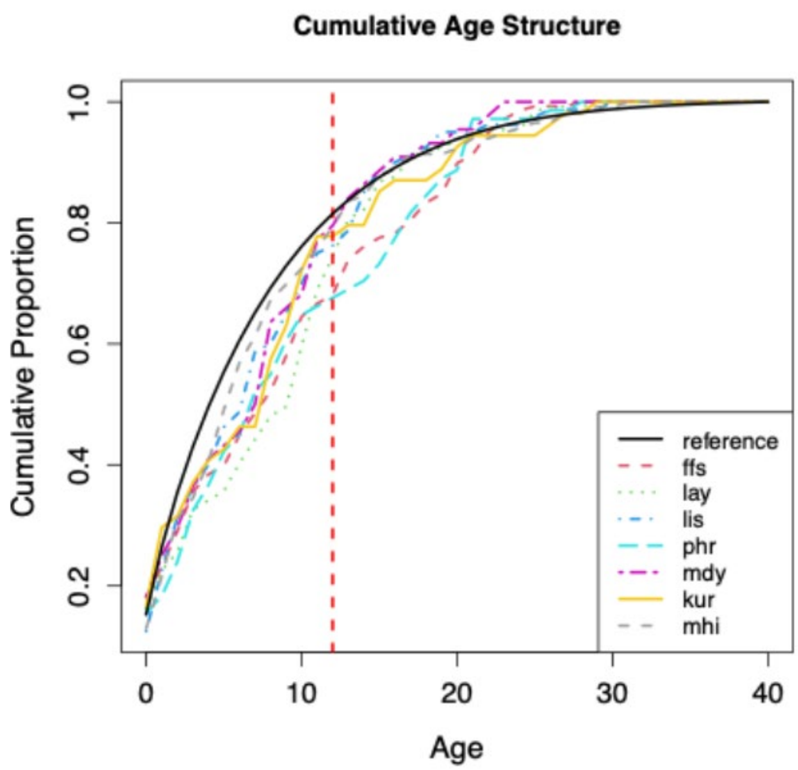

Figure 27. Female age-structure evaluation metric for three NWHI populations and the MHI. The observed cumulative female age structures (colored lines) are contrasted with a hypothetical reference age structure (solid black line). The cumulative proportion at and below age 12 yr intersects the vertical dashed red line.

Survivorship (l_x)—Survivorship (proportion of newborns which survive to each age) is presented in Figure 28. For most NWHI subpopulations, means of available age-specific survival rate point estimates (see Figures 16–23) since 2016 were used in this analysis (and subsequent lifetable analyses below). Estimates since 2018 were used at French Frigate Shoals to reflect more current conditions. This was not done at other subpopulations which had gaps in survey effort. The number of estimates and the years to which they correspond vary by subpopulation because there was no resighting effort or tagging at various locations in 2020. In the MHI, where no time variation in survival has been detected, survival estimates from all years were used. The MHI curve lies higher than the other sites up to about age 9 yr due to higher survival of young seals. However, adult survival in the MHI was lower than at the three NWHI subpopulations.

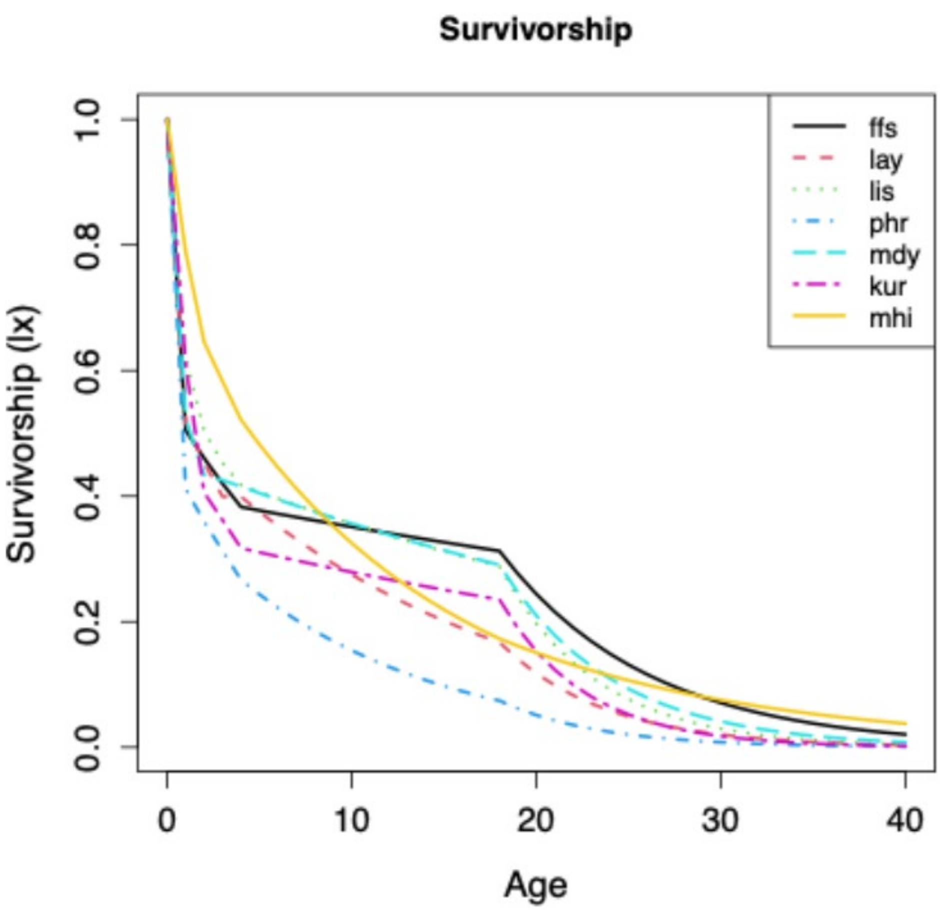

Figure 28. Survivorship (lx) curves for three NWHI subpopulations based on average annual estimates from 2016 to present. The MHI curve is based on all years combined. The curves show the proportion of newborn pups that survive to each age.

Intrinsic and Realized Growth Rates—The intrinsic growth rate, lambda (λ), is a metric that coalesces all the vital rates into a single value that represents the expected growth rate for a population with constant vital rates at its stable age distribution. The intrinsic growth rate does not typically match the actual growth rate that a subpopulation is likely to exhibit in the short term. Factors that may alter the trajectory include stochasticity in the vital rates (so that λ itself varies over time) and age structures that do not conform to the theoretical stable age structure. Current age structure may exert considerable influence over short term population trends. The magnitude of age structure effects are demonstrated through a deterministic population projection over a brief (5-year) time horizon. The differences between the intrinsic growth rate vs. realized growth rate are shown in Table 4 and Figure 29. Notably, all subpopulations except Pearl and Hermes Reef have intrinsic and realized growth rates greater than or equal to one, indicating that if vital rates remain relatively constant, they should grow or remain stable in the next five years. These lambda estimates and subsequently presented lifetable metrics make use of reproductive rates that were estimated in 2022.

Table 4. Intrinsic and realized growth rates estimated using Leslie matrices and 5-year projections, respectively, at four monk seal subpopulations. NWHI survival rates were based on averages of available age-specific point estimates after 2016. The exception was FFS, where estimates from 2018-2024 were averaged. MHI survival rates were estimated using all available years. Reproductive rates were based on curves fitted to pooled observations at FFS, LAY, LIS, and the MHI since 2000. LAY reproductive rates were applied to PHR, MDY, and KUR.

Lambda	FFS	LAY	LIS	PHR	MDY	KUR	MHI
Intrinsic	1.024	1.000	1.000	0.955	1.026	1.008	1.050
Realized	1.022	1.013	1.005	0.956	1.034	1.009	1.063

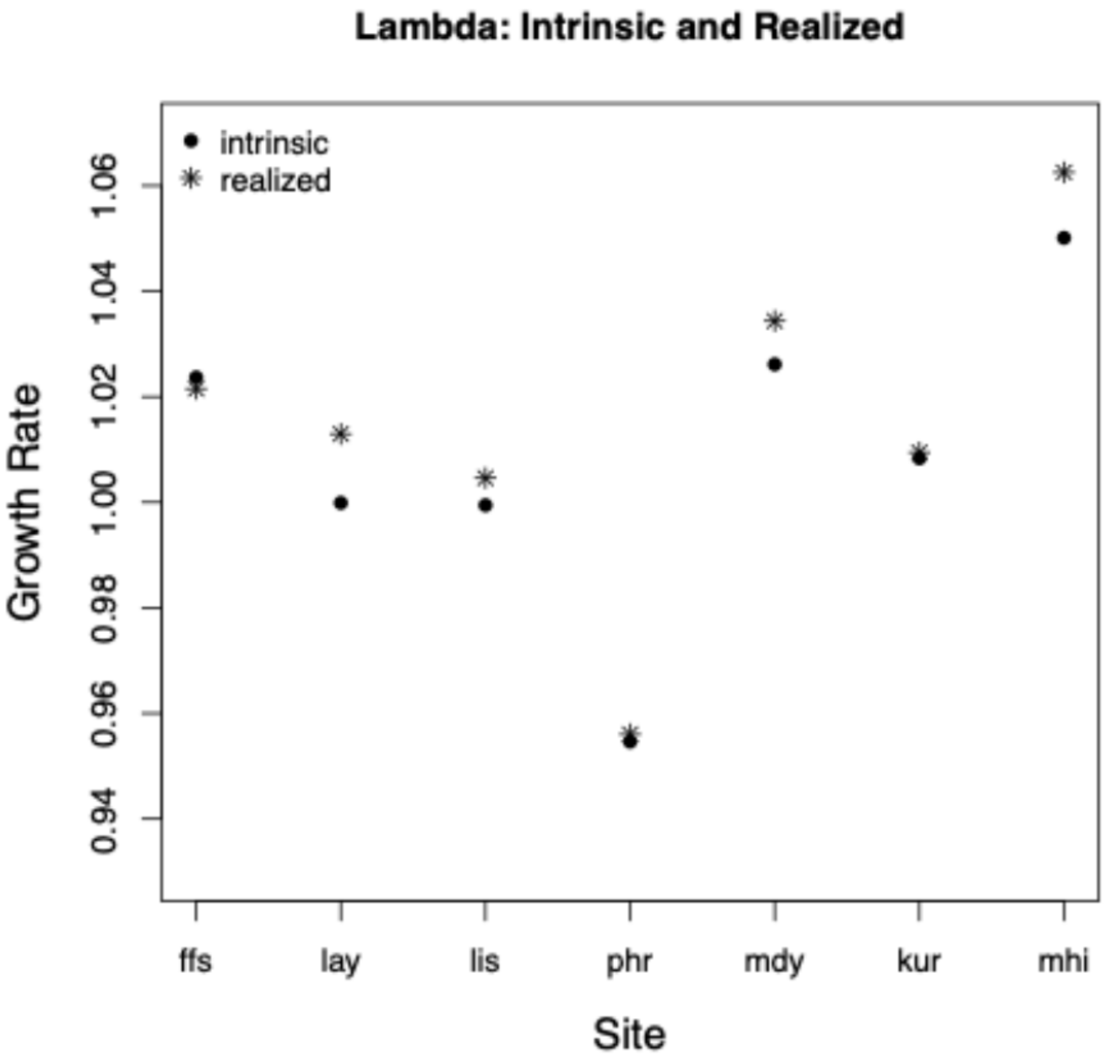

Figure 29. Comparison of estimated intrinsic growth rates (λ) to "realized" growth rates over a 5-yr deterministic projection.

Age-Specific Reproductive Value (v_x)—Reproductive value (v_x) is the relative “value” of a female of each age as compared to a newborn pup in the same subpopulation. The value of v_x at a given age is essentially a function of its expected future survival and reproductive output relative to that of a newborn pup (Figure 30).

The peak v_x, attained at ages 8 to 9 yr, ranges from about 2 to 4 newborn equivalents. The v_x curve for the main Hawaiian Islands is relatively flat compared to the other subpopulations, reflecting favorable survival of young seals.

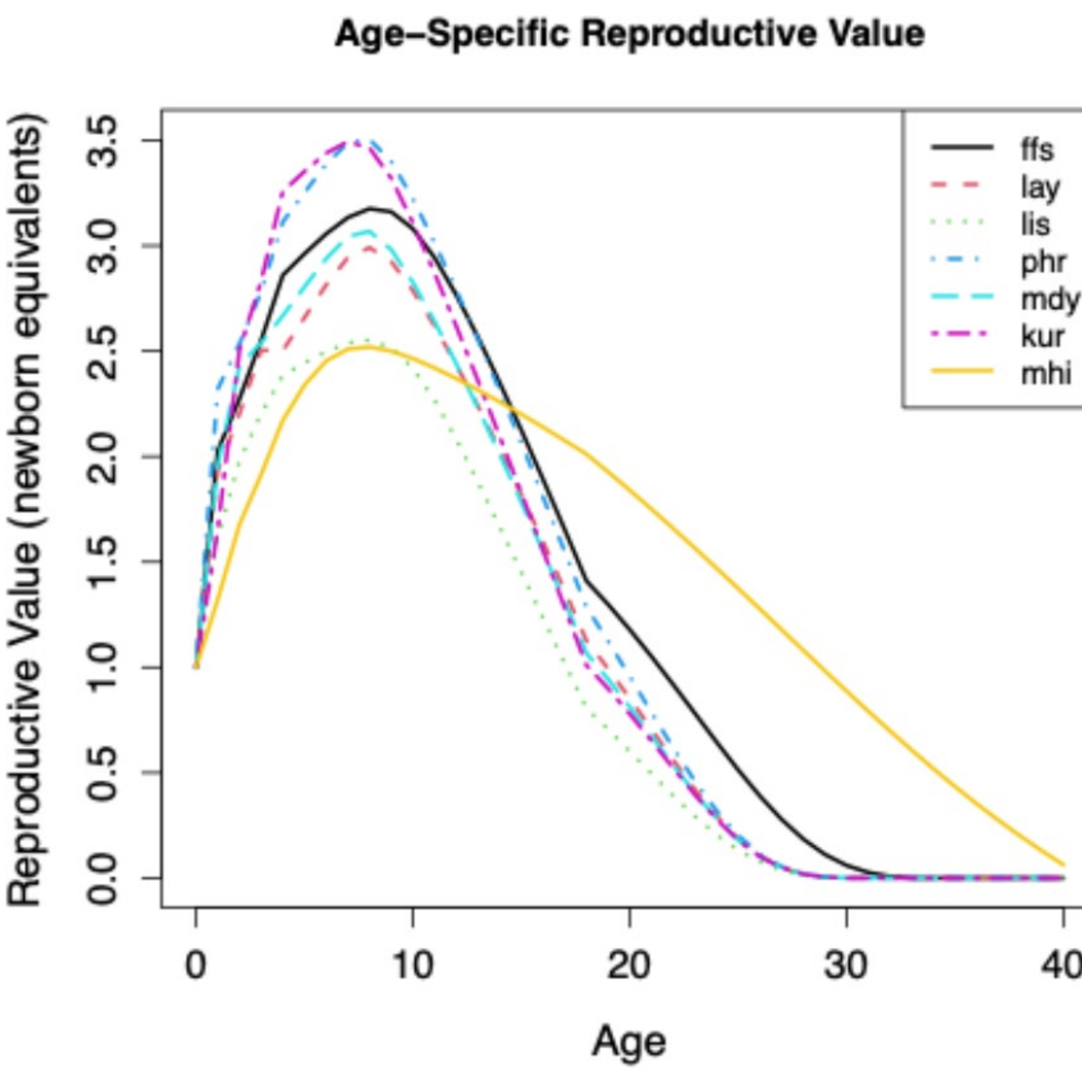

Figure 30. Age-specific reproductive value (vx) in the NWHI and MHI determined from survival rate estimates since 2016 and reproductive rates estimated from 2000-2022.

Quantifying the population-level cost of a female seal—The demographic cost associated with the death of a female seal is not just that one individual, but also the offspring she would have produced had she lived longer. A metric that reflects this is based on the net maternity function evaluated from the age of death forward.

For example, given the demographic rates estimated over all data years, an average newborn MHI female is likely to have 3 to 4 pups during her lifetime, and an average 5-yr-old female is likely to produce about 6 pups (Figure 31). Those values differ because some newborns will die prior to reaching age 5 yr. The total cost for losing a 5-yr-old female is, therefore, more than *7* seals (herself plus her expected future offspring). Analogous values can be gleaned for the other subpopulations, the curves for which vary due to their specific demographic rates.

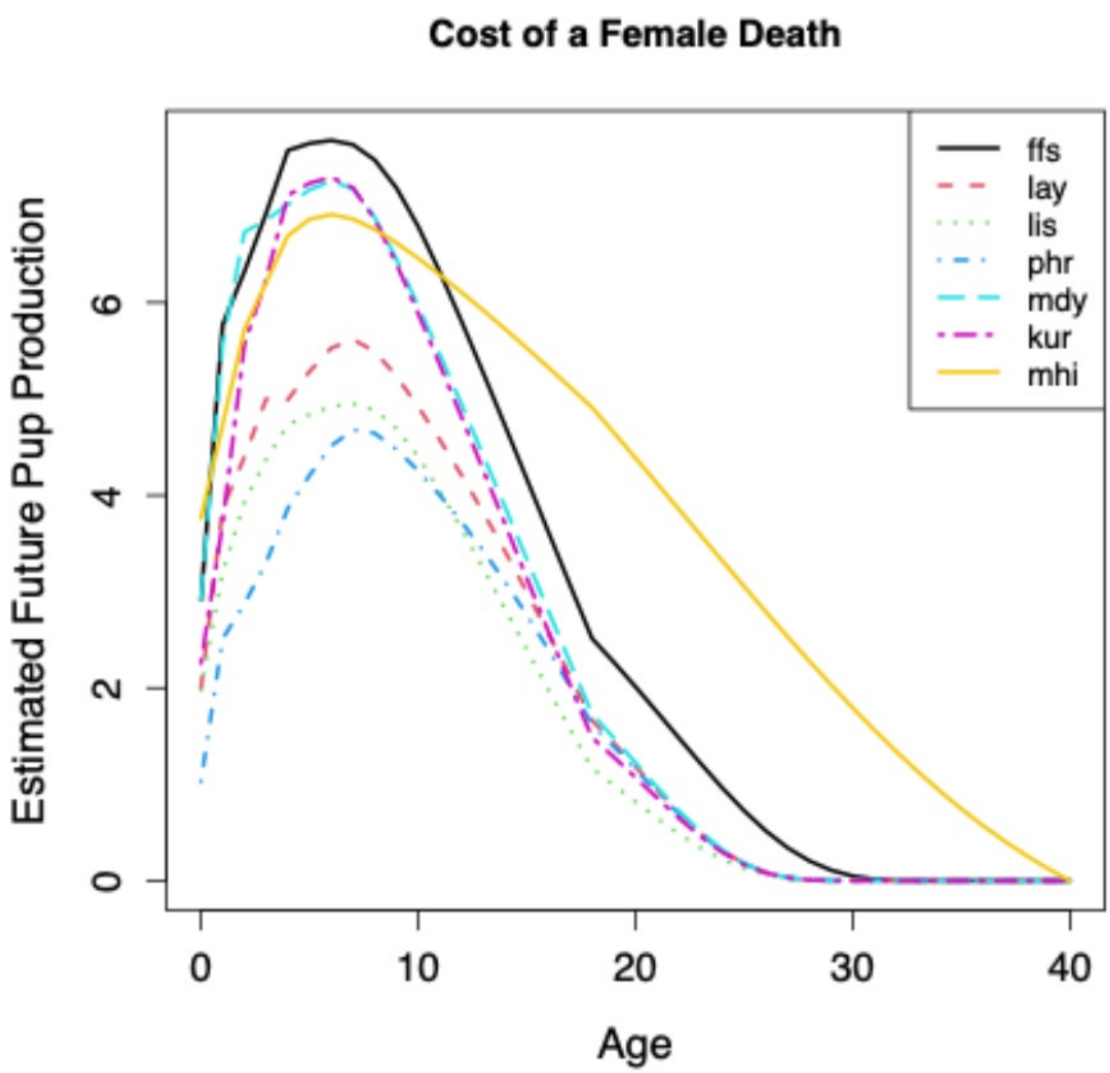

Figure 31. Number of future pups an average female monk seal is expected to produce by age at various subpopulations.

Preliminary indications of impacts of reduced NMFS field effort

Below are summarized bullet points based upon preceding results in this report:

- Extrapolating discovery curves to estimate non-pup abundance and associated error is likely becoming a less reliable method due to changes in the pattern of field survey effort and the fact that there have no new reference curves (based on total enumeration) obtained in recent years.
- Estimated recapture probabilities at the sites with short field seasons in 2023 indicate that approximately 30% of cohort seals were not identified in 2023. It is possible that a higher proportion of non-cohort seals may not have been identified in 2023 because they are likely to be less well-marked (tagged) than cohort seals. At Midway and Kure Atolls, the estimated recapture rates in recent years have been relatively high (0.85 and greater), indicating that partners have identified most of the cohort seals at those sites.
- Survival rates for adults age 4 to 17 yr were estimated to be 1.0 from 2023 to 2024 at Laysan I., Lisianski I., and Pearl and Hermes Reef. This is not uncommon and essentially occurs when all the adults seen the previous year were resighted in the current year. However, in the case of Laysan I., Lisianski I., and Pearl and Hermes Reef from 2023 to 2024, this estimate may be biased high if, for example, some live adults were not identified in 2023 due to low survey effort and subsequently died.
- The previous bullet is an example of a broader circumstance whereby uncertainty in abundance, survival rates, and the age at which mortalities occur is introduced as a consequence of years with low or no survey effort.
- Declining apparent survival of adults age 4 to 17 years at Midway and Kure Atolls is plausibly a consequence of "loss of marks". That is, known cohort seals may be present but may not have been identified if they lacked tags. Making those identifications can be painstaking and requires adequate current photographs and a complete photo ID database, an experienced team member, and sufficient time to scrutinize the current and past images. It is important to understand whether apparent declines in adult survival are real because population trend is extremely sensitive to adult survival rates.
- Notwithstanding the above, the fact that teams tagged as many pups as possible at Laysan I., Lisianski I., and Pearl and Hermes Reef in 2023 allows for a portion of that cohort to be monitored, especially for juvenile survival.
- A survey scheme with alternating years of abbreviated effort (as in 2023) and more standard duration field seasons is under consideration. One concept associated with this approach is that the longer field seasons would provide thorough data to "catch up" on key information such as abundance and individual identification. The 2024 season was not sufficient to document all, or nearly all, individuals present based upon discovery curves at Laysan I., Lisianski I., and Pearl and Hermes Reef. Therefore, data recovery in 2024 was deficient in terms of maintaining seal identities long term. Consequently, if the alternating short and long season is pursued without achieving more complete data in the long seasons, the monk seal demographic database will likely degrade over time.
- Laysan I., Lisianski I., and Pearl and Hermes Reef are the three subpopulations with the lowest intrinsic growth rates, primarily due to variable and low juvenile survival. Even with

long duration field seasons it is challenging to deduce the causes of low juvenile survival. Alternating seasons with field effort similar to both 2023 and 2024 would likely hamper efforts to diagnose and potentially address causes of low juvenile survival.

- The opportunity to conduct interventions to improve the probability of survival of individual seals is related to the length of the field season. Field effort has been most consistent at FFS and has recently varied dramatically at other sites in the NWHI. During 2019 and 2022, years with more typical length seasons, field staff conducted 32 and 19 life-saving interventions at non-FFS sites in the NWHI, compared with 2 interventions during 2023, the first ARC-Light season, and 9 interventions this year.
- While partners at Midway and Kure Atolls have provided crucial demographic data, more intensive survey effort and perhaps more focus on photographic identification and re-tagging may be warranted at those sites in order to maintain long-term adequate population monitoring.

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