COMPARISON OF SUBMERGENCE PATTERNS OF GREEN SEA TURTLES IN THREE DISTINCTIVE HABITATS: INTERNESTING, MIGRATORY, AND RESIDENT FEEDING AREAS.

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Comparison of submergence patterns of green sea turtles in three distinctive habitats: internesting, migratory, and resident feeding areas.

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Green turtles, *Chelonia mydas*, are listed as Threatened under the U.S. Endangered Species Act. Green turtles are from the phylum *Anapsida,* class *Tstudinata*, family *Chelonioidae.* They are herbivorous, feeding mainly on seagrasses (*Halophila spp.*) or algae (e.g., *Codium spp., Acathophora spidifera, Amansia gromerata, Ulva spp.;* Balazs, 1987). Sexual maturity can range from 10 to 60 years (average of 25 years; Balazs, 1991). An average adult measures from 80 to 100 cm in carapace length, and weighs 70 kg or more.

Green turtle reproduction takes place on remote beaches (Zug, 1993). Adult females lay about 100 or more eggs each time they come to nest, and they lay an average of 3 clutches of eggs. There is an interval period of about 14 days between each clutch, and this interval period is called the "internesting period." Long range migration by adults from nesting areas to foraging grounds usually covers thousands of miles and can take an average of 35 days. Adult females have a migration interval of 2 or more years, whereas the males will often migrate to breed annually (Balazs, 1987).

Research has been conducted using tagging and satellite transmitter tracking to determine breeding areas, migration patterns and foraging grounds for these reptiles. A satellite system called Argos, previously reserved for environmental applications, has been used. It has proven to be a "reliable and low-cost tool" in processing environmental data received from a fixed location anywhere in the world (Service Argos Inc., 1987). Previous studies based on the diving patterns and swimming environment of sea turtles have been done. Sakamoto et al. (1993) used time depth recorders (TDRs) and time temperature recorders (TTRs) to track the vertical swimming behavior of loggerheads (*Caretta caretta*). Renaud (1995) however, successfully reported the submergence patterns of the Kemp's ridley turtle (*Lepidochelys kempii*) using satellite data.

A recent study in the South Pacific used satellite telemetry to track three adult green turtles during their post-nesting migrations from Rose Atoll to the Fiji Islands between October 1995 to April 1996 (Balazs and Ellis, 1996; *Figure 1)*. Rose Atoll (14.55° S, 168.15° W) is located at the eastern most end of the Samoan archipelago. It is known to be a colonial breeding area for green turtles in the South Pacific. Rose Atoll is a small uninhabited island that also serves as a breeding site for numerous sea birds. It has been legally protected for several decades as a National Wildlife Refuge, administered by the U.S. Fish and Wildlife Service and the Government of American Samoa. The independent country of Fiji (15 to 22° S, 177° W to 175° E) is about 1,460 km southwest of Rose Atoll. Fiji has 320 island groups not including hundreds of tiny unrecorded atolls and rocks.

The purpose of this paper is to compare the submergence patterns between the internesting, migration, and foraging habitats of the three turtles studied by satellite tracking from Samoa to Fiji. It is hypothesized that there should be a significant difference in submergence patterns between each habitat due to different behaviors in habitat conditions.

METHODS AND MATERIALS:

Satellite tracking of three adult female green turtles was accomplished during the 1995-1996 post-nesting migration from Rose Atoll, American Samoa to the Fiji Islands. The ST-14 transmitters used were custom manufactured by Telonics, Inc. Each transmitter weighed 765 g (1.7 pounds) with dimensions of 17

X 10 X 3.5 cm. An antenna projecting 13 cm from the top of each transmitter was located in the front end of the transmitter. Two of the transmitter were programmed with a 3 hours on, 9 hours off duty cycle for 39 days, and thereafter a 3 hours on 3 hours off cycle. The third transmitter was programmed with a three hours on, three hours off cycle. The duty cycle affects the number of locational position received from transmitter. However, it has no effect on diving information as these data are stored and transmitted intact when the unit is "on". Transmitters were attached to the turtles' carapace using thin strips of fiberglass and resin. A silicone elastomer, a two part rubber product, was used to mount the transmitter against the carapace (Balazs, 1996). This method is an improved modification of techniques used by Beaver et al. (1995) and Renaud (1990). The three Argos identification numbers deployed for each turtle were 25692, 25693, and 25694, which were named respectively; Leilua, Isalei, and Aulotu. Leilua (25692) had been previously flipper tagged (tag 5818) at Rose Atoll in October 1992 and resighted there again in October 1986. Isalei (tag Q206) and Aulotu (tag Q217) were new sightings and therefore newly tagged in October 1995.

The data collected by the Argos system from each transmitter included: the Argos program number, turtle's identification number, name of satellite, date and time, temperature of transmitter, duration of last dive, average dive in last 12 hours, dive count, value of sensor, number of sensors, location class of satellite, latitude and longitude, and transmitter frequency. To determine the submergence patterns of the three turtles, date and time, duration of last dive, average dive in last 12 hours, and dive count were used.

There were three areas of study for the turtles which are defined as follow: internesting area - the period while the turtle was in the water near Rose Atoll, between successive nestings, before departing on their oceanic migration; migration route - the period the turtles left Rose Atoll to the date they arrived at their foraging or resting area in Fiji; foraging area - which is the period when the turtles arrived in Fiji (determined by using the locational data from Argos) to the time the trasmitter went off.

Calculations were used to determine the actual duration of dives in the last 12 hours in minutes, and average percent time spent underwater.

The actual duration of the last dive (minutes) was calculated by :

$$\text{Argos duration of last dive} * 2 / 60.$$

The actual average time of dives in the last 12 hours was calculated by:

Argos average in last 12 hours * 2 / 60.

The percent time spent underwater was calculated as follows: Actual duration of dives in last 12 hours * dive count/60/12*100. Percent time on surface is 100 - above number.

Analyses of diving behavior in the three habitats were done to determine significant differences in means using an analyses of variance (comparison of means; PROC ANOVA, SAS Institute Inc., 1987). Significant differences between each habitat were determined using Duncan-Waller analyses (PROC ANOVA; SAS Institute Inc., 1987). Data were analyzed with all turtles combined and then individually.

RESULTS

Analyses of variance were done for four variables: time of last dive, average time of dives in a 12 hour period (referred to as average dive time), percent time underwater (%UW), and dive number. Data for time of last dive are not presented since the results from this closely paralleled that of the average dive time. Analyses were done with all turtles combined, then for each individual turtle. Analysis of variance showed that there was a significant difference in means between habitats for all variables analyzed (Table 1). Duncan-Waller analyses provide results of paired t-tests indicating the difference in means by groupings.

ALL TURTLES COMBINED:

Duncan-Waller analysis for the average dive time showed significant difference between all habitats (see Figure 2a). Analysis for %UW showed no significant difference in means between the migrating and foraging areas, but a significant difference between these and the internesting area (see Figure 2b). Analysis for dive number showed a significant difference in means between all areas (see Figure 2c). Table 2 provides the means, standard deviations, range and 95% Confidence intervals (CI) for all of the variables.

LEILUA (25692):

Duncan-Waller analysis for the average dive time showed no significant difference between the means of the internesting and foraging areas, but a significant difference between these and the migrating habitat (see Figure 3a). Analysis for %UW showed no significant difference between the migrating and foraging areas, but a significant difference between these and the internesting areas (see Figure 3b). Analysis for dive number showed a significant difference in the means between all the habitat areas (see Figure 3c). Means ± 95% CI, standard deviations, and ranges for all variables are shown in Table 3.

ISALEI (25693):

Duncan-Waller analysis for the average dive time showed significant differences between the internesting, foraging, and migrating habitats (see Figure 4a). Analysis for %UW showed no significant difference in means between the migrating and foraging areas, but a significant difference between these and the internesting area (see Figure 4b). Analysis for dive number showed no significant difference between the internesting and foraging areas, but a significant difference between these and the migrating area (see Figure 4c). Means ± 95% CI, standard deviation, and ranges for all variables are shown in Table 4.

AULOTU (25694):

Duncan-Waller analysis for the average dive time showed no significant differences between foraging area and migratory area but a significant differences between these and the internesting area (see Figure 5a). Analysis for %UW showed no significant difference between these and the internesting area (see Figure 5b). Analysis for the dive number showed a significant differences between all the habitat areas (see Figure 5c). Table

5 shows means ± 95% CI, standard deviations, and ranges for all variables analyzed.

DISCUSSION:

The results showed a significant difference of diving pattern in each habitat. A possible explaination is perhaps, different behavioral acvtivities are being conducted by the three turtles.

In general (Figure 2a), we see a high average dive time during the internesting period (mean ± 95% CI = 14.5 ± 1.3). The longer periods spent underwater may have been spent resting. The longer average dive time is off set by a lower number of dives. This produces a lower percentage of time spent underwater by the turtles in the internesting. In this study, we carefully matched the dates and times of possible emergence using the most accurate satellite data available (Balazs and Ellis, 1996). Diving data within 24 hours around these times were discarded. We are relatively confident the results reflect actual diving behavior. All individual turtles follow the general pattern seen in the combined data for the internesting area.

Turtles had very low average dive times during their migration (mean ± 95% CI = 5.7 ± 6.1). They also had very high number of dives during this time. Turtles are expending a lot of energy during their migration, traveling about 1460 km in a matter of 30 - 40 days (Balazs and Ellis, 1996). Locational data indicated that the turtles rarely stopped to rest during migration. Using numerous short dives, the turtles would be able to breath often, fueling their high energy output and yet spend a significant percent of their time underwater. Perhaps making their swimming more efficient by reducing drag they would experience swimming at the surface. All individual turtles follow the pattern seen with the combined data for the migrating habitat.

The data for all turtles combined showed an intermediate number for average dive time and dive number in the foraging area. One explanation for this could be the turtles behavior of spending their time between resting underwater and feeding, where feeding may require more energy (*e.g., shorter more numerous dives*) than resting. The other explanation could be the variations between individual turtles. Leilua (25692) seemed to have a slightly higher average dive time and yet the number of dives was an intermediate number. Isalei (25693) has an intermediate average dive time with a slightly lower number of dives than the other two turtles. Aulotu (256943) had a very low average dive time and a very high dive number. Comparing the turtles, Leilua and Isalei's foraging area patterns are more similar to their internesting behavior, indicating they may have been resting more. Aulotu's foraging area pattern, however, was closer to its' migrating diving behavior, and as seen in Figure 5, the foraging area has an even shorter average dive time than the migrating area. Aulotu also had more dives in the foraging area than migrating area. A few possible explanations for Aulotu's foraging diving pattern are: 1) Aulotu may not have actually reached her foraging area, even though locational data indicated that Aulotu had stopped in a specific area,

2) Environmental and geographic conditions may have contributed to the diving pattern seen or

3) this may be Aulotu's normal pattern of behavior in her foraging area.

In conclusion, we have shown that there are significant differences in submergence patterns between the three habitats studied for Leilua, Isalei, and Aulotu. Further studies should be done to see if the patterns found in this study are replicable. Satellite telemetry will be a valuable tool for further studies and to help understand marine animal activities.

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Tofa Soifua :)

Work cited

Balazs, G. 1996. Satellite tracking of adult green turtles during their post-nesting migrations from Rose Atoll, American Samoa to the Fiji Islands. Fifth Meeting of the Regional Marine Turtle Conservation Programme. Report of meeting.

Balazs, G., and D. Ellis 1996. Satellite telemetry of migrant male and female green turtles breeding in the Hawaiian Islands. Proceedings of the sixteenth annual symposium on sea turtle biology and conservation. U.S. Department of Commerce, NOAA Tech. Memo. NOAA-TM-NMFSA-SEFSC.

Balazs, G. 1993. Homeward Bound: Satellite Tracking of Hawaiian Green Turtles From Nesting Beaches to Foraging Pastures. Proceedings of the Thirteenth Annual Symposium on Sea Tutle Biology and Conservation. 23-27 February, 1993. U.S. Department of Commerce. NOAA Tech Memo. NMFS-SEFC-341.

Beaver, S., G. Balazs, and R. Miya 1995. Procedures to attach a satellite transmitter to the carapace of an adult green turtle, *Chelonia mydas*. Proceedings of the fifteenth annual symposium on the biology and conservation of sea turtles. U.S. Department of Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SEFSC.

CLS and Service ARGOS INC. 1987. Service Argos Inc.

Grossblatt, N., Ed. 1990. Decline of the Sea Turtles. Library of Congress Cataloging-in-Publication Data.

Lohmnn, K., and C. Lohman 1996. Orientation and open-sea navigation in sea turtles. The Journal of Experimental Biology 199:73-81.

SAS (SAS Institute, Inc.) 1987. SAS/STAT guide for personal computers, sixth ed. Cary, NC. 378 p.

Renaud, M. 1995. Movement and Submergence patterns of Kemp's ridley turtles (Lepidochelys kempii) Journal of Herpetology. Biol. 29(3):370-374.

Sakamoto, W., R. Sato, H. Tanaka, Y. Naito 1993. Diving patterns and swimming environment of two loggerhead turtles during internesting. Department of Fisheries Services.

Wessel, P. and W.H.F. Smith. 1991. Free Software helps map and display data. EOS Trans. Amer. Geophys. U. 72:441, 445-446

Zug, G. 1993. Herpetology: An Introductory Biology of Amphibians and Reptiles. Academic Press, Inc. V. San Diego, CA. 527p.

	Average dive	% underwater	Dive number
All data combined	.0001	.0001	.0001
Leilua (25692)	.0001	.0001	.0001
Isalei (25693)	.0001	.001	.0001
Aulotu (25694)	.0001	.004	.0001

Table 1. Significant differences in means between habitats are shown for average dive time, percent time underwater and dive number. Probability values shown are Pr > F.

	Internesting n = 192	Foraging n = 143	Migration n = 138
Average dive:	a) 14.5 ± 1.30 b) 9.0 c) 0.9 - 42.9	a) 8.9 ± 0.98 b) 6.0 c) 1.1 - 51.4	a) 5.7 ± 0.61 b) 3.6 c) 1.8 - 24.5
% UW:	a) 87.9 ± 2.55 b) 18.0 c) 8.3 - 97.8	a) 94.9 ± 0.48 b) 2.9 c) 87.4 - 99.9	a) 95.8 ± 1.17 b) 7.0 c) 21.3 - 99.8
Dive number:	a) 65.8 ± 7.32 b) 51.5 c) 16.0 - 360	a) 111.2 ±13.5 b) 81.6 c) 14.0 - 576	a) 150.4 ±10.2 b) 60.4 c) 28.0 - 336

Table 2: Variation in average dive time, percent time underwater (%UW), and dive number between internesting, foraging, and migration areas for all turtles combined. Data was collected during the post-nesting migration between Rose Atoll and the Fiji Islands (October 1995 to April 1996). n= the number of observation, a) mean ± 95% CI, b) standard deviation (sd), and d) range.

	Internesting n = 54	Foraging n = 26	Migration n = 36
Average dive:	a) 12.2 ± 1.22 b) 5.9 c) 1.7 - 24.8	a) 13.5± 4.15 b) 10.3 c) 1.1 - 51.4	a) 6.7 ± 1.52 b) 4.5 c) 2.8 - 24.5
% UW:	a) 85.3 ± 5.41 b) 19.9 c) 8.26 - 96.7	a) 98.1 ± 0.82 b) 2.3 c) 90.7 - 99.9	a) 96.8 ± 0.7 b) 2.07 c) 89.4 - 99.5
Dive number:	a) 54.3 ± 7.7 b) 28.3 c) 27.0 - 182	a) 103.8 ±44.4 b) 110.5 c) 14.0 - 576	a) 135.1 ±19.4 b) 57.5 c) 28 - 248

Table 3: Variation in average dive time, percent time underwater (%UW), and dive number between internesting, foraging, and migration areas for Leilua (25692). Data was collected during the post-nesting migration between Rose Atoll and the Fiji Islands (October 1995 to April 1996). n= the number of observation, a) mean ± 95% CI, b) standard deviation (sd), and d) range.

	Internesting n = 63	Foraging n = 72	Migration n = 49
Average dive:	a) 13.9 ± 2.37 b) 9.4 c) 0.9 - 368	a) 10.3 ± 0.89 b) 3.8 c) 4.4 - 24 50	a) 4.9 ± 0.99 b) 3.4 c) 1.8 - 16.4
% UW:	a) 86.1 ± 4.49 b) 19.62 c) 19.4 - 97.1	a) 92.9 ± 0.53 b) 2.2 c) 87.4 - 97.4	a) 94.5 ± 3.12 b) 10.9 c) 21.3 - 98.7
Dive number:	a) 79.3 ± 18.0 b) 71.5 c) 19.0 - 360	a) 73.0 ± 5.81 b) 24.7 c) 28.0 - 149	a) 177 ± 19.3 b) 67.2 c) 42.0 - 281

Table 4: Variation in average dive time, percent time underwater (%UW), and dive number between internesting, foraging, and migration areas for Isalei (25693). Data was collected during the post-nesting migration between Rose Atoll and the Fiji Islands (October 1995 to April 1996). n= the number of observation, a) mean ± 95% CI, b) standard deviation (sd), and d) range.

	Internesting n = 75	Foraging n = 45	Migration n = 53
Average dive:	a) 15.7 ± 2.43 b) 10.6 c) 1.9 - 42.9	a) 4.6 ± 0.68 b) 2.3 c) 1.5 - 14.3	a) 5.8 ± 0.83 b) 3.0 c) 2.1 - 21.7
% UW:	a) 91.3 ± 3.31 b) 14.4 c) 16.8 - 97.8	a) 96.4 ± 0.40 b) 1.3 c) 93.9 - 98.6	a) 96.3 ± 1 b) 3.6 c) 78.8 - 99.8
Dive number:	a) 62.8 ± 9.56 b) 41.6 c) 16 - 228	a) 176 ± 24.7 b) 82.4 c) 48.0 - 461	a) 136 ± 12.96 b) 46.9 c) 32 - 336

Table 5: Variation in average dive time, percent time underwater (%UW), and dive number between internesting, foraging, and migration areas for Aulotu (25694). Data was collected during the post-nesting migration between Rose Atoll and the Fiji Islands (October 1995 to April 1996). n= the number of observation, a) mean ± 95% CI, b) standard deviation (sd), and d) range.

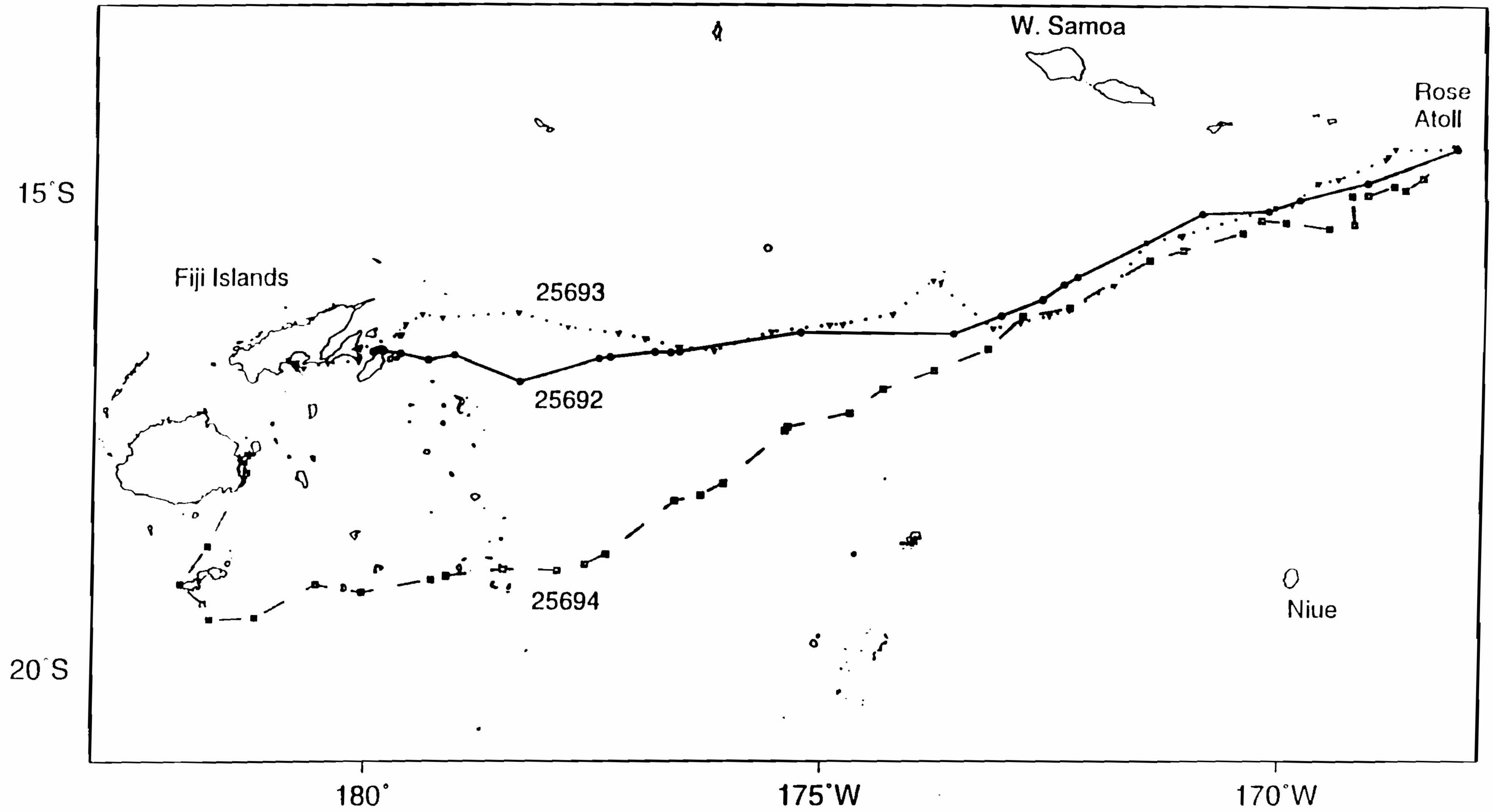

Figure 1. Map of Samoa to the Fiji Islands, Rose atoll is indicated by an open circle. Map covers post-nesting migratory area to the three green turtles tracked in October 1995 to April 1996. Map was created using the Generic Mapping Tool (Wessel and Smith, 1991). Unpublished data provided by G.H. Balazs and D.M. Ellis.

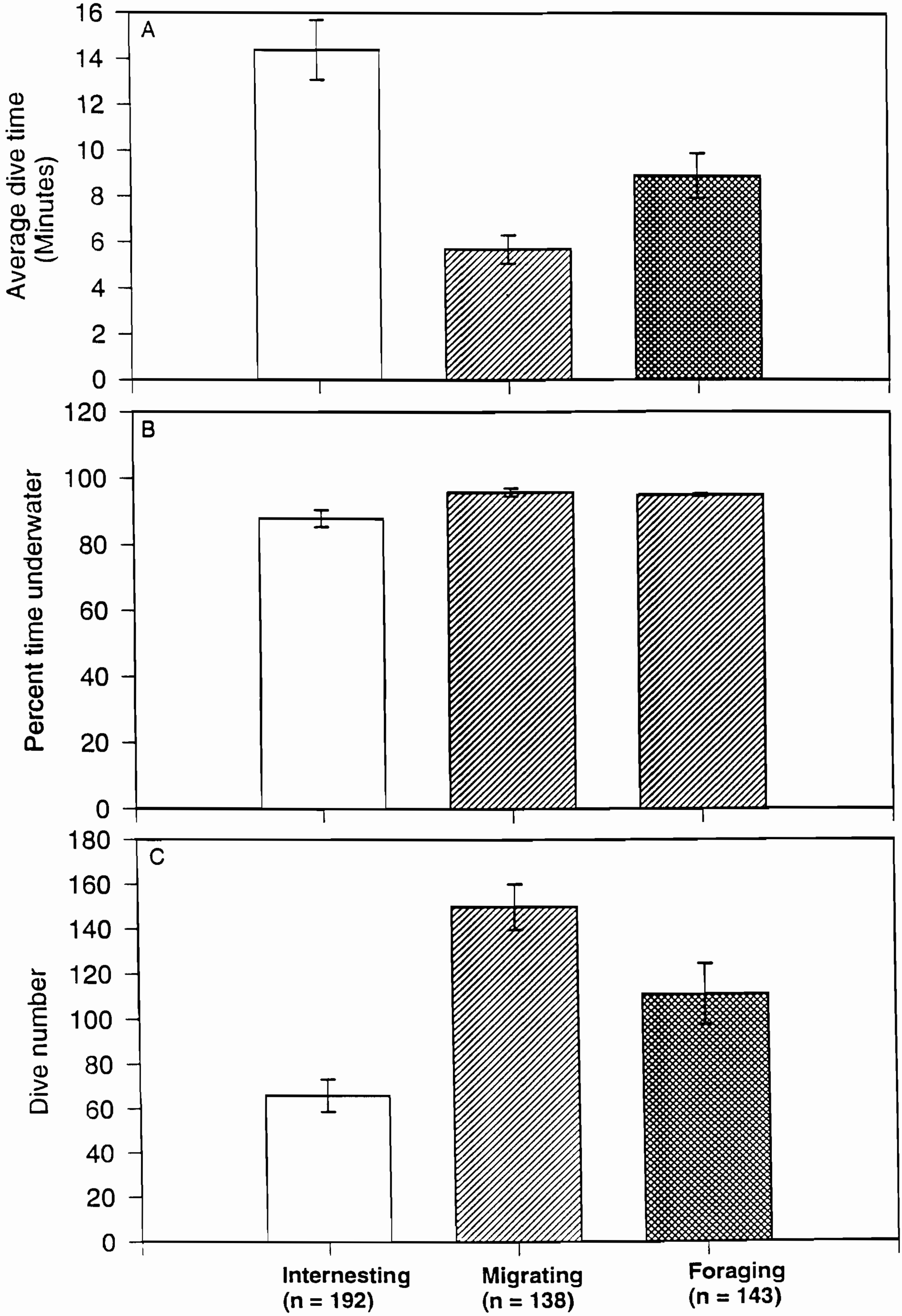

Figure 2. Variation in habitat areas for average dive time, percent time underwater and dive number for all turtles combined. Different fill patterns indicate a difference in means between the habitats.

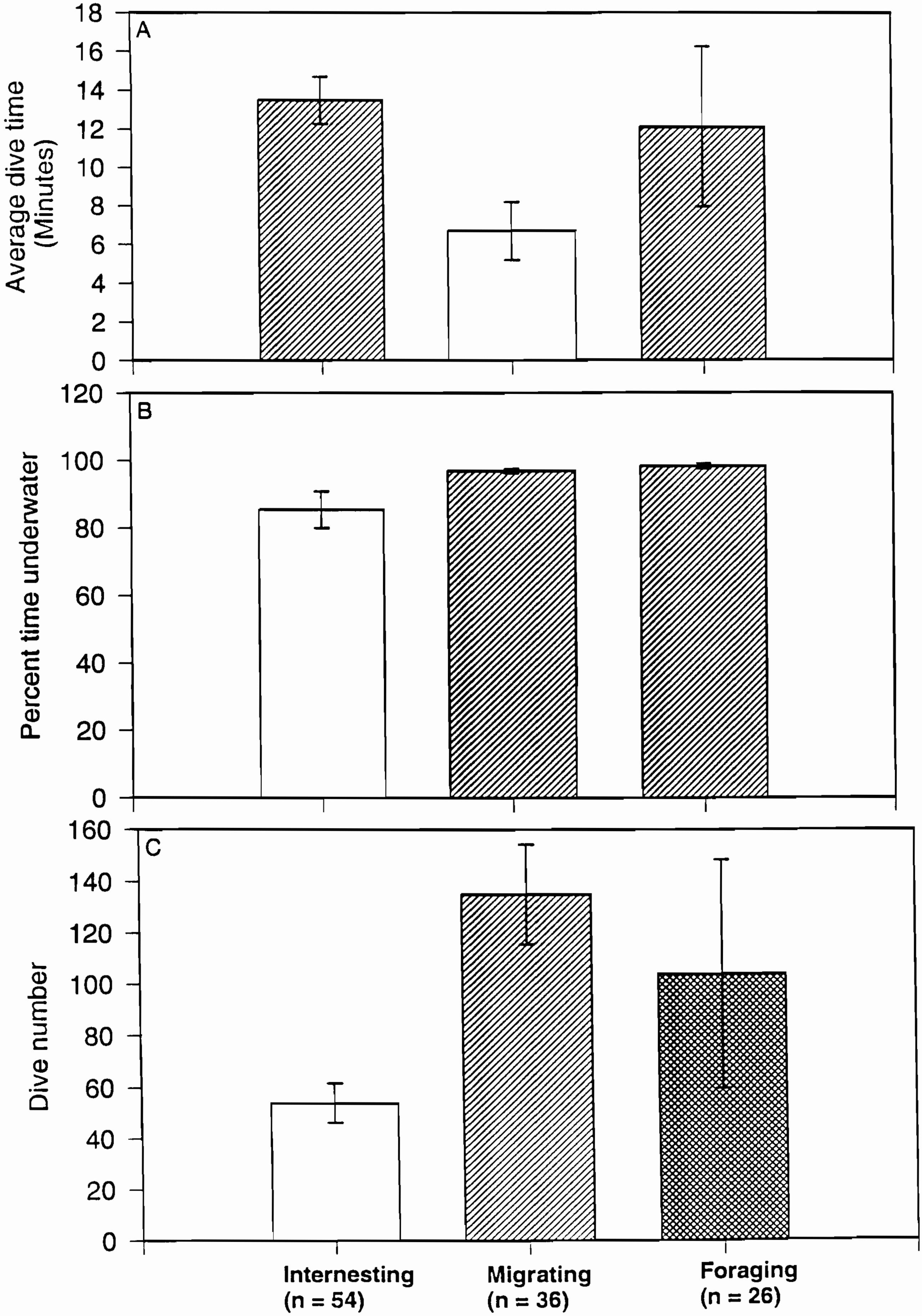

Figure 3. Variation for average dive time, percent time underwater and dive number between habitats for Leilua (25692). Different fill patterns indicate a difference in means between the habitats.

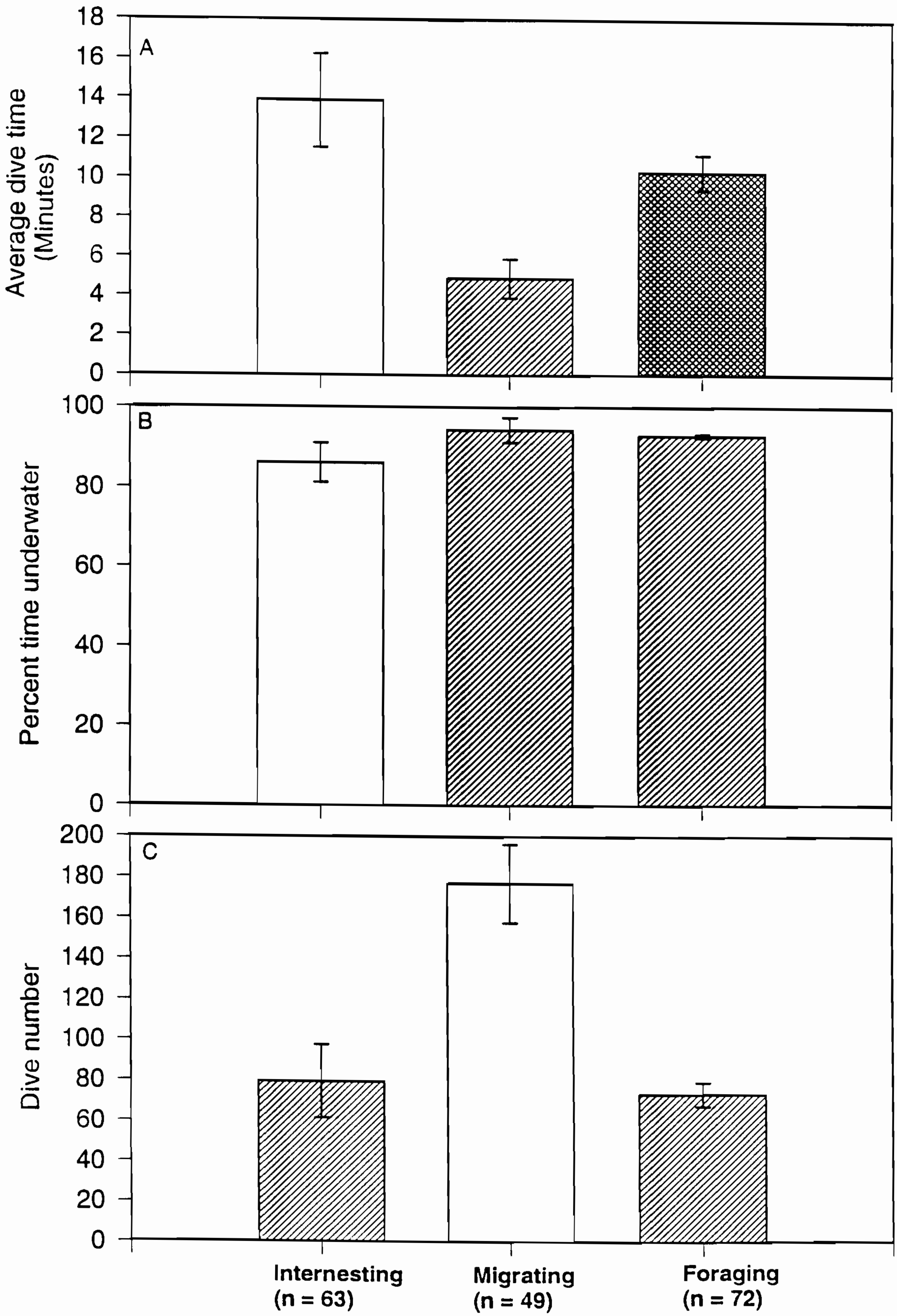

Figure 4. Variation in average dive time, percent time underwater, and dive number between habitat areas for Isalei (25693). Different fill patterns indicate a differnece in means between habitats.

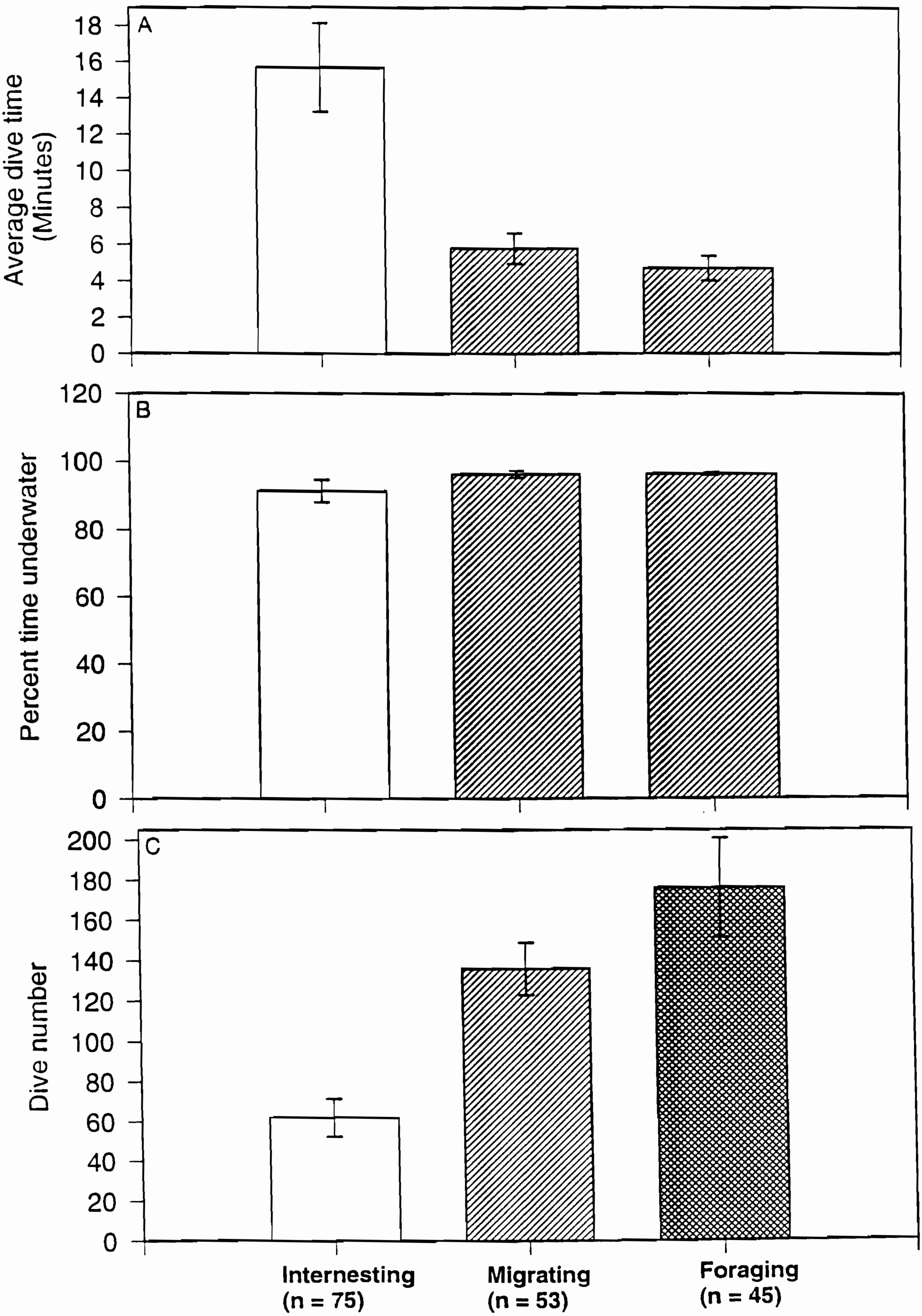

Figure 5. Variation in habitat areas for average dive time, percent time underwater and dive number for Aulotu (25694). Different fill patterns indicate a difference in means between habitats.