DIET COMPOSITION AND TERRESTRIAL PREY SELECTION OF THE LAYSAN TEAL ON LAYSAN ISLAND

BY

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ABSTRACT

The Laysan teal (*Anas laysanensis*) is an endangered dabbling duck endemic to the Hawaiian Archipelago but currently restricted to a single breeding population on Laysan Island. We studied its diet using fecal analysis and behavioral observations. Laysan teal fecal samples (N=118) contained prey items in 15 primary prey categories with a mean of 2.9 (range 0-7) taxa per sample. Sixty-two of these fecal samples were quantified with 2,270 prey items identified (mean items per sample 37; range 0-205). Based on fecal analysis and behavioral observations, we learned that the Laysan teal is not strictly a macroinsectivore as previously reported, but consumed seeds, succulent leaves, and algae, in addition to adult and larval diptera, ants, lepidoptera, coleoptera, and *Artemia*. We compared abundance of invertebrates from two terrestrial foraging substrates, soil and standing vegetation, to the abundance of invertebrate prey items counted in fecal samples collected from these habitats for the same period. In the soil substrate, Laysan teal selected two of the most abundant invertebrates, lepidoptera larvae and coleoptera. In the standing vegetation, Laysan teal selected the most abundant taxa: coleoptera. Amphipods were consumed in proportion to their abundance, and small gastropods (*Tornatellides sp.*), isopods, and arachnids were avoided or were identified in fecal matter in disproportion to their abundance in the foraging habitat. We compared fecal composition of samples collected in aquatic and terrestrial habitats and detected significant differences in samples' species compositions. The conservation implications of the adult Laysan teal's diet are positive, since results indicate that the Laysan teal are opportunistic insectivores, and exhibit dietary flexibility that includes seeds and other food. Dietary flexibility improves the possibility of successfully reestablishing populations on other predator-free islands.

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INTRODUCTION

The Laysan teal, an endangered species, is restricted to a single breeding population (approximately 500 birds) on Laysan Island and a small, recently translocated population on Midway Atoll (42 birds). The species was previously widespread across the Hawaiian Archipelago, but was extirpated from the main islands during Polynesian colonization and associated mammalian predator introductions (1,400-1,600 ybp) (Cooper et al., 1996; Burney et al., 2001). Due to the remoteness of Laysan Is., only three other studies have preceded the current work (Warner, 1963; Moulton and Weller, 1984; Marshall, 1989).

Little is known about the food habits of Laysan teal, and what information exists is conflicting. Observations in the late 1950s indicated that the birds fed primarily on moth (*Agrotis dislocata*) larvae (Warner, 1963). More recent work suggests that brine flies are the most important dietary component (Caspers, 1981; Moulton and Weller, 1984). Whether this shift in diet was due to environmental conditions on Laysan during the early observations (which were conducted during dry years) or the effect of introduced insects, such as predatory ants, depleting *Agrotis* larvae is unknown.

To learn more about the ecology and conservation potential of this endangered species, we studied the diet of Laysan teal and the relationship between terrestrial invertebrate prey abundance and food habits by sampling invertebrates, analyzing teal feces, and observing teal foraging behavior.

METHODS

Study Site

Laysan Is. is an important nesting colony for several million seabirds. Although plumage collectors, seal and turtle hunters, and other mariners visited the island, there is no evidence of human habitation on Laysan before guano miners who occupied the Island from 1893-1909 (Ely and Clapp, 1973). U.S. President Theodore Roosevelt declared the Island a bird reserve in 1909, subsequent to which exploitation of Laysan's wildlife was much reduced. A small U.S. Fish and Wildlife Service (USFWS) field camp exists on Laysan today, and the Island is part of the Hawaii Islands National Wildlife Refuge (NWR).

Laysan Is. has the largest continuous land area of the Hawaiian atoll islands. It is roughly rectangular, approximately 3 km long from north to south and 1.5 km east to west. Laysan lies 1,506 km northwest of Honolulu (25°46' N latitude, 171°44' W longitude) and is accessible only by boat (Fig. 1). The island consists of 187 ha of mostly low herbaceous vegetation, a 105-ha interior lake and associated mudflats, and approximately 123 ha of unvegetated blowout areas, coastal dune, and beach (Moulton and Marshall, 1996). The highest point of the Island is 12 m above sea level, and coastal reef flats and tide pools surround its perimeter.

Laysan's lake is characterized by hypersalinity, high nutrients, and low species diversity. Evaporation frequently exceeds precipitation, and salinity is two to four times oceanic salinity (5.8-13.0 g/100g; USFWS data). The lake supports algal and cyanobacterial growth (*Dunaliella spp.*, *Schizothrix sp.*), and dense populations of brine shrimp (Anostraca: *Artemia franciscana*) and brine flies (Ephidridae: *Scatella sexnotata*; Caspers, 1981; Lenz, 1987). *Artemia* feed on phytoplankton and occur throughout the lake's water column. Larvae of *S. sexnotata* are salt-tolerant and aquatic and feed on microorganisms and detritus. Pupae adhere to the algal substrate on the lake bottom, and the adult flies feed on organic matter occurring in the wetlands surrounding the lake. A subterranean freshwater lens occurs on Laysan, and fresh-to-brackish (0.0 - 3.0 g/100g) water seeps occur in the interior of the Island surrounding and within the lake, and at several locations on the coast (Reynolds, 2002; Warner, 1963). The lake's maximum depth was 6.5 m. in 1984 (USFWS data), but size and depth vary seasonally. Rainfall on Laysan is moderate, averaging 79 cm per year from 1992 to 2000 (range 38-120 cm per yr; USFWS data).

Vegetation associations form concentric bands between the coast and the lake. Scattered ground cover dominated by *Nama sandvicensis* is found closest to the coast. Moving inland, vegetation consists of 1) coastal shrubs, 2) interior bunch grasses, 3) vines 4) interior shrubs, and 5) wetland vegetation. The dominant species of these vegetation associations are 1) *Scaevola sericea,* 2) *Eragrostis variabilis,* 3) *Ipomoea pes-caprae* or *Sicyos maximowiczii, S. pachycarpus,* or *S. semitonsus, 4) Pluchea indica,* and 5) *Sesuvium portulacastrum, Heliotropium curassavicum,* and *Cyperus laevigatus* (Newman, 1988). The bunch grass association and the viney association comprise 112.6 ha and 50.8 ha, respectively (Morin, 1992). Laysan Island has four general habitat zones used by the Laysan teal. The coastal zone includes area below the high surf zone and coastal or dune areas on the outer perimeter of the interior bunch-grass associations. The "camp" zone includes all areas within 60 m of human structures and storage areas associated with the camp. The terrestrial zone is comprised of vegetation bands 1-4. The "lake zone" consists of all wetland plant associations, mudflats, ephemeral wetlands, and the hypersaline lake.

Diet

Fecal analysis is a nonintrusive prey sampling method, appropriate for endangered species (Rosenberg and Cooper, 1990). We collected fecal samples from birds within each of the four habitat zones, assuming this represented what birds typically ate. Scleritized arthropod body parts are identifiable after passing through the bird's digestive system. Fecal samples were collected within 5 minutes of deposition, during banding, radio telemetry, and behavioral observations from the four habitat zones from March 1998 – July 2000, and preserved in 70% ethanol.

For identification, samples were placed in Petri dishes and separated using forceps and fine probes. Prey items were viewed at 160-400x with a binocular scope (Leica MZ6) and identified using reference specimens and taxonomic keys. (Zimmerman, 1948; Gepsink, 1969; Hardy and Delfinado, 1980; McAlpine, 1987). Reference specimens were collected and crushed to better resemble the parts found in fecal samples. For all samples, the frequency of occurrence (presence or absence) of prey items in an individual fecal sample was determined. A subsample was analyzed further, and identified taxa were counted. Taxa were classified by order and, when possible, by species and life stage.

Foraging Behavior

We studied the Laysan teal's foraging by observational sampling of behavior in 1998-2000. Continuous focal sampling was conducted on radio-tagged birds located as part of home range studies (Reynolds, 2004). To supplement this sample, focal animals lacking radio tags were selected by traversing a particular habitat zone in a random direction until an individual was encountered. All focal samples were 20 minutes in duration (Altmann, 1972; Reynolds, 2002).

Behavioral observations were collected from each habitat zone during the same four time periods: morning (2 hrs before and after sunrise: approx. 0400– 0830 hrs), day (approx. 0900-1530 hrs), evening (2 hrs before and after sunset: approx. 1600-2030 hrs), and night (2100-0300 hrs).

Terrestrial Prey Abundance

We collected data on prey abundance to relate habitat use and diet to the resource base (see also Reynolds, 2004). We sampled prey abundance, the total amount of prey in the environment, by sampling terrestrial substrates (soil and vegetation) for taxa previously identified in the diet of Laysan teal (Warner, 1963; Caspers, 1981; Lenz and Gagne, 1986). We acknowledge that prey availability, the amount of prey actually available to the individual bird, may differ from abundance, because we cannot sample the environment as the birds themselves do (Hutto, 1990).

Macroinvertebrates were sampled from soil and vegetation during active feeding hrs of the Laysan teal between 2100 and 0100 hrs, at randomly chosen locations along a trail used by Laysan teal for foraging, nesting, and cover. The trail, which meanders from the coast to the interior wetlands, was used to prevent disturbance to nesting birds and damage to the seabird burrows that honeycomb the island. Prior to each sampling session, a random point was selected as the starting location for collecting samples every 5 m at the nearest vegetation clump, alternating to the left and the right of the trail. If a nesting or resting seabird prevented our collecting a sample at a designated vegetation clump, the next nearest vegetation clump was sampled. Each type of vegetation sampled was classified to genus and later grouped into the following categories: grassy (bunch grass), viney, shrubby, or mixed (Table 1). Ten samples were collected twice monthly between May 1998 – Oct 1999 from the soil, and from November 1998 – October 1999 from the vegetation. We intensified sampling and collected invertebrates weekly from both the soil and vegetation from April – July 2000.

Soil samples (excavations of 360.7 cm^3 each) were sieved for macroinvertebrates (> 1 mm) using three screen sieves (mesh sizes 10, 60, and 230 openings per linear inch; Hubbard Scientific soil profile kit 3196). Invertebrates from sieved soil samples were counted, categorized by order, and released the next day. Unknown taxa were collected and preserved in 70% ethanol for later identification. Ants (Formicidae) were too numerous to quantify, and we determined only their presence or absence.

Vegetation was sampled by expulsion of invertebrates using a stick and "beating sheet" (0.5 m^2 per sample; Southwood, 1978). Dislodged macroinvertebrates were counted, categorized, and released at the sampling site. Unknown and some commonly occurring taxa were aspirated into vials for later identification and used as reference specimens for fecal analysis. Again, ants were not counted but categorized as present or absent. Additional data collected during each sampling period included time, weather, index of soil moisture, wind speed, and direction.

Data Analysis

We used nonparametric tests (Kruskal Wallis) for statistical comparisons of fecal data that lacked a Gaussian distribution (SYSTAT version 9; Zar, 1999). Prey selection indices are based on ratios of used and available resources (Manly et al., 1993):

$$w_i = \frac{o_i}{p_i},$$

where w_i = the selection index for invertebrate taxon *i*,
o_i = the proportion invertebrate taxon (*i*) used by Laysan teal, and
p_i = the proportion of invertebrate taxon (*i*) available in the environment (estimated).

Resource ratio indices, w_i, of 1.0 indicate resources are used in proportion to availability; indices above 1.0 provide evidence of "selection," and values less than 1.0 suggest "avoidance" or use disproportionately less than availability. Resource indices are statistically significant if the confidence intervals for w_i do not contain the value 1.0 (Manley et al., 1993). Standardized selection indices also are given by Manley et al. (1993):

$$B_i = \frac{w_i}{\sum_{i=1}^{n} w_i},$$

where B_i = standardized selection index, and *n* is the number of resource categories (i.e., invertebrate taxa). Values of $B_i < 1$ indicate no preference, and values above or below 1 provide evidence of preference and avoidance, respectively. To test the null hypothesis that the Laysan teal are selecting resources at random, G-tests were used, assuming a chi-square distribution (Manly et al., 1993; Krebs, 1999):

$$\chi^2 = 2\sum_{i=1}^{n}\left[u_i \ln\left(\frac{u_i}{Up_i}\right) + m_i \ln\left(\frac{m_i}{(m_i + u_i M/(U+M))}\right)\right],$$

where χ^2 is the chi-square value (df = n-1), u_i = the number of observations of each invertebrate taxon (*i*), m_i is the number of observations of available invertebrate taxon (*i*), *U* is the total of observations of use, and *M* is the total observations of availability. Standard errors and confidence limits for multiple tests of selection ratios are given by

Manly et al. (1993). Assumptions of these analyses are that 1) resource availability and use have been correctly identified, 2) resource availability and use do not change during the study, 3) birds have free access to all resource units, and 4) resource units were sampled randomly and independently.

RESULTS

Fecal Analysis

Laysan teal fecal samples (N=118; 59 females, 53 males, 4 fledged juveniles, and 2 adults of unknown sex) contained prey items in 15 primary prey categories with a mean of 2.9 taxa per sample (range 0-7 taxa). Many samples contained sand and prey parts too finely ground for identification or quantification. Dipteran adults were most abundant, occurring in 47% of the samples, followed by dipteran larvae and pupae (39%), ants (36%), seeds (31%), lepidopteran larvae (25%), and coleopteran adults (23%) (Table 2).

Sixty-two fecal samples were analyzed by counting diet items in the samples. The number of prey items averaged 36.7 per sample (range 0-205). Dipteran adults made up 32% of the total identified prey items counted, followed by *Artemia* (21%), dipteran larvae or pupae (16%), lepidopteran larvae (8%), seeds (8%), and plant fibers (7%; Table 3). Ants made up only 2% of the total items counted despite their high frequency of occurrence in the samples. Nearly half (47.4%) of the seeds counted were from succulent plants, *Portulaca spp*., found in the terrestrial zone. Other intact seeds identified in fecal samples included *Cyperus laevigatus, Fimbristylis cymosa,* and *Mariscus pennatiformis* ssp. *bryanni.* An unpublished analysis of fecal samples (N=28) collected from birds at the lake during the summer of 1985 showed higher occurrence of *Artemia* and *Blattaria*, fewer ants, and no seeds (Lenz and Gagne, unpublished data; Table 2)

We tested for differences in the frequency of occurrence between the composition of prey items collected from two habitat zones where the ducks spent most of their time: the lake zone (N= 45 fecals) and the terrestrial zone (N=30 samples; Fig. 2). We lacked data on an individual bird's time spent in the zone prior to the collection of fecal samples and the food passage rates for these prey species, therefore variation due to birds recently foraging in other areas was expected. Significant differences in the occurrence of taxa were found for ants, lepidopteran larvae, and seeds, which occurred more frequently in samples collected from the terrestrial zone, and adult dipterans, which occurred with greater frequency in the samples from the lake zone (Table 4). *Artemia* occurred in only 14 samples from the lake and terrestrial zones, and its frequency of occurrence did not significantly differ between them. However, the number of *Artemia* counted was significantly higher in the lake-zone samples than the terrestrial samples (Kruskal Wallis $H=4.72$, $p=0.030$). *Artemia* are found exclusively in the lake, and lepidopteran larvae typically are absent from the lake zone.

Behavoral Observations

Because of the difficulty in observing the consumption of small dietary items in dabbling ducks, diet from focal observations could not be reliably quantified from focal observations. Nevertheless, visually biased diet observations are valuable since we suspect that succulent leaves, algae, and adult lepidopteran, which were well represented in foraging observations (Table 6), may have been underrepresented or not identified in the fecal samples.

We analyzed 402 focal observations from 123 males, 251 females, and 28 unknown birds totaling 8,511 minutes from 1998-2000. Focal observations are summarized in Table 5 and 6. Adult and larval lepidopteran, terrestrial dipteran adults and larvae including maggots from seabird carcasses, *Blattaria* (cockroaches), grass seeds (*Sporobulus* spp.), sedge achenes, *Fimbristylis cymosa*, and succulent leaves from *Portulaca sp.* were taken while foraging in the terrestrial habitat. Laysan teal in the lake zone ate mostly wetland invertebrates and algae.

Prey Abundance and Selection

The most abundant soil invertebrates captured during sieve sampling were lepidoteran larvae (24%), gastropods (19%), coleopteran (14%), and amphipods (10%) (N=487 sieve samples; Fig. 3). Note that in the field we could not easily distinguish from live, dead, and estivating snails, thus the abundance of gastropods in the sieve samples is an overestimate of available live prey. Dominant taxa counted from the standing vegetation (N=367 samples; Fig. 4) included coleoptera (37%), arachinida (19%), lepidopteran adults (15%), and diptera adults (12%).

Invertebrate abundance for the two terrestrial substrates sampled, soil (N = 487) and standing vegetation (N=367), was analyzed separately to explore differences in composition and abundance of invertebrates among grassy, viney, and mixed substrates using Kruskal Wallis tests. Soil samples within the grassy (N=302), viney (N=101), and mixed vegetation (N=84) were tested for differences in the abundance of taxa captured between vegetation types. Significant differences were identified for lepidopteran larvae ($H=26.712$; $df = 2$; $p<0.0001$), gastropods ($H=6.597$; $df=2$; $p=0.037$), "other" combined taxa ($H=7.279$; $df=2$; $p=0.026$), and coleoptera ($H=7.562$; $df=2$; $p=0.023$). Lepidopteran larvae were more abundant in soil of the mixed and viney vegetation than the grassy vegetation. Gastropods were more abundant in the grassy vegetation's soil, "other" invertebrates were more abundant in the mixed vegetation soil, and coleoptera in the viney vegetation soil.

Invertebrates sampled in the standing vegetation (grassy N=231, viney N=67, and mixed vegetation N=69) showed significant differences for coleoptera ($H=68.47$, $df=2$, $p<0.0001$), arachnida ($H=51.91$, $df=2$, $p<0.0001$), diptera ($H=53.86$; $df=2$; $p<0.0001$) and adult lepidoptera ($H=13.09$; $df=2$; $p=0.001$). Pair-wise comparisons indicated coleoptera were more abundant in the viney standing vegetation, arachnida in the grassy vegetation, diptera in the viney vegetation, and adult lepidoptera in the mixed and viney vegetation.

We compared abundance of invertebrates from two terrestrial foraging substrates, soil and standing vegetation, to the abundance of invertebrate prey items counted in fecal samples collected from these habitats for the same period. An assumption of the analysis, that available food resources are constant during the study period, is difficult to satisfy for most studies (Manly et. al., 1993), and was not met for this study because some taxa, such as adult diptera, showed seasonal variability (Reynolds, 2002). In this case, prey selection inferences are made with respect to "typical" conditions during the study period (Manly et. al., 1993). We excluded aquatic prey (*Artemia*) and diptera that could be from either wetland or terrestrial habitats, but included diptera identified as terrestrial. We tested the hypothesis of equal use with a chi-squared log likelihood statistic. Results provide evidence of nonrandom prey use in both the soil substrate (X^2 =341.517, df =7, P<0.0001), and standing vegetation (X^2=77.54, df =4, p<0.0001; Table 7). Laysan teal selected the most abundant invertebrates in some cases but did not use other abundant taxa. In the soil substrate, Laysan teal preferred two of the most abundant invertebrates, lepidoptera larvae and coleoptera. Amphipods were selected in proportion to their abundance, and small gastropods (*Tornatellides sp.*), isopods, and arachnids were not consumed or were used in disproportion to their abundance. We did not distinguish between live, dead, or estivating snails and suspect many were dead, and unlikely prey. In the standing vegetation, Laysan teal preferred the most abundant taxon: coleoptera. Laysan teal avoided arachnids, however sample sizes of resource use (fecals containing identifiable arachnid parts) were too low to be reliable (Table 7).

DISCUSSION

Previous researchers described the Laysan teal as a 100% macroinsectivore (Moulton and Weller, 1984; Moulton and Marshall, 1996); however, fecal analysis and behavioral observations reveal that seeds and other plant parts are important components of their diet. We observed significant differences in prey compositions from samples collected in the lake and wetlands compared to terrestrial habitats indicating the potential importance of habitat bias from fecal diet studies. The discrepancy between our research and earlier studies may be because most of the granivory and herbivory occurred in the terrestrial zone and therefore was more difficult to observe than foraging at the lake where naturalists made most of their observations.

The prevalence of terrestrial foraging and the importance of lepidopteran larvae in the diet were first described by Warner (1963). He also described cutworm larvae climbing the vegetation at night. We did not observe this phenomenon, but found that lepidopteran larvae were common in the soil substrate, particularly in the viney *Ipomoea-Sicyos* and mixed vegetation complexes. Indeed, radio-tracking studies indicated these habitats and substrates were used more for nocturnal foraging than would be expected by chance (Reynolds, 2002).

The Laysan teal consumes a wide variety of prey using a broad foraging strategy. Comparisons between fecal and invertebrate samples indicate that the most abundant prey was often the most frequently consumed. However, some abundant invertebrates were not consumed in relation to their abundance. These abundant invertebrates may lack required nutrients or be energetically expensive to process due to high sodium content, for example *Artemia* (Reynolds, 2002). Other prey not selected may be unpalatable (e.g., ants due to formic acid), difficult to capture, or have defenses against predators (e.g., some spider and cockroach species) rendering them less available as prey. Collection of fecal samples and behavioral observation from all habitats used by the Laysan ducks (see also Reynolds, 2004) was essential to identify the variety of food consumed.

The Laysan teal appear to be opportunistic in that they consume the most abundant "profitable" prey. Although we have limited long-term historical data on food resources on Laysan, it is possible that this "opportunistic" foraging strategy likely helped it survive during prey and food scarcity from the past rabbit invasion (Dill and Bryan, 1912). The high risks of extinction for this isolated population, together with the evidence of the species' previously wide distribution in Hawaii (Cooper et al., 1996), provide justification for translocation to promote the species' conservation. The diet plasticity exhibited by the adults of this species improves the chance for successful re-establishment in mammalian-predator-free habitats on additional islands where terrestrial and aquatic prey are abundant. Most islands of the Hawaiian Archipelago are dissimilar to Laysan and lack hypersaline ecosystems, including important wetland and aquatic prey brine flies and *Artemia*. However, we anticipate that the Laysan teal's foraging flexibility and opportunism will allow them to adapt to novel environments with suitable habitat. The importance of a varied and abundant prey base, dense vegetative cover, a source of fresh water during brood rearing, and the absence of mammalian predators should be emphasized when choosing suitable habitat for new populations.

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Table 1. Vegetation categories and habitat zones of plant species sampled for terrestrial invertebrates.

Category	Habitat Zone	Plant species
Grassy	Terrestrial	*Eragrostis variabilis*, *Fimbristylis cymosa*, *Boerhavia repens*
Viney	Terrestrial	*Ipomoea pes-caprae*, *Sicyos* spp., *Tribulus cistoides*
Shrubby	Terrestrial	*Scaevola sericea*, *Tournefortia argentea*
Mixed	Terrestrial or lake transition	*Portulaca lutea*, *Conyza bonariensis*

Table 2. Frequency of occurrence (percent of samples with prey types) of taxa in Laysan teal fecal samples collected on Laysan Island during 1985 and 1998-2000.

Prey type	1998-2000[1] (N=118)	1985[2] (N=28)
Diptera adult	47	39
Dipteran larvae/pupae	39	21
Formicidae	36	4
Seeds	31	0
Lepidopteran larvae	25	32
Coleoptera	23	0
Plant fibers	17	0
Artemia	15	32
Acari	11	7
Amphipoda	8	14
Unknown arthropod	7	0
Blattaria	3	21
Diptera terrestrial	3	11
Lepidopteran adult	3	0
Araneida	2	7
Dermoptera	0	4

[1] MHR data from samples collected from all habitats and seasons.
[2] Lenz & Gagne (1986) unpublished data from samples collected from the lake zone in 1985.

Table 3. Total number of prey items and percent of total items identified in Laysan teal fecal samples collected on Laysan Island 1998-2000 (N=62 samples).

Prey type	Number	Percent of total items identified
Dipteran adult	725	31.9
Artemia	472	20.7
Dipteran larvae or pupae	355	15.6
Lepidopteran larvae	188	8.3
Total Seeds	179	7.9
Portulaca seeds	85	(47.4 % of seeds; 3.7 % of total items)
Plant fiber	149	6.6
Coleoptera	81	3.6
Formicidae	47	2.0
Amphipoda	37	1.6
Lepidopteran adult	13	0.5
Acari	12	0.5
Dipteran terrestrial	9	0.3
Blattaria	3	0.1

Table 4. Results of Kruskal Wallis tests comparing taxa counted in fecal samples from lake and terrestrial zones.

Taxa counted	H	P-value
Amphipods	0.77	0.38
Ants	6.43	*0.01
Artemia	2.44	0.12
Coleoptera	1.84	0.18
Diptera adult	4.25	*0.04
Diptera larvae or pupae	1.08	0.3
Lepidoptera larvae	7.61	>*0.001
Plant fiber		
Seeds	5.52	*0.02

*Significant at 95% level

Table 5. Total number of food items and water consumed (events) by Lasyan teal during behavioral observations in four habitat zones on Laysan Island.

Consumption observed	Camp	Coast	Lake	Terrestrial	Total
Algae			11		11
Amphipod			1		1
Artemia			2		2
Brine fly			1274		1274
Blattaria				5	5
Terrestrial Diptera (adult)	49		155	481	685
Maggot			6	99	105
Moth	37				37
Portulaca	4			2	6
Seeds				36	36
Spider	1				1
Unk. soil inverts.				20	20
Unknown	11	1	15	33	60
Water	181	27	220	31	459

Table 6. Indices of preference (w) for select prey types from the terrestrial zone based on abundance (all dates combined) from soil and standing vegetation sampling and the number of prey items counted in fecal samples (n=62).

Prey type	Amt. prey[1]	Proportion Prey	Prey counted in fecal samples	Proportion prey in fecal samples	95% CI	$(w)^2$	Bonferroni 95% CL	Standardized selection index B[3]
Soil samples N=487								
Larval Lepidoptera	366	0.26	188	0.63	0.55-0.70	2.42*	2.00-2.83	0.45
Gastropoda	301	0.21	0	0.0	0-0	0	0	0
Coleoptera	225	0.16	76	0.25	0.18-0.32	1.59*	1.08-2.05	0.29
Amphipoda	150	0.11	34	0.11	0.06-0.16	1.07	0.54-1.59	0.20
Other	136	0.10	0	0.0	0.0	0	0.0	0
Isopods	134	0.10	0	0.0	0.0	0	0.0	0
Arachida	67	0.05	1	0.003	0-0.01	0.07	0-0.26	0.01
Standing Veg. N=367								
Coleoptera	2132	0.40	76	0.77	0.66	1.91*	1.62-2.19*	0.56
Arachnida	1158	0.22	1	0.01	0-0.04	0.05	0-0.17	0.01
Adult Lepidoptera	880	0.17	13	0.13	0.04-0.22	0.79	0.26-1.32	0.23
TZ Diptera[4]	721	0.14	9	0.09	0.02-0.01	0.67	0.12-1.22	0.20
Gastropoda[5]	407	0.08	0	0.00	0-0	0	0	0

[1] Amount prey =invertebrate abundance is the pooled total of abundant taxa identified during sampling from 1998-2000.
[2] *w*= proportion of prey used by Laysan teal/proportion of prey available in the environment (estimated).
[3] B = standardized selection index. Values less than 1 divided by the number of resources indicate no preference and values above or below provide evidence of "preference and avoidance", respectively.
[4] The taxa category "Diptera" from the fecal samples was excluded from the analysis because it included mixed species, some from the wetland habitat. Taxa in fecal samples identified as terrestrial diptera were likely underestimated due to the difficulty in separating and identifying members of this order.
[5] Both live and dead gastropods were included in the total abundance; therefore live prey is likely to be overestimated.
* Indicates strong evidence of selection.

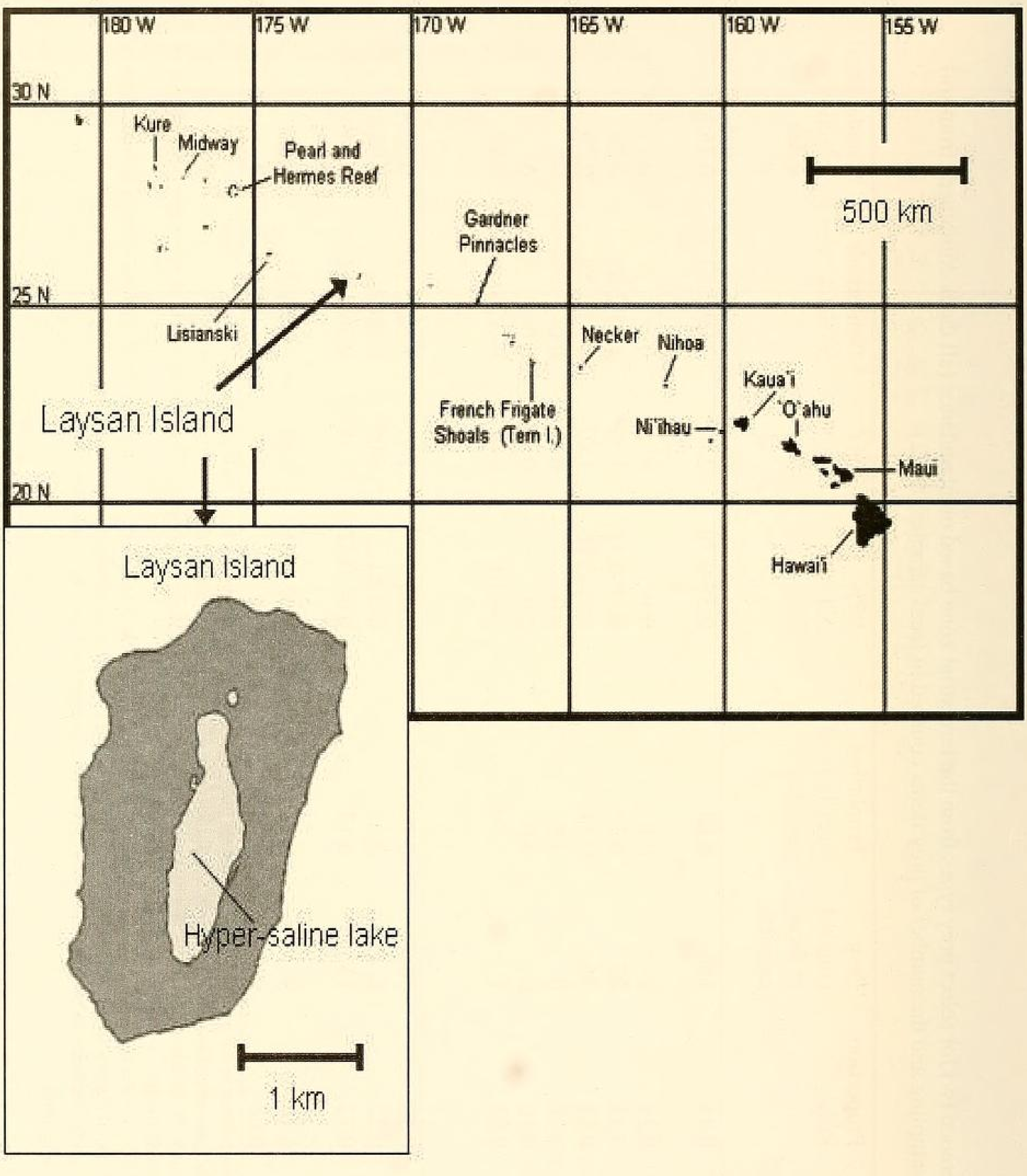

Figure 1. Map of NWHI with Laysan Island enlarged in inset.

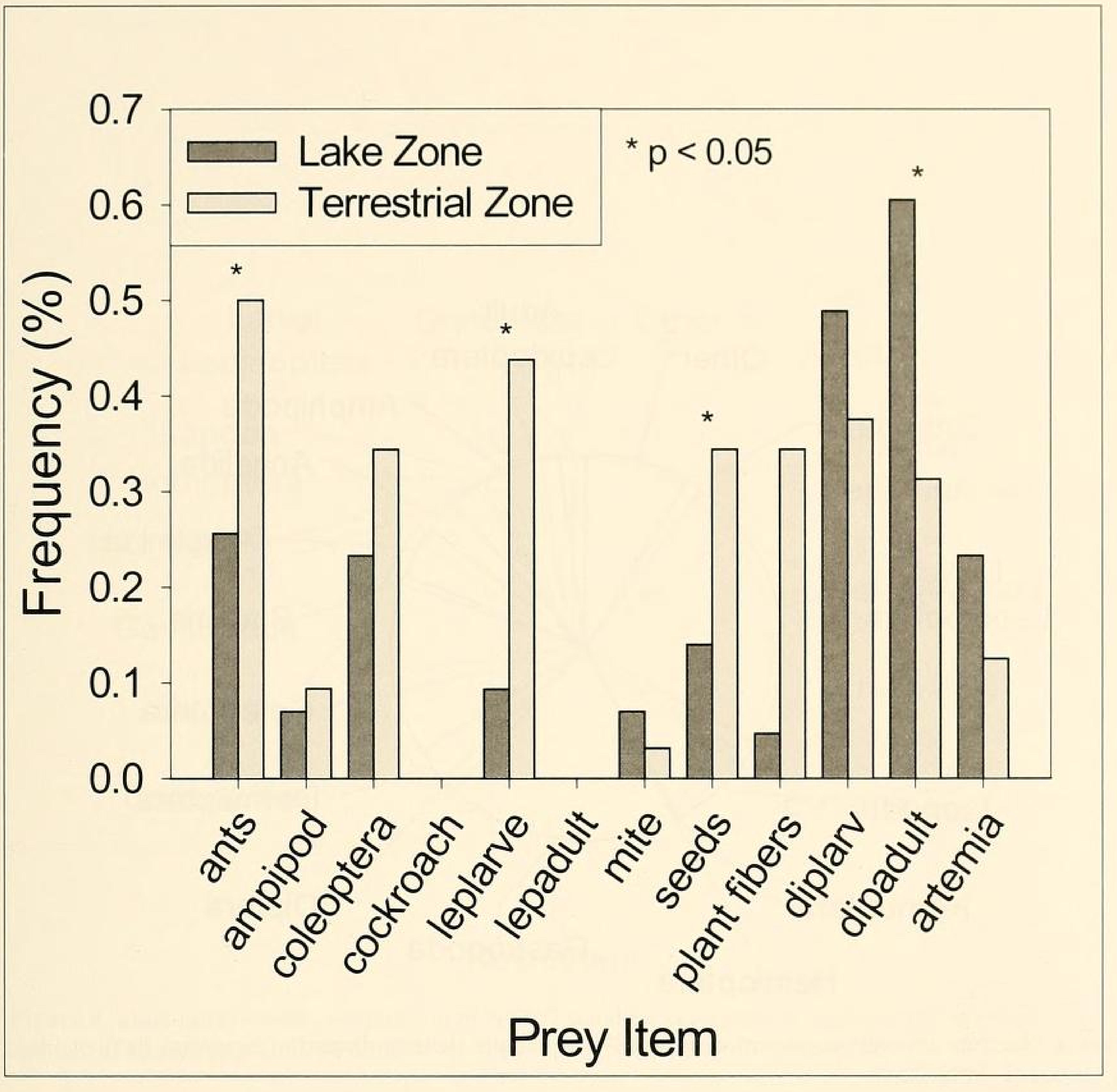

Figure 2. Frequency of prey items in fecal samples collected from lake zone (N=45) and terrestrial zone (N=30). Differences between zones revealed by Kruskal Wallis tests are indicated by *. Lep=Lepidoptera, dip=diptera. .

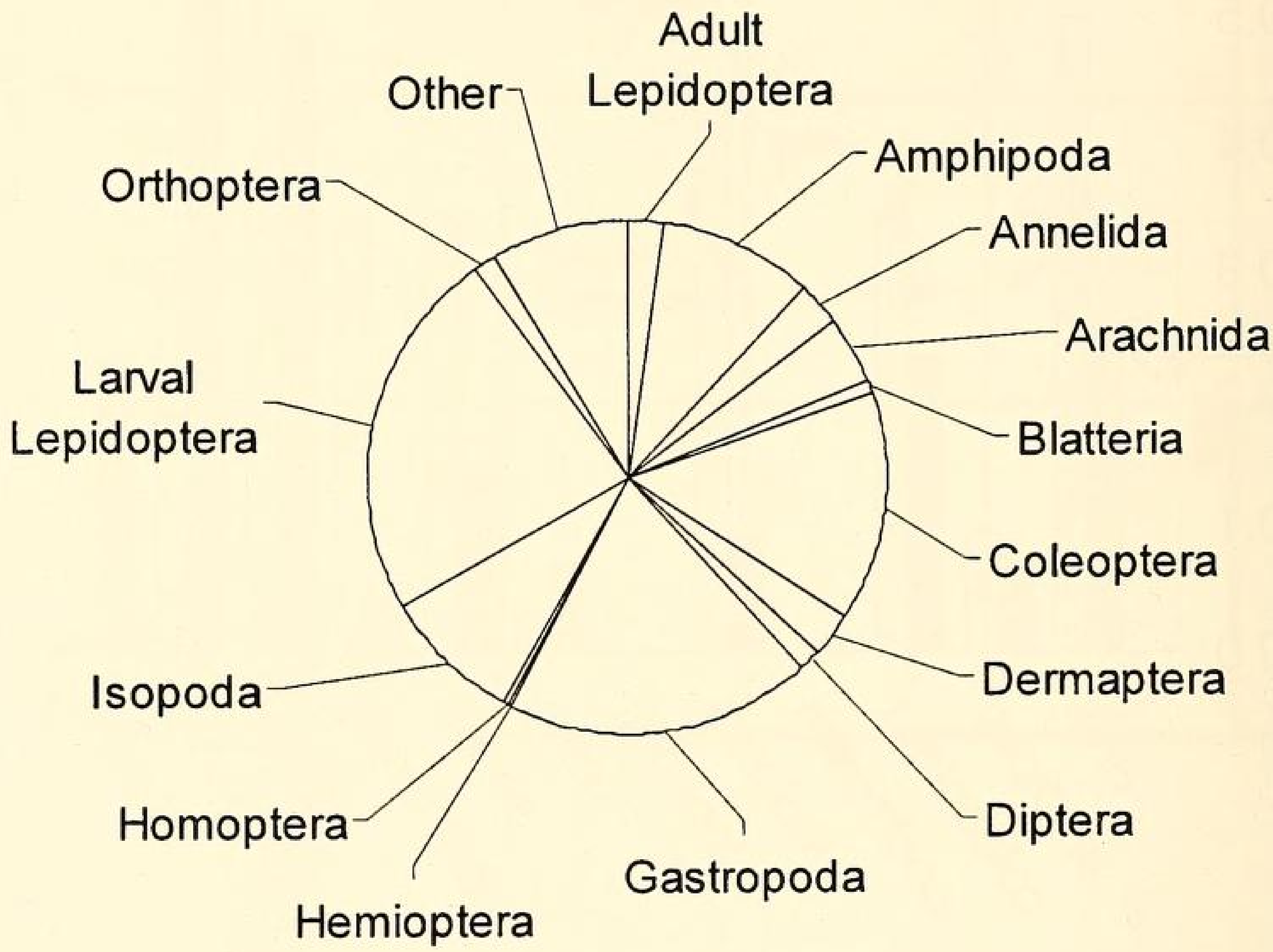

Figure 3. Macroinvertebrate composition of N=487 soil sample sieves collected in terrestrial habitats of Laysan Island, 1998-2000.

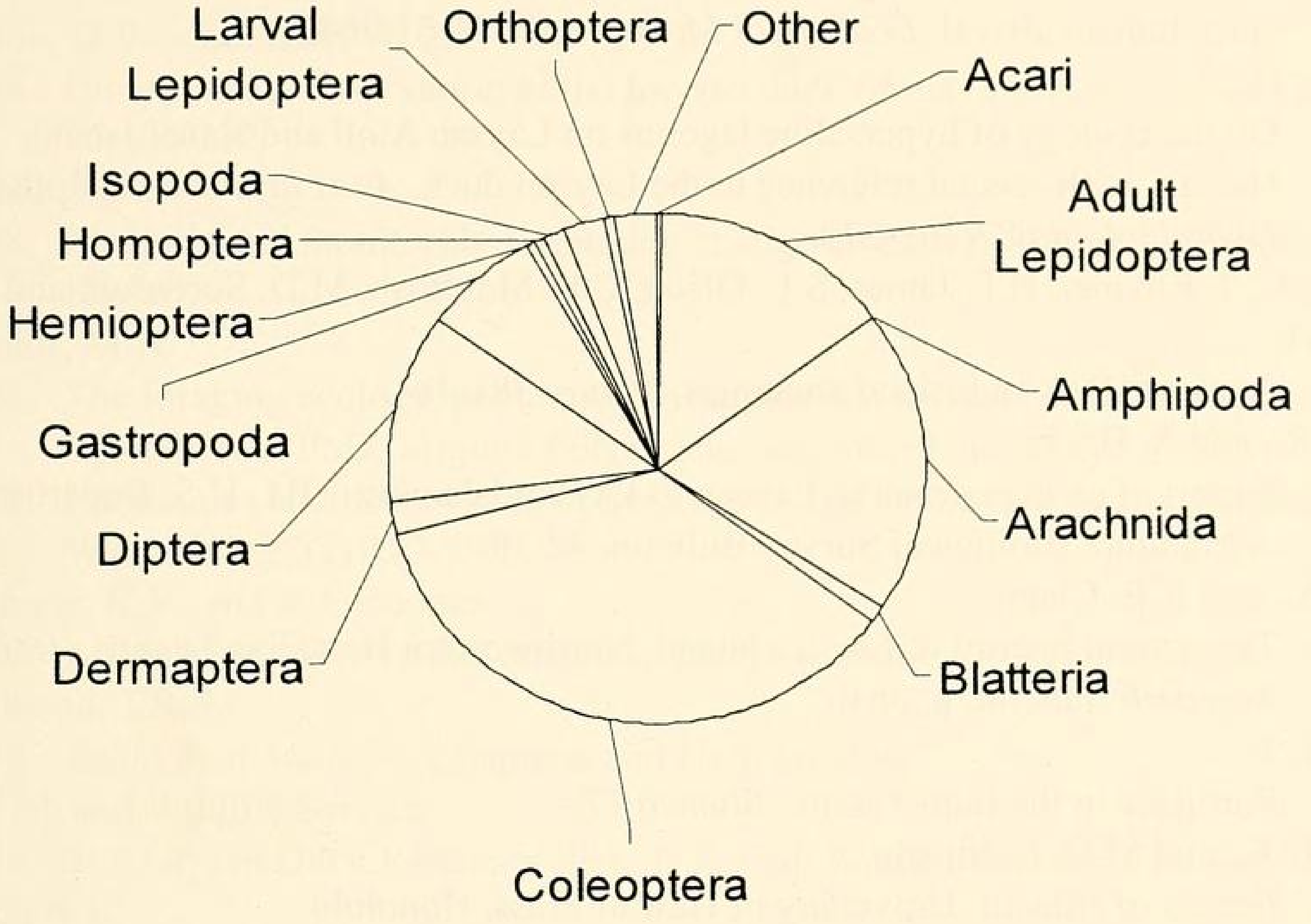

Figure 4. Macroinvertebrate composition of N=367 standing vegetation samples collected in terrestrial habitats of Laysan Island, 1998-2000.

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