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Juvenile and Subadult Feeding Preferences of the Guadalupe Fur Seal (*Arctocephalus townsendi*) at San Benito Archipelago, Mexico

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Abstract

The feeding ecology of juvenile and subadult Guadalupe fur seals (*Arctocephalus townsendi*) at San Benito Archipelago, Baja California, Mexico, was investigated to determine if dietary differences exist between these two age classes. During the summer of 2007, 108 scats of fur seals were collected from areas used mainly by juveniles (n = 54 scats) or subadults (n = 54 scats). Cephalopod beaks and/or otoliths were found in all samples collected. Only 702 squid beaks of 1,144 were identified to species level (61.3%). Only four of eight otoliths found were identified to species level (50%). Six squid species and two fish species were identified. Both juveniles and subadults showed similar dietary composition; however, differences between prey selection were found. The California market squid (*Loligo opalescens*) was the most common squid species for both age classes in the summer of 2007.

Key Words: Guadalupe fur seal, *Arctocephalus townsendi*, San Benito Archipelago, California market squid, *Loligo opalescens*, cephalopods, juveniles, subadults

Introduction

Until recently, Guadalupe fur seals (*Arctocephalus townsendi*) only bred at Isla Guadalupe. In 1997, a new breeding colony of *ca.* 300 individuals was found at Isla San Benito del Este (Maravilla-Chávez & Lowry, 1999). By 2000, the Guadalupe fur seal population had grown close to 500 individuals (Aurioles-Gamboa & Hernández, 2001). The expansion of the breeding area and the increase of the Guadalupe fur seal population may have resulted in increased competition for food resources with other pinniped species in the archipelago such as the California sea lion (*Zalophus californianus)*, the northern elephant seal (*Mirounga angustirostris*), and the Pacific harbor seal (*Phoca vitulina richardsi*). Previous studies have identified diet similarities between the California sea lion and the Guadalupe fur seal at San Benito Archipelago, showing that both species feed on the squid species *Loligo opalescens*, *Gonatus* sp., and *Dosidicus gigas*; the fish species *Merluccius angustimanus*, *Argentina sialis*, *Synodus* sp., *Lepophidium* sp., *Trachurus symmetricus*, and *Citharichthys stigmaes*; and *Octopus* sp. However, the Guadalupe fur seal prefers to feed on cephalopods, while the California sea lion prefers fish species (Aurioles-Gamboa & Camacho-Ríos, 2007).

Although it has been reported that Guadalupe fur seals feed mainly on squid and a few fish species, Guadalupe fur seal diet data are scarce for both Isla Guadalupe (Gallo-Reynoso, 1994) and San Benito Archipelago (Camacho-Ríos, 2004; Esperón-Rodríguez, 2008). This study describes the summer diet of juvenile and subadult Guadalupe fur seals at San Benito Archipelago.

Methods

Study Area

The San Benito Archipelago is located 31.5 km west of Isla de Cedros, 110 km east of Isla Guadalupe, and 130 km west from the Baja California Peninsula (Figure 1). The archipelago is over a long continental shelf that extends from Bahía Sebastián Vizcaíno on the Baja California Peninsula. The San Benito Archipelago contains three major islands with numerous islets and exposed rocks of volcanic origin: (1) Isla del Este (28° 30' N, 115° 32'50" W), (2) Isla del Centro (28° 30' N, 115° 32'50" W), and (3) Isla del Oeste (28° 30'75" N, 115° 32'50" W) (Figure 2).

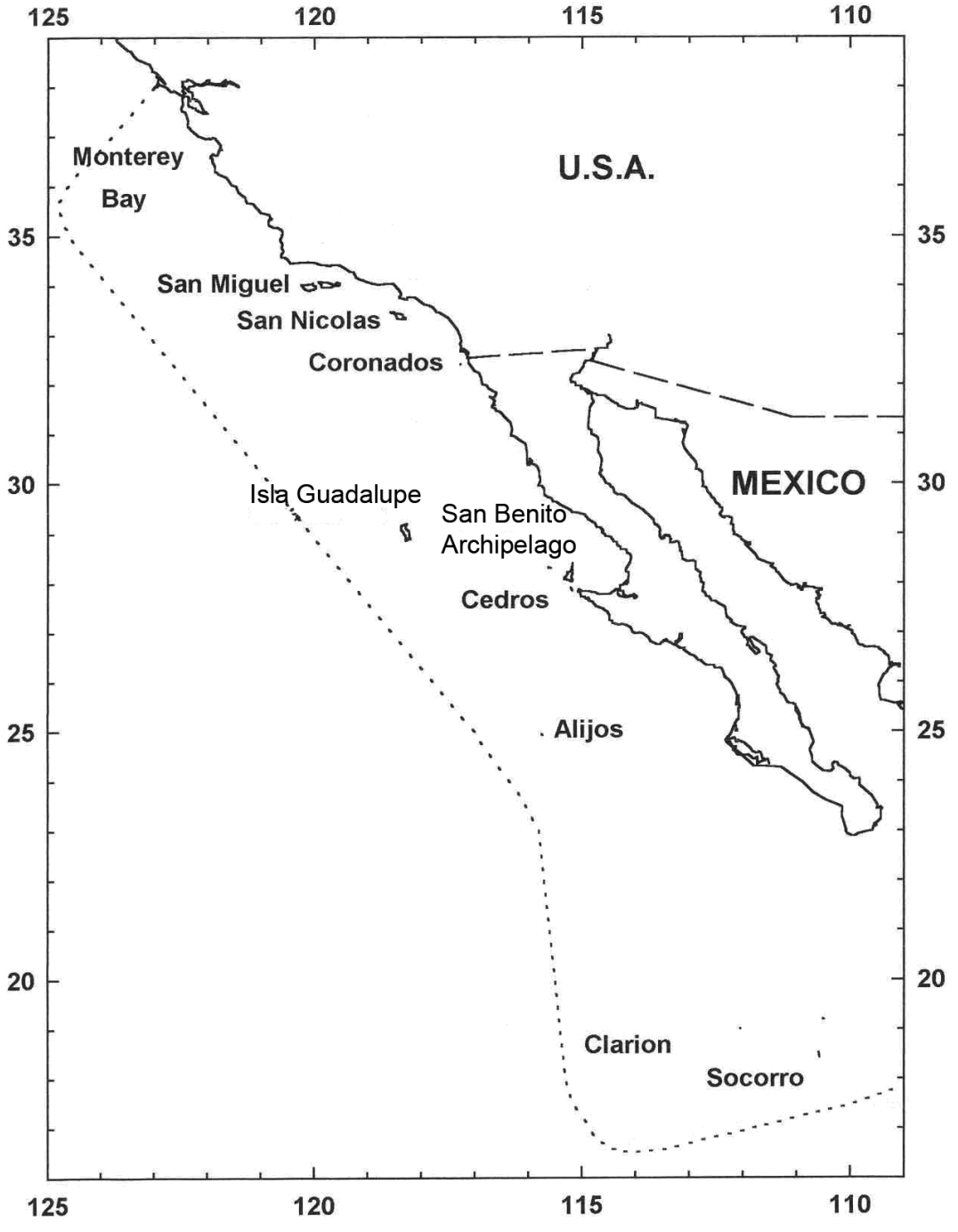

Figure 1. Geographical distribution of the Guadalupe fur seal showing two breeding sites, Isla Guadalupe and San Benito Archipelago

Scat Collection

Based on the descriptions of Gallo-Reynoso & Figueroa-Carranza (1996), two Guadalupe fur seals' age categories were separated by using fur coloration, body size, and behavior: (1) *Juveniles:* smaller than females and larger than weaners

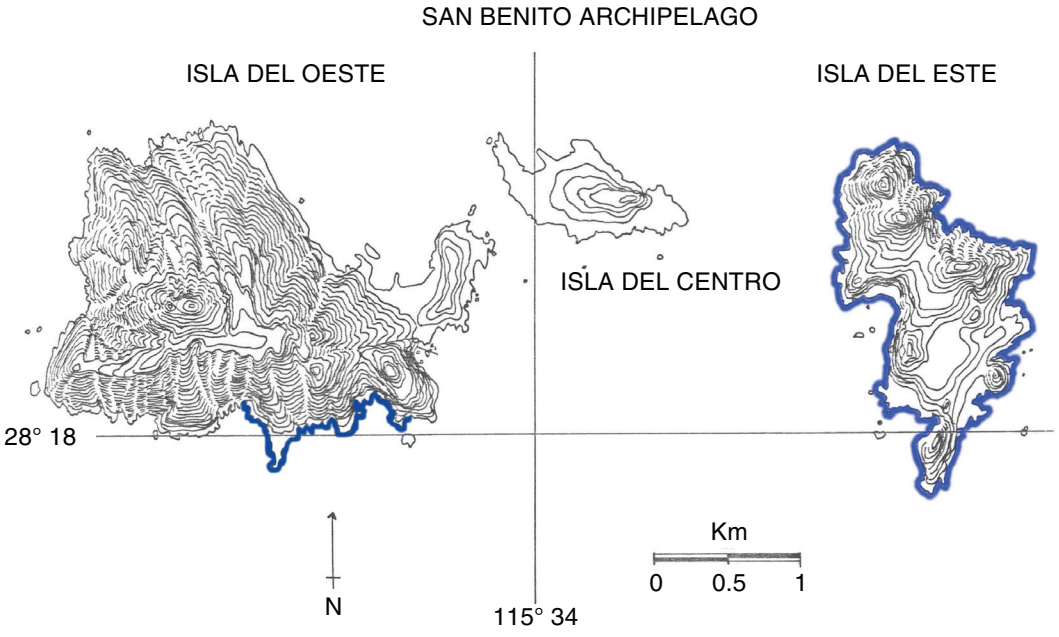

Figure 2. San Benito Archipelago and the areas occupied by the Guadalupe fur seal in 2007

(Gallo-Reynoso & Figueroa-Carranza, 2010), with no territorial behavior, segregated in playgroups or flotation groups, and dark-brown or gray coloration; and (2) *Subadult Males:* individuals smaller than adult males, with dark-brown coloration, and which exhibit territorial defense behavior. No data were collected on adult females because during the summer, they alternate periods of feeding at sea and suckling their young onshore, and their defecation occurs mainly in the ocean making it impossible to collect samples (Gallo-Reynoso, 1994; Esperón-Rodríguez & Gallo-Reynoso, 2012). Samples were only collected in areas occupied by either juveniles or subadult males; samples were not collected from areas occupied by adult females and pups or having mixed age/sex classes.

Scat samples were used to study the diet of the Guadalupe fur seal. Samples were collected on 29 June and on 2, 3, and 11 July 2007. Scat samples were collected from juveniles (n = 54) and subadult males (n = 54). Each sample was placed in a self-sealing plastic bag with a data label describing animal age/sex class, collection area, and date of collection. Each sample was soaked in a solution of mild dish soap. Hard parts (cephalopod beaks and fish otoliths) were retrieved after washing each scat sample through four sieves (mesh size of 2.0, 1.4, 1.0, and 0.45 mm) at the laboratory. Collected material was stored in glass vials containing 70% ethanol. Upper and lower beaks were used to identify the squid to species level, but only the upper beak was measured to estimate mantle size (mm) and weight (g) using squid growth curves from Wolff (1984). Fish were identified to species from otoliths. Otoliths were measured, and the size was calculated using a correction factor. Length and weight of fish were estimated from the otolith size using the equations of Aurioles-Gamboa (1991) and Harvey et al. (2000).

In order to calculate the biomass consumed, the total number of individuals was obtained using the maximum count of upper beaks for each squid species and the maximum count of left otoliths for each fish species. Then, the number of individuals was multiplied by the average estimated weight for each species. To adjust the number of otoliths and beaks, the maximum counts were multiplied by a correction factor according to Sweney & Harvey (2011) (the correction factor used for fish species was *T. symmetricus*, and for squid species, *L. opalescens*) (Table 1).

The frequency and the percent occurrence (OPi) was calculated for each species:

$$OPi = Oi\ (100) / M$$

Where: Oi = number of occurrences or scats where the species i was found
M = number of scats which were counted on occurrences

All material is stored at Laboratorio de Ecofisiología, CIAD-Guaymas.

Table 1. Maximum count of upper beaks for squid species and maximum count of left otoliths for fish species (*n*), and biomass provided by the five squid species and the two fish species consumed by the Guadalupe fur seals at San Benito Archipelago during summer 2007

Squid species		
Species	Biomass (g)	*n*
Loligo opalescens	1,725.15 ± 1,040.89	415
Dosidicus gigas	1,392.47 ± 1,247.27	145
Onychoteuthis banksii	886.06 ± 784.15	120
Pterygioteuthis giardi	49.19 ± 23.58	9
Histioteuthis dofleini	31.52 ± 40.59	6
Fish species		
Species	Biomass	*n*
Synodus lucioceps	123.36 ± 20.04	2
Porichthys notatus	47.04	1

Statistical Analysis

Data collected were analyzed with *Statgraphics Centurion XV* software package. Data were separated into two age/class categories (juveniles vs subadults) and three squid species (*L. opalescens, D. gigas*, and *Onychoteuthis banksii*). Data were analyzed using ANOVA, non-parametric Kruskal-Wallis, and chi-square tests to identify any significant differences.

Results

Squid beaks were found in all samples collected (N = 1,144), and 702 beaks were identified to species level (61.3%). Six squid species from five families were identified: (1) *L. opalescens* (opalescent inshore squid/market squid), (2) *O. banksii* (hooked squid), (3) *D. gigas* (giant squid/jumbo squid), (4) *Histioteuthis dofleini* (flowervase jewel squid), (5) *Pterygioteuthis giardi* (roundear enope squid), and (6) *Symplectoteuthis luminosa* (luminous flying squid). Fish remains were found in eight scat samples, but only *Synodus lucioceps* (California lizardfish) and *Porichthys notatus* (plainfin midshipman) were identified from the otoliths present.

For all squid species, the average mantle length was 98.78 ± 32.38 mm (for juveniles, 66.88 ± 31.06; for subadults, 78.67 ± 24.12); and the average weight of individual squid consumed by juveniles was 87.97 ± 72.81 g, while it was 89.46 ± 81.36 g for subadults. No significant differences ($p = 0.12$) in average weight and mantle length were found between squid species consumed by juveniles and subadults (Table 2).

Loligo opalescens was identified as the main prey of the Guadalupe fur seal (using OP*i*) with a frequency estimated at 84%, followed by *D. gigas* (40%) and *O. banksii* (25%). The least frequently found squid species was *H. dofleini* (4.8%). Both juveniles and subadults showed a similar diet composition, with *L. opalescens* being the most common prey species for both categories. Both fish species (*S. lucioceps* and *P. notatus*) were the least common prey for both categories (Table 3).

Significant differences were found when comparing age categories (juveniles vs subadults) and prey species (Kruskal-Wallis: $p = < 0.001$); to corroborate these results, a chi-square test was also performed according to Wright (2010) based on the absolute frequency of occurrence (AFO). The two age classes fed differentially on the three main squid species (*L. opalescens, D. gigas*, and *O. banksii*). Yet, there was no significant difference in feeding preference of *H. dofleini* (Table 4).

Statistical analyses showed that both categories prefer *L. opalescens* over all the other species;

Table 2. Estimated average mantle length, weight, and number of individuals (*n*) of the five squid species consumed by juvenile and subadult male Guadalupe fur seals at San Benito Archipelago during summer 2007

	Juvenile			Subadult		
			Squid species			
Species	Mantle length (mm)	Weight (g)	*n*	Mantle length (mm)	Weight (g)	*n*
Loligo opalescens	121.35 ± 65.54	4.19 ± 2.69	172	116.45 ± 60.15	4.13 ± 2.33	243
Dosidicus gigas	122.13 ± 72.22	6.57 ± 4.93	105	125.32 ± 88.19	8.21 ± 8.15	40
Onychoteuthis banksii	39.61 ± 15.58	9.33 ± 7.68	86	85.26 ± 52.72	9.86 ± 9.5	34
Pterygioteuthis giardi	46.29	6.48	9	42.29 ± 13.48	4.71 ± 2.68	--
Histioteuthis dofleini	22.56	5.67	5	24.04 ± 17.58	5.79 ± 7.38	1
			Fish species			
Species	Length (mm)	Weight (g)	*n*	Length (mm)	Weight (g)	*n*
Synodus lucioceps	72.93 ± 2.64	61.68 ± 10.02	2	--	--	--
Porichthys notatus	26.41	47.04	1	17.66	33.64	1

Table 3. Percentage of occurrence (OP*i*), number of individuals (*n*), and frequency of juvenile and subadult male Guadalupe fur seal scat samples having squid and fish species during summer 2007

	OP*i*		*n*		%	
			Squid species			
Species	J	SA	J	SA	J	SA
Loligo opalescens	63.20	68.60	172	243	80.56	87.76
Dosidicus gigas	32.00	10.74	105	40	50.00	30.61
Onychoteuthis banksii	27.20	30.99	86	34	30.56	20.41
Histioteuthis dofleini	2.40	--	9	--	5.56	8.16
Pterygioteuthis giardi	1.60	2.07	5	1	5.56	6.12
Symplectoteuthis luminosa	1.60	2.07	--	3	5.56	6.12
			Fish species			
Species	J	SA	J	SA	J	SA
Synodus lucioceps	1.03	1.03	1	1	2.77	2.04
Porychthys notatus	--	1.49	--	2	--	4.08

Table 4. Absolute frequency of occurrence (AFO) contingency table of prey consumed by age category (juveniles and subadults) of the Guadalupe fur seal

Prey species	Detected	Juvenile	Subadult	X^2	*p*
Loligo opalescens	Yes	28	38	3.89	0.048
	No	26	16		
Dosidicus gigas	Yes	12	4	4.69	0.030
	No	42	50		
Onychoteuthis banksii	Yes	15	6	4.78	0.028
	No	39	48		
Histioteuthis dofleini	Yes	2	1	0.34	0.558
	No	52	53		
Pterygioteuthis giardi	Yes	4	0	4.15	0.041
	No	50	54		

however, juveniles prefer *D. gigas* over *O. banksii*, while subadults prefer *O. banksii* over *D. gigas*. It was also found that juveniles are more likely to feed on the other squid species (*H. dofleini* and *P. giardi*) than subadults.

These results show that there is a tendency toward a differential feeding strategy between these two age classes, and evidence of a preference for certain squid species by animals in each category.

Discussion

At San Benito Archipelago, Camacho-Ríos (2004) reported that the diet of Guadalupe fur seals was composed of 95.6% cephalopods and 4.4% fish, with *L. opalescens* being the most important prey consumed during winter of 2001 and spring of 2002. In this study, *L. opalescens* was the most prevalent prey in the diet of Guadalupe fur seals (51.1% of all the items found in the diet). Similar to the Camacho-Ríos (2004) study, the present study found that the summer diet of the Guadalupe fur seal at San Benito Archipelago was comprised mainly of squid (92.6%). Fish represented only 7.4% of the fur seals' diet during that summer.

Bowen & Siniff (1999) reported that the major source of energy in the diet of several marine mammals comes from two to five species. This was also observed in this study for Guadalupe fur seals, where *L. opalescens, O. banksii*, and *D. gigas* together constituted 89.4% of the total prey consumed.

The Guadalupe fur seal presents a pelagic feeding strategy (Gallo-Reynoso, 1994; Gallo-Reynoso et al., 2008) specializing in cephalopods, particularly squid (Gallo-Reynoso, 1994; Hanni et al., 1997; Camacho-Ríos, 2004; Esperón-Rodríguez, 2008). At Isla Guadalupe, Gallo-Reynoso (1994) and Gallo-Reynoso et al. (2008) found *O. banksii* as the most common prey, with *D. gigas* and *S. luminosa* also being present; *L. opalescens* was absent in the diet of fur seals in that study. This is because *L. opalescens* are found over a continental shelf and

slope, further away from the feeding area of the population (Gallo-Reynoso, 1994). At San Benito Archipelago, Guadalupe fur seals foraged mainly on *L. opalescens* (Aurioles-Gamboa & Camacho-Ríos, 2007; Esperón-Rodríguez, 2008). The diet of Guadalupe fur seals at Isla Guadalupe showed greater diversity in prey selection, with an increased presence of pelagic fish in their diet (Gallo-Reynoso, 1994). In contrast, at San Benito, the largest biomass contribution in the diet was provided by *L. opalescens*, reflecting the preference for squid in the diet, but also indicating that Guadalupe fur seals have some plasticity in their foraging preferences. If the squid population declines, Guadalupe fur seals might increase their fish consumption in response. It is also possible that they might compensate for the reduction of a given squid species by increasing the consumption of other species.

The prey found in the Guadalupe fur seal's diet suggest that they forage pelagically when their prey migrate to the surface at night. *L. opalescens* is distributed at sea to more than 100 m deep on the continental shelf; *O. banksii* lives in pelagic waters, offshore and near the surface; *H. dofleini* is a relatively abundant species in pelagic and demersal waters; and *D. gigas* lives in superficial and mesopelagic waters (Okutani, 1980). No information about the average diving depth of a Guadalupe fur seal male is available; however, for females, the average diving depth was found to be 16.9 ± 10.3 m, with an interval depth range between 3 and 82 m (Gallo-Reynoso, 1994; Lander et al., 2000; Gallo-Reynoso et al., 2008). The shallow dive depth of Guadalupe fur seals reflects their nocturnal feeding strategy. The fur seals forage when the scattering layer rises and squid migrate vertically to the subsurface zone. It also explains the low diversity of consumed prey, or the greater abundance of *L. opalescens* found in their scats.

Reproduction of *L. opalescens* occurs from April to November, peaking in May and June. This species undergoes vertical migrations at night (Forsythe et al., 2004), forming large aggregations during the mating season (Fields, 1965). The formation of these large aggregations over the continental shelf of Bahía Sebastián Vizcaíno during summer could explain why this species is the main prey for Guadalupe fur seals at San Benito Archipelago. This abundant prey source may also explain the large number of Guadalupe fur seals present during the summer months at San Benito Archipelago.

The current study indicates that there are differences in prey selection between the two age classes of Guadalupe fur seals, as evidenced by the preference for certain species of squid in each category. However, *L. opalescens* was the most common prey for both age classes. Juveniles preferred to feed upon *L. opalescens* than either *D. gigas* or *O. banksii*, while subadult males preferred to prey on *L. opalescens*, followed by *O. banksii*, and finally *D. gigas*. Juveniles and subadults show a tendency to feed differentially in relation to the squid species. The results also show that although both categories mainly feed on three squid species, juveniles present a greater plasticity to feed on the other species found in their diet. This might indicate that when individuals age, they become more specialized, showing a preference for certain prey species.

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Literature Cited

Aurioles-Gamboa, D. (1991). Otolith size versus weight and body length relationships for some fishes off the Pacific coast of Baja California Sur, Mexico. *Fishery Bulletin*, *89*, 701-706.

Aurioles-Gamboa, D., & Camacho-Ríos, F. J. (2007). Diet and feeding overlap of two otarids, *Zalophus californianus* and *Arctocephalus townsendi*: Implications to survive environmental uncertainty. *Aquatic Mammals*, *33*(3), 315-326. http://dx.doi.org/10.1578/AM.33.3.2007.315

Aurioles-Gamboa, D., & Hernández, C. (2001). *Tamaño y estructura invierno-verano de las poblaciones de pinnípedos de las Islas San Benitos, B.C. México, 1999-2001* [Size and structure of the pinnipeds population at San Benito Island, B.C., Mexico, 1999-2001]. XXVI Reunión Internacional para el Estudio de los Mamíferos Marinos, Ensenada, BC, México.

Bowen, W. D., & Siniff, D. B. (1999). Distribution, population biology, and feeding ecology of marine mammals. In J. E. Reynolds III & S. A. Rommel (Eds.), *Biology of marine mammals* (pp. 423-484). Washington, DC: Smithsonian Institution Press.

Camacho-Ríos, F. J. (2004). *Estructura alimentaria y posición trófica de dos especies de otáridos Zalophus californianus* y *Arctocephalus townsendi, en las islas San Benito, B.C. México* [Feeding structure and trophic position of two otariids species *Zalophus californianus* and *Arctocephalus townsendi* at San Benito island, B.C. Mexico] (Tesis de Maestría). Instituto Politécnico

Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, BCS, México. 94 pp.

Esperón-Rodríguez, M. (2008). *Estado actual del lobo fino de Guadalupe (*Arctocephalus townsendi *Merriam, 1897) en el Archipiélago de San Benito, Baja California: Tamaño de la población, biología reproductiva y alimentación* [Current status of the Guadalupe fur seal *(Arctocephalus townsendi* Merriam, 1897) at San Benito Archipelago, Baja California: Population size, reproductive biology and feeding] (Tesis de Maestría). Instituto de Ciencias del Mar y Limnología, UNAM. 56 pp.

Esperón-Rodríguez, M., & Gallo-Reynoso, J. P. (2012). Analysis of the re-colonization of San Benito Archipelago, Baja California, Mexico, by the Guadalupe fur seal (*Arctocephalus townsendi*). *Latin American Journal of Aquatic Research*, *40*(1), 213-223. http://dx.doi.org/10.3856/vol40-issue1-fulltext-20

Fields, W. G. (1965). *The structure, development, food relations, reproduction, and life history of the squid,* Loligo opalescens *Berry* (Fish Bulletin 131). Sacramento: State of California, The Resources Agency, Department of Fish and Game. 108 pp.

Forsythe, J., Kangas, N., & Hanlon, R. T. (2004). Does the California market squid (*Loligo opalescens*) spawn naturally during the day or at night? A note on the successful use of ROVs to obtain basic fisheries biology data. *Fishery Bulletin*, *102*, 389-392.

Gallo-Reynoso, J. P. (1994). *Factors affecting the population status of Guadalupe fur seal,* Arctocephalus townsendi *(Merriam, 1897) at Isla Guadalupe, Baja California, Mexico* (Ph.D. dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Biology). University of California, Santa Cruz. 199 pp.

Gallo-Reynoso, J. P., & Figueroa-Carranza, A. L. (1996). Size and weight of Guadalupe fur seals. *Marine Mammal Science*, *12*(2), 318-321. http://dx.doi.org/10.1111/j.1748-7692.1996.tb00584.x

Gallo-Reynoso, J. P., & Figueroa-Carranza, A. L. (2010). Pup growth of the Guadalupe fur seal, *Arctocephalus townsendi*. *Therya*, *1*(1), 75-90.

Gallo-Reynoso, J. P., Figueroa-Carranza, A. L., & Le Boeuf, B. J. (2008). Foraging behavior of lactating Guadalupe fur seal females. In C. Lorenzo, E. Espinoza, & J. Ortega (Eds.), *Avances en el estudio de los mamíferos de México* [Advances in the study of Mexican mammals] (pp. 595-614). La Paz, BCS, México: Publicaciones Especiales, Vol. II, Asociación Mexicana de Mastozoología, A. C.

Hanni, K., Long, D., Jones, R., Pyle, P., & Morgan, L. (1997). Sighting and strandings of Guadalupe fur seals in central and northern California, 1988-1995. *Journal of Mammalogy*, *78*(2), 684-690. http://dx.doi.org/10.2307/1382920

Harvey, T. J., Loughlin, R. T., Perez, A. M., & Oxman, S. D. (2000). *Relationship between fish size and otolith length for 63 species of fishes from the Eastern North Pacific Ocean* (NOAA Technical Report NMFS). Washington, DC: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 150 pp.

Lander, M. E., Gulland, F. M. D., & DeLong, R. L. (2000). Satellite tracking of a rehabilitated Guadalupe fur seal. *Aquatic Mammals, 26*(2), 137-142.

Maravilla-Chávez, M. O., & Lowry, M. S. (1999). Incipient breeding colony of Guadalupe fur seals at Isla Benito del Este, Baja California, Mexico. *Marine Mammal Science*, *15*, 239-241. http://dx.doi.org/10.1111/j.1748-7692.1999.tb00796.x

Okutani, T. (1980). *Calamares de las aguas mexicanas: Breve descripción de los calamares existentes en aguas mexicanas* [The squids of Mexican waters: Brief description of the existing squid in Mexico]. Pesca, México DF: Departamento de Pesca. 64 pp.

Sweney, J. M., & Harvey, J. T. (2011). Diet estimation in California sea lions, *Zalophus californianus*. *Marine Mammal Science*, *27*(4), E279-E301. http://dx.doi.org/10.1111/j.1748-7692.2010.00459.x

Wolff, G. (1984). *Identification and estimation of size from the beaks of 18 species of cephalopods from the Pacific Ocean* (NOAA Technical Report NMFS, pp. 17-50). Washington, DC: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, U.S. Department of Commerce.

Wright, B. E. (2010). Use of chi-square tests to analyze scat-derived diet composition data. *Marine Mammal Science*, *26*, 395-401. http://dx.doi.org/10.1111/j.1748-7692.2009.00308.x