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Spatial and seasonal variation in a target fishery for spotted eagle ray *Aetobatus narinari* in the southern Gulf of Mexico

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Abstract The target fishery for the spotted eagle ray *Aetobatus narinari* in the southern Gulf of Mexico is little known. The landings of four small-scale vessels at two fishing localities were sampled and fishermen were interviewed in 2009. Rays landed at Campeche [mean ± standard deviation (SD) 1204 ± 225.3 mm disc width (DW)], fished at 30–50 km from the shore, were larger than rays landed at Seybaplaya (924 ± 206.5 mm DW), fished at 8–15 km from the shore. Ray catches were male biased off Campeche and female biased off Seybaplaya. Catch rate off Campeche was 6.6 (±4.9) rays per vessel trip and off Seybaplaya was 3.0 (±2.9) rays per vessel trip. Fishermen stated that catches of *A. narinari* are positively influenced by winter cold fronts, turbidity, low sea temperature, and new moon phase, and negatively influenced by the presence of cownose rays *Rhinoptera bonasus*. Spatial variation in size composition, and sex and maturity ratios of *A. narinari* were evident between sites. Catch rates of *A. narinari* varied with individual fisherman and seasonally between months with winter cold fronts versus warmer months. Fishermen reported a general decline in catches of *A. narinari* over recent decades in this region.

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Introduction

The spotted eagle ray *Aetobatus narinari* is a large-sized ray (230 cm disc width, DW) distributed in tropical and warm-temperate coastal areas of all oceans [1]. Recent molecular studies have revealed that genetic exchange among ocean basins is highly restricted and that *A. narinari* should be considered to be a species complex rather than a cosmopolitan species [2]. In the Indo-West Pacific, for example, *Aetobatus ocellatus* has been reported to replace *A. narinari*. A major revision of the *A. narinari* complex is needed to delineate species and determine population structure [3].

In the western Atlantic, *A. narinari* is distributed from North Carolina, USA to southern Brazil, including the Gulf of Mexico [1]. It is usually found in coastal waters, either alone or in large schools, where it can be caught with diverse fishing gears [1]. In Mexican coastal towns along the southern Gulf of Mexico (mainly in the Bay of Campeche), *A. narinari* is traditionally used for human consumption [4].

Low reproductive rates (1–4 pups annually) combined with intense and unregulated inshore exploitation have led to the *A. narinari* species complex being listed as “near threatened” globally and “vulnerable” in Southeast Asia [5]. In the USA, this species is fully protected in the State of Florida by state law as a risk-averse conservation action [5].

Mexican fisheries for elasmobranchs have been managed since 2007 by the Mexican Official Standard NOM-029-PESC-2006, Responsible Fisheries of Sharks and

Rays, Specifications for their Use [6]. However, these fisheries are poorly documented, and catch information for the nation's extensive artisanal fisheries is particularly limited [7, 8]. Available information from the Gulf of Mexico indicates that landings of batoids (rays) have been declining since the late 1990s [9], which suggests that more information and management are needed. A target fishery for *A. narinari* currently exists only in Campeche and Yucatán States in Mexican waters of the gulf, where it is one of the few target fisheries for elasmobranchs on the Mexican Atlantic (Gulf of Mexico and Caribbean Sea) coast.

Along the coast of Campeche State, *A. narinari* is targeted by an artisanal fleet of 22 small boats and is the second most landed batoid species after the southern stingray *Dasyatis americana* (Pérez-Jiménez et al. unpubl. data; Mexican Official Fishery Statistics, SAGARPA). Between 1998 and 2008, this fleet landed an average ± SD of 40.6 ± 21.5 tons of *A. narinari* per year (Mexican Official Fishery Statistics, SAGARPA). More detailed information on this fishery, including allocation of fishing effort, catch rates, and composition of landings, is not available.

The objectives of this study were to: (1) describe the past and present target fishery for *A. narinari* off the coast of the State of Campeche in the southern Gulf of Mexico; and (2) determine the size, sex, and maturity composition of *A. narinari* as they relate to individual fisherman, season, and capture location.

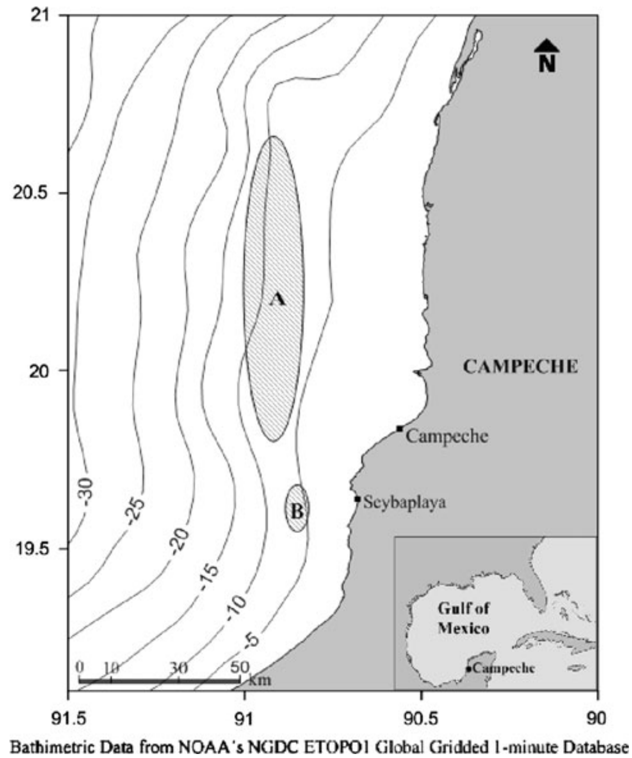

Fig. 1 Fishing areas for the spotted eagle ray *Aetobatus narinari* off the locality of Campeche (**a**) and off the locality of Seybaplaya (**b**) in the Bay of Campeche, southern Gulf of Mexico

Materials and methods

Description of the fishery and fishermen perceptions

A total of 10 fishermen, each with 10–60 years of experience fishing for *A. narinari* in the State of Campeche, were interviewed following the methods described by Arce-Ibarra and Charles [10]. Fishermen were asked about their perceptions of catches through decades, gear characteristics, seasonality of catches, commercialization (prices, market, and local consumption), and the effects of environmental factors on catch rates of *A. narinari*. Another 12 fishermen who targeted *A. narinari* were contacted but rejected the interview.

Catch composition

Rays were provided by four fishermen during the 2009 fishing season: one fisherman from the locality of Campeche fished a wide area in front of and northwest of its locality, 30–50 km from shore at 8–12 m depths (Fig. 1), and three fishermen from the locality of Seybaplaya fished a narrow area off their locality, 8–15 km from shore at 6–8 m depths (Fig. 1). The fishery for *A. narinari* typically extends from January to July. Between August and December, fishing effort is switched to target the Mexican four-eyed octopus, *Octopus maya*. In 2009, however, fisherman from the locality of Campeche targeted *A. narinari* only from January to April because of low catches.

To catch the rays, fishermen used small fiberglass outboard-motored boats 7–7.6 m in length. The fisherman from Campeche made trips of 1–3 days, set fishing gear for 12 h during the night (around 1800–0600 hours), and used 30.5 cm stretched mesh, drift nets made from silk. The three fishermen from Seybaplaya made 1-day trips, set for 19 h (around 1100–0600 hours), and used 36.5 cm stretched mesh, silk bottom-fixed nets.

Details on the size, sex, and maturity status were obtained from landed specimens. Disc width (DW) of rays was measured between the tips of the widest portion of the pectoral fins [1]. Females and males were classified as juvenile or adult following opportunistic macroscopic assessment of reproductive organs. Calcification of claspers was used to determine maturity for males following Clark and von Schmidt [11]. Claspers of adult males (size at maturity 1070–1280 mm DW) exceeded the posterior edge of the pelvic fins, presented hardened internal structure, and could be flexed and rotated toward the anterior part without bending.

First ovulation was the criterion used to determine maturity for females. The diameter of oocytes of the largest cohort and the left uterus width were measured. In the uterus, the length and vascularization of trophonemata were recorded and the uterus was examined to determine the presence of embryos or uterine eggs or uterine milk (histotrophe) that would be indicative of recent parturition or abortion.

Females were classified as adult when pregnant, or when nonpregnant if: (a) they were not dissected but had length equal to or larger than the smallest adult female that was dissected and analyzed (1550 mm DW, oocytes 11 mm and uterus 106 mm width), or (b) they were dissected and had a wide uterus (55–126 mm width), well-developed and vascularized trophonemata (>5 mm in length), and occasionally large amounts of uterine milk (post partum condition).

Size- and sex-specific variation in catch composition was evaluated between fishing locations and month of capture. Analysis of variance (ANOVA) was used to test for size differences of rays caught by fishermen. A factorial ANOVA procedure was used to test for size differences per month and sex of rays landed at the locality of Campeche from January to April, and at the locality of Seybaplaya from February to July. To test for size differences between sexes in the overall sample, a *t* test was used. The data met statistical assumptions of normality and homogeneity of variances [12]. Chi-square procedures were used to test for sex frequency difference per vessel trip, and contingency tables were used to test for independence between sex and months [12].

Catch rates (fishing season 2009)

Catch rate was characterized as the number of rays caught per vessel trip. To test for differences in the number of rays in vessel trips off Seybaplaya, an ANOVA procedure was used. Factors in the model included individual fisherman, winter cold fronts, and lunar phases. Data were square-root transformed for analysis, and the transformed data met the statistical assumptions for the ANOVA procedure [12]. According to fishermen's perceptions, other environmental variables such as sea surface temperature, turbidity, and local abundance of cownose rays *Rhinoptera bonasus* can affect catch rates of *A. narinari*. These variables were not included in the factorial model, however, because data were not available.

Lunar cycle was determined by using tidal prediction tables provided by the Mexican Navy for the Campeche Station. The winter cold front season in this area is characterized by strong winds blowing north to south over the Gulf of Mexico [13]. In 2008–2009, this season extended from October 2008 to March 2009 according to the National Meteorological Service of Mexico. Based on this information, the fishing season of *A. narinari* was divided into two periods: (a) a winter cold front season from January to March (with sea surface temperatures of 23.9–24.8°C), and (b) a warmer season from April to July (with sea surface temperatures of 24.6–28.7°C); sea surface temperatures were obtained from the Environmental Research Division, Southwest Fisheries Science Center, NOAA.

Results

Description of the fishery and fishermen perceptions

The fishery for *A. narinari* in the State of Campeche began at least 100 years ago. A 70-year-old, third-generation fisherman recalled during his interview that approximately 40 years ago *A. narinari* was targeted from small wooden sailing boats using harpoons in this region.

Fishermen noted a decline in catches of rays over time despite an increase in fishing power, such as use of outboard-motored boats and large nets. More than 10 years ago, catches were reported to range from 20 to 90 rays per vessel trip, while currently, fishermen consider 8–20 rays per vessel trip to be a good catch (Table 1). From January to July 2009, the highest catches recorded off Campeche and off Seybaplaya were 17 and 22 rays per vessel trip, respectively.

According to fishermen, catches of *A. narinari* have declined because of: (1) a general increase in fishing effort for all species, (2) overexploitation of this species, (3) overexploitation of some of its supposed main food (mollusks including the west Indian chank *Turbinella angulata*, perverse whelk *Busycon perversum*, fighting conch *Strombus pugilis*, and milk conch *Strombus costatus*), and (4) increases in the population of *R. bonasus*, resulting in competition for food and space.

Aetobatus narinari meat is sold fresh in local markets and also is salted and dried for local consumption. Bycatch elasmobranchs in this fishery were (in order of importance): *R. bonasus*, *D. americana*, Caribbean whiptail stingray *Himantura schmardae*, bull shark *Carcharhinus leucas*, nurse shark *Ginglymostoma cirratum*, Atlantic sharpnose shark *Rhizoprionodon terraenovae*, and bonnethead *Sphyrna tiburo*.

Catch composition

A total of 896 *A. narinari* were recorded from fishery landings during 2009. Measurements and other biological details were obtained from a subset (85%) of the total landings. Of the 761 specimens directly examined, 157

Table 1 Fishermen's perceptions of good and low catches (in number of rays per vessel trip) in the past versus the present, and years in the fishery, for *A. narinari*

Fisherman	Years in the fishery	Good catch		Low catch	
		In the past (>10 years)	In the present	In the past (>10 years)	In the present
1	60	30–40	10	4–5	0
2	55	70–80	15	15–20	0–3
3	48	40–50	10	Unusual	0
4	40	30–40	8	Unusual	0–2
5	40	60	15	10–15	0
6	30	80–90	20	2	0
7	32	40	8	8	0–2
8	27	30	13	Unusual	2
9	25	40–50	8–10	10	0
10	20	20–25	8	12	0–2

Table 2 Comparison of fishing methods and catch composition of *A. narinari* between one fisherman from Campeche and three fishermen from Seybaplaya. The mean and standard deviation is used to describe the size of rays, and the range is used to describe distances from shore and depths

	Fisherman from Campeche	Fishermen from Seybaplaya
Fishing area		
Distance from shore	30–50 km	8–15 km
Depth	8–12 m	6–8 m
Fishing gear		
Net type	Drift	Bottom fixed
Mesh size	30.5 cm	36.5 cm
Catch composition		
Overall size (mm)	1204 ± 225	924 ± 206
Size (females)	1339 ± 290	903 ± 254
Size (males)	1146 ± 163	997 ± 184
Comparison by sex	Females > males	Females < males
Sex ratio	Male biased (1:0.5)	Female biased (1:0.6)
Maturity stages (males)	Mainly adults (68%)	Mainly juveniles (85%)
Maturity stages (females)	Mainly juveniles (69%)	Mainly juveniles (98%)

were sampled from Campeche (52 females and 105 males) and 604 from Seybaplaya (383 females and 221 males).

The size composition of *A. narinari* differed between fishing locations (Table 2). The size range of females landed at Campeche was 580–1860 mm DW and for males 745–1500 mm DW (Fig. 2a). Females in fishery landings from Seybaplaya ranged between 540 and 2020 mm DW and males were 440–1300 mm DW (Fig. 2b). The rays landed by the fisherman from Campeche were significantly larger than those landed by the fishermen from Seybaplaya (ANOVA, $P < 0.0001$; Tukey test, $P < 0.001$ for all comparisons). The size of the rays landed at Seybaplaya did not differ significantly among fishermen (Tukey tests, $P = 0.69$–0.98).

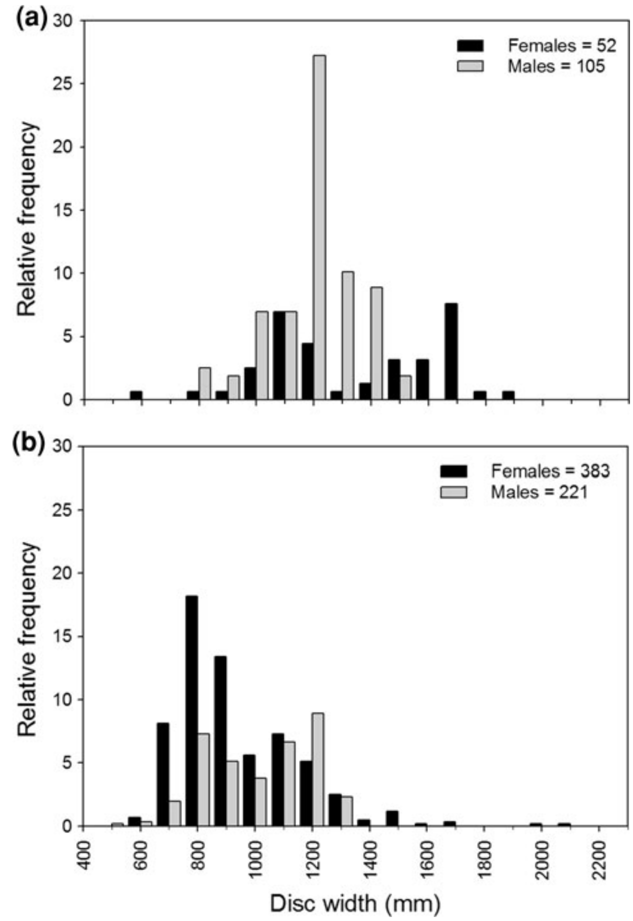

Fig. 2 Size composition of the spotted eagle ray *Aetobatus narinari*: **a** off Campeche ($n = 157$) and **b** off Seybaplaya ($n = 604$)

The size and sex composition of *A. narinari* differed significantly among months. In Campeche, rays caught in April were larger than rays caught in January and February (ANOVA, $P < 0.01$; Tukey tests, $P = 0.006$–0.014; Fig. 3),

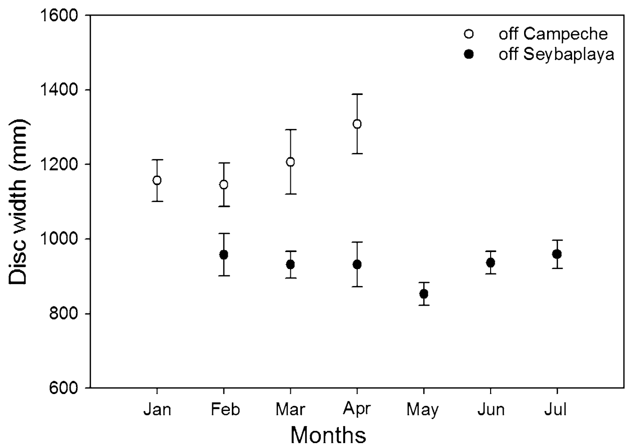

Fig. 3 Monthly mean disc width of spotted eagle rays *Aetobatus narinari* caught off Campeche and off Seybaplaya (mean ± 95% confidence interval)

whereas there were no differences for the rest of the comparisons (Tukey tests, $P = 0.16$–0.99). At Seybaplaya, rays landed in May were smaller than those landed in all other months, with the exception of April (ANOVA, $P < 0.01$; Tukey tests, $P = 0.001$–0.035; Fig. 3), whereas there were no differences for the rest of the comparisons (Tukey tests, $P = 0.21$–0.99). No significant difference was detected in the interaction between month and sex at either fishing location (ANOVA tests, $P = 0.10$–0.39).

The mean size of females and males differed significantly between fishing location. In Campeche, females were larger than males (ANOVA test, $P < 0.01$). However, among rays landed at Seybaplaya, females were significantly smaller than males (ANOVA test, $P < 0.0001$) (Table 2). Overall, females were significantly larger (*t* test, $P < 0.0001$) than males.

The sex composition of *A. narinari* landings differed between fishing locations. Catches from Campeche were dominated by males (105 males and 52 females), with a ratio of 0.5:1 females to males (chi-square test, $P < 0.001$). The observed sex frequency was independent of the month of capture (independence test, $P = 0.053$). Landings from Seybaplaya, however, were female biased (383 females and 221 males) with a ratio of 1.0:0.6 females to males (chi-square test, $P < 0.0001$). Sex frequency within the landings was found to be dependent on the month of capture (independence test, $P < 0.01$). Females were more frequently landed in March, with 27% recorded in this month, 20% in May, and 18% in June, and less frequently captured in February (10%) and July (11%). Males were more frequently landed in March (28%) and July (19%), and less frequently in April (7%).

Assessments of maturity status indicated that the landings at both locations were dominated by juveniles. At Campeche, most males were adult and the majority of females were determined to be juveniles (females: 16 adults, 36 juveniles; males: 71 adults, 34 juveniles; Table 2). Rays of both sexes were predominately juveniles in the landings at Seybaplaya (females: 378 juveniles, 5 adults; males: 188 juveniles, 32 adults; Table 2).

Catch rates

A total of 195 rays were caught off Campeche in 30 vessel trips (mean ± SD, 6.6 ± 4.9 rays per vessel trip) (Fig. 4a). With regard to average monthly catch rates, the highest average catch rate was recorded in January (7.8 ± 2.9 rays per vessel trip). Average monthly catch rates for February, March, and April were 5.8 ± 2.0, 6.6 ± 7.2, and 6.2 ± 7.5 rays per vessel trip, respectively. Eight vessel trips were made per month, with the exception of April, in which only six trips were made.

In the fishing area off Seybaplaya, a total of 701 rays were recorded in 250 vessel trips (3.0 ± 2.9) (Fig. 4b). The highest catch rate (7.6 ± 4.4) and fewest number of trips ($n = 14$) were recorded in February. The second highest

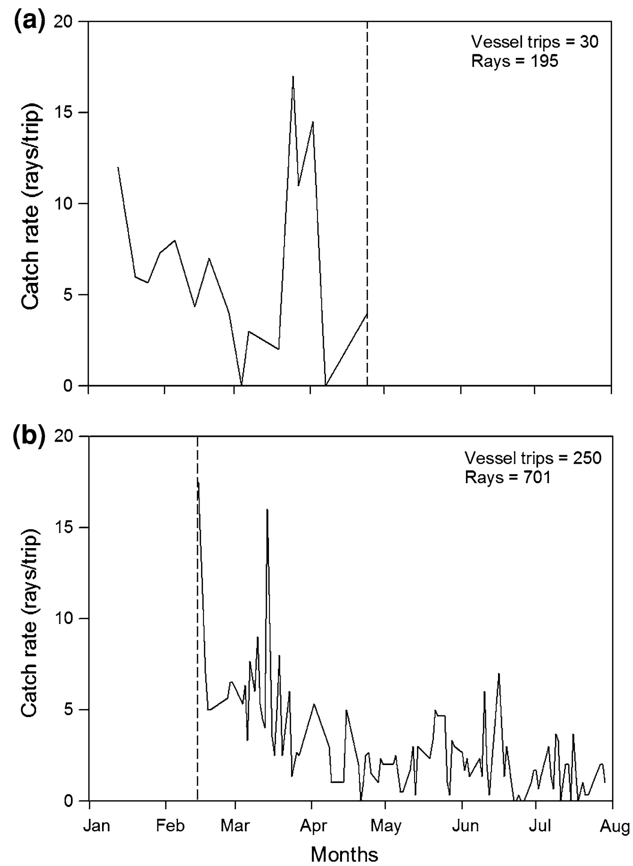

Fig. 4 Time series of the catch rate of the spotted eagle ray *Aetobatus narinari*: **a** fisherman from Campeche, and **b** fishermen from Seybaplaya. The *dotted line* represents the end of the fishing season at Campeche and the beginning of the fishing season at Seybaplaya

Table 3 Fishermen's perceptions of the effects of environmental factors on the catch rate of *A. narinari*

Factor	Perception
Winter cold fronts	10 fishermen: highest catch rate in winter cold front season
Turbidity	10 fishermen: highest catch rate in turbid areas
Sea temperature	8 fishermen: catch rate increased when sea temperature is lower
	2 fishermen: sea temperature has no effect on catches
Lunar cycle	5 fishermen: highest catch rate in the new moon phase
	5 fishermen: the moon cycle has no effect on catch rate, as they only fished in highly turbid areas
Rhinoptera bonasus	7 fishermen: presence of *R. bonasus* negatively influences catch rate of *A. narinari*
	3 fishermen: *R. bonasus* has no effect on catch rate; they only fished very close to the shore (2–3 km from shore)

catch rate was recorded in March (5.3 ± 3.3). The lowest catch rates were recorded in June and July (1.9 ± 1.9 and 1.4 ± 1.1, respectively) during a period in which the largest number of vessel trips were made (58 and 56, respectively).

The number of rays caught per vessel trip off Seybaplaya was statistically different among individual fishermen (ANOVA test, $P < 0.01$), lunar phases (ANOVA test, $P < 0.01$), and between the winter cold front season and the warmer season (ANOVA test, $P < 0.0001$). Fisherman 1 had higher catch rates (3.6 ± 3.6) than fishermen 2 and 3 (2.3 ± 2.6 and 2.3 ± 2.7, respectively). During the full (3.3 ± 3.2) and waning (3.3 ± 3.9) phases, more rays were caught per vessel trip than during the new phase (2.0 ± 2.6), and the number of rays caught in waxing phase (2.7 ± 2.5) was not different from any other phase. During the winter cold front season, with relatively low sea surface temperatures of 23.9–24.8°C, more rays were caught per vessel trip (5.6 ± 3.8) than during the warmer season (2.0 ± 2.3) with its higher sea surface temperatures of 24.6–28.7°C.

Based on surveys with fishermen, catch rates of *A. narinari* are positively influenced by the winter cold front season, turbidity, low sea temperature, and new moon phase (Table 3). Presence of *R. bonasus* is also perceived by the fishermen to negatively influence the catch rate of *A. narinari*, especially for fishermen who operate more than 5 km from shore, such as in the localities of Campeche and Seybaplaya.

Discussion

Mexican elasmobranch fisheries of the Gulf of Mexico use multiple gear types and are multispecific [14, 15], and fisheries of batoids are often opportunistic off the Mexican Pacific coast [7, 8] as occurs off the Mexican Atlantic coast. The fishery for *A. narinari* in the southern Gulf of Mexico is one of the few targeted batoid fisheries in Mexican waters of the Atlantic coast or in any other part of the Gulf of Mexico. This is mainly due to the traditional food consumption of this species in the State of Campeche, where *A. narinari* meat commands one of the highest prices among all elasmobranchs in Mexico (US $4.10–$5.80 per kg).

According to fishermen, catches of *A. narinari* have declined over recent decades, but a lack of data (time series of catch and effort) makes it impossible to confirm this trend. Declines in *A. narinari* populations due to overfishing have been suggested previously [5, 16]. Other factors may contribute to potential declines; for example, fishermen from the State of Campeche believe that declines of this species have been a result of increased fishing pressure on all marine resources, declines in some of its potential prey (mollusks), and increased populations of *R. bonasus*. Baqueiro-Cárdenas et al. [17] documented that, starting in 1984, mollusk populations off Seybaplaya began to decline in response to increasing exploitation which included an expansion of the fishery to greater depths.

The fishermen surveyed in this study ceased fishing operations when large schools of *R. bonasus* were detected in the fishing area. These large schools sometimes destroyed their nets. They perceive that the local population of *R. bonasus* has increased in the last decade. Increases in mesoconsumer elasmobranchs, such as *R. bonasus* in the northwestern Atlantic, have been linked to declines in populations of apex predatory sharks [18]. This and other possible ecological connections should be explored in future studies in the southern Gulf of Mexico.

Allocation of target fishing effort for spotted eagle ray is probably related to consumption preferences of people from the localities of Campeche and Seybaplaya, affecting the catch composition. Fisherman from the locality of Campeche tend to target large rays, in a wide area with multiday trips, due to the larger rays' high price in the Campeche fish market (approx. US $4.50 per kg). Fishermen from Seybaplaya targeted small and medium-sized rays close to the shore, because of local size preferences and prices (approx. US $5.00 per kg). Additional fisherman from Campeche not directly surveyed as part of this study also targeted *A. narinari* in an extended area. Fishermen from Seybaplaya who were not included in this study also reported a similar pattern of allocating fishing effort closer to shore as those included in our survey. However, an alternative explanation is that fishermen probably are using traditional fishing areas, and markets and consumption preferences in both localities were developed based on the size of rays landed there.

Fishing gear characteristics, such as mesh size and gillnet location in the water column, probably do not contribute to the observed differences in size composition between fishing locations. Rays caught with the smallest mesh size nets (30.5 cm, off Campeche) were larger than the rays caught with the largest mesh size nets (36.5 cm, off Seybaplaya). In addition, despite the fact that sexual dimorphism exists in *A. narinari* with females growing larger than males [19; also observed in this study], male rays caught offshore of Campeche were larger than females caught close to shore near Seybaplaya. Because myliobatiform rays are often entangled in nets by their tail spine and are therefore vulnerable to a broad range of mesh sizes, considerably less size selectivity is observed in fisheries for these species [20]. Furthermore, mainly juvenile rays of both sexes were caught off Seybaplaya, where 85% of males and 98% of females were juveniles, whereas adult rays were more predominant off Campeche, where 68% of males and 31% of females were adults. The size range of *A. narinari* observed in this study is therefore likely to be representative of spatial variation in the size composition in the region during the study period.

In addition to differences in allocation of fishing effort, potential size and/or sex segregation of *A. narinari* also could affect the composition of the catches. Segregation by size and sex is a common feature of elasmobranch populations [21, 22]. Although landings of *A. narinari* consisted of both sexes, significant bias in the sex composition was evident. Catches off Campeche were male biased, whereas those sampled from Seybaplaya were strongly female biased. Differences in the size composition of rays between fishing areas also suggest spatial segregation of size classes in the region. Larger rays were caught further from shore (off Campeche) and smaller rays closer to shore (off Seybaplaya). A similar pattern has been observed for *A. narinari* in Puerto Rico (Dubick JD, unpubl. data, 2000).

Catch rates off Seybaplaya differ for individual fisherman and are influenced by the winter cold front season (with low sea temperatures 23.9–24.8°C). The first result underscores the importance of considering the variation in fishing success of individual fishermen when making comparisons of catch rates between fishing areas or years. There is no literature specifically on the influence of winter cold fronts on the catch rates of elasmobranch species. However, Heupel et al. [23] found that juvenile blacktip sharks *Carcharhinus limbatus* sensed the approach of a tropical storm, moved out of their shallow nursery area to deeper waters in response, and then returned to the protection of the nursery after the storm's passage. In this study, our data corroborate the fishermen's perception of the positive influence of winter cold fronts on the catch rate of *A. narinari*. Fishermen stop fishing for safety reasons when winter cold front events occur (durations of 2–3 days) because of high winds (>30 km/h). They perceive that catch rates of elasmobranch and teleost species increase when they resume fishing, because these species move towards the shore during periods of high, cold winds.

Abundance and distribution of elasmobranchs are influenced by water temperature [24, 25], and catches of *A. narinari* off Seybaplaya decline in warmer months (April–July). Silliman and Gruber [26] found that *A. narinari* move to deeper waters around Bimini, Bahamas, in late spring, and the rays return to shallow waters at the end of summer. These authors suggest that temperature is the primary causal factor. This is in agreement with the analysis of catches in the present study and the perception of fishermen, who believe that *A. narinari* moves offshore in warm months, around April, and moves back inshore when temperatures begin to decrease, around October.

According to fishermen, turbidity is another factor that positively influences the catch rate of *A. narinari*, and they prefer to set their nets in turbid areas when fishing for the rays. Hueter et al. [27] selected study areas for juvenile shark tagging in Mexico based on the experience of fishermen from Yalahau Lagoon (northeastern Yucatán Peninsula), who recommended the use of turbid areas to maximize catches of *C. limbatus* in gillnets.

Future studies using fishery-independent approaches could help determine the influence of temperature [24, 25], lunar cycle [28], and turbidity on the catch rates of *A. narinari*, and use of satellite tags could provide information on the influence of winter cold fronts on the behavior of this species.

Because of the global near-threatened status of *A. narinari* [5] and the fact that it is the target species in this specialized Mexican fishery, we strongly recommend that harvest of *A. narinari* in the Mexican Atlantic be managed by use of a species-specific fishing permit rather than the multispecific permit for all elasmobranch species. Fishermen should provide records of fishing trips and catches by means of a logbook system, as established in NOM-029-PESC-2006 [6], to generate time series of catch and effort data for analysis of fluctuations in catch per unit effort. Future analyses of Mexican elasmobranch fisheries should carefully consider the spatial allocation of fishing effort as it may strongly influence the size and sex composition of landings as well as the proportion of juvenile and adult individuals within catches. Fisherman identity (individual variability) likewise must be considered in comparisons of catch rates between areas or years, because differences can be influenced by this factor [29].

If the perceptions of fishermen are correct and catches of *A. narinari* have declined over past decades, the near-threatened status determined by the IUCN [5] is valid in this region. However, it is important to consider that the incidence of adult rays is relatively low in this fishery (5%

and 32% of females and males, respectively, were adult rays). To better evaluate the status of this population and determine the most appropriate management measures, development of a demographic stage-based model is recommended. Age and longevity data are lacking for this species, and a stage-based model based on size classes would assess the potential impacts of fishing pressure on various size classes on the overall population growth rate [30] of *A. narinari* in this region.

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