

Ecological data for *Myxine circifrons* Garman, 1899 (Myxiniiformes: Myxiniidae)
in the gulf of California, Mexico

Información ecológica de *Myxine circifrons* Garman, 1899 (Myxiniiformes: Myxiniidae)
en el golfo de California, México

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Abstract. Specimens of the hagfish *Myxine circifrons* Garman, 1899, were captured in traps in three sampling stations in the southern gulf of California, Mexico. There was no clear relation between oxygen concentration and hagfish abundance. This species appears to be tolerant of moderate (0.28-0.6 ml/l) hypoxia. Other species collected in the traps include *Pandalus amplus* (Bate, 1888) and *Heterocarpus affinis* Faxon, 1893, two relatively large species of Pandalidae, and *Lebbeus scrippsi* Wicksten and Méndez, 1982, a small-size Hippolytidae shrimp. Capture of pandalids was low when hagfish were abundant, thus indicating that competition between the fish and shrimps might prevent the latter to enter the trap.

Keywords: *Myxine circifrons*, Myxiniiformes, gulf of California, Mexico, new records.

Resumen. Especímenes de mixinas (peces brujas), *Myxine circifrons* Garman, 1899, fueron capturados con trampas en tres estaciones de muestreo en el golfo de California, México. No se observó una relación clara entre la concentración de oxígeno y la abundancia de los especímenes. La especie parece ser tolerante a un ambiente moderadamente hipóxico (0.28-0.6 ml/L). Otras especies recolectadas con las trampas incluyeron los crustáceos *Pandalus amplus* (Bate, 1888) y *Heterocarpus affinis* Faxon, 1893, dos especies relativamente grandes de Pandalidae y a *Lebbeus scrippsi* Wicksten y Méndez, 1982, un camarón Hippolytidae de tamaño pequeño. La captura de pandálidos en las trampas fue baja cuando los peces bruja eran abundantes,

indicando así que la competencia entre éstos y los camarones pudo impedir que estos últimos entraran en la trampa.

Palabras clave: *Myxine circifrons*, Myxiniiformes, golfo de California, México, nuevos registros.

Hagfishes include approximately 70 species of jawless, eel-like chordates that are typically associated with muddy substrates and found in marine waters from a few meters to at least 2,700 m depth (Mincarone, 2001; Nelson, 2006). Their potential importance in marine communities is indicated by their often high biomass that has been estimated at over 8,000 kg km⁻² for *Myxine glutinosa* Linnaeus, 1758 in the gulf of Maine (Martini *et al.*, 1997). Increasing demand for hagfish skin in the South Korean market has brought increased pressure on the hagfish fishery in Canada and the USA, and revenues reached ca \$100 million US in 1990 for this Asian country (Gorbman *et al.*, 1990; Grey *et al.*, 2006).

During a survey in the SE gulf of California to evaluate the potential of benthic traps to capture the caridean shrimp *Heterocarpus affinis* Faxon, 1893, a commercially interesting species that had been collected previously in the area using a benthic sledge (see Hendrickx, 2004), the hagfish *Myxine circifrons* Garman, 1899 was caught in approximately 75% of the traps. The genus *Myxine* includes 22 species of hagfishes, of which six have been recorded in the East Pacific (Wisner & McMillan, 1995; Mincarone, 2001; Møller *et al.*, 2005). Two of these are found in the northern hemisphere of the East Pacific: *M. circifrons* and *M.*

hubbsi (Wisner & McMillan, 1995). Herein we report on the abundance of *M. circifrons* and some environmental data measured during this survey.

A small series of deep-water traps (three at each station) were deployed in three field stations in April 2002 during the PANDAL Cruise to the gulf of California, Mexico by the R/V "El Puma" of the Instituto de Ciencias del Mar y Limnología, UNAM, using an anchor attached to 1.2 cm tick polyethylene cable and a double buoys system (King, 1987). Fish-heads were used as bait. Traps remained on the bottom for different periods of time due to navigation time restrictions. At each station, a CTD-O₂ probe (Seabird SBE probe) attached to a Rosette sampler was submerged to approximately 10 m above the bottom; water samples were simultaneously collected with opening-closing bottles. Dissolved oxygen content was measured using duplicate samples following the Winkler method. Fish specimens were preserved onboard, measured in the laboratory (TL, total length \pm 0.5 mm), and identified using the key in Wisner and McMillan (1995). Voucher material (SIO 05-83; ICMYL-353.01) was deposited at the Scripps Institution of Oceanography Marine Vertebrate Collection and the fish collection of the Unidad Académica Mazatlán, in Mazatlan, Mexico.

A total of 69 specimens of adult *Myxine circifrons* were captured in the 9 samples (3 traps at each of 3 stations). The smallest specimen was 312 mm TL and the largest 471 mm. Most specimens were found inside traps, but a few were found attached to the external walls when the traps were retrieved on deck. Collection details are as follows. Station 1 (24°17.36'N,

108°21.86'W), 1150 m, trap 1: 7 specimens (TL 312-455 mm); Station 2 (24°51.33'N, 108°57.37'W), 850 m: trap 1, 17 specimens (TL 395-472 mm), trap 2, 6 specimens (TL 378-450 mm); Station 3 (25°40.83'N, 109°54.38'W), 1435 m: trap 1, 16 specimens (TL 330-452 mm), trap 2, 6 specimens (TL 350-435 mm), trap 3, 17 specimens (TL 360-471 mm).

The number of specimens captured per trap varied considerably, from none (St. 1, two traps with no hagfish) to 17 specimens. Catch per station estimated for a standard 24-hour period was 3.9 specimens (St. 1), 9.2 (St. 3) and 31.3 specimens (St. 2) (Table 1). Dissolved oxygen measured close to the bottom level does not indicate any clear relation between oxygen concentration and hagfish abundance. Thus this species, like other hagfishes (e.g., Hansen & Sidell, 1983) appears to be tolerant of moderate (0.28-0.6 ml/L) hypoxia, but was also found in water with a higher oxygen concentration (St. 3, 1.15 ml/L). The oxygen concentrations measured in the sampling area correspond well with previous records in the region, with a remarkable increase starting at depth > 700-800 m after an almost anoxic zone (MOZ, Minimum Oxygen Zone) that extended roughly from 150 to 750 m (Hendrickx, 2001). Epibenthic water temperatures (from 3.0 to 5.3° C) were in agreement with standard depth distribution of water masses between 850 and 1,435 m in the SE gulf of California (Alvarez-Borrego, 1983).

Only a few other species were collected in the traps, including *Pandalus amplus* (Bate, 1888) and *H. affinis*, two relatively large species of Pandalidae with potentially high commercial market value (Holthuis, 1980; Hendrickx & Wicksten, 1989). The

Table 1. Sampling stations where traps were deployed, duration of sampling, and environmental parameters measured at the epibenthic level. Dh, duration in hours; TS, total number of hagfish specimens in all three traps; C/24, catch per 24 hours; Dm, depth in meters; T (°C), epibenthic temperature; O₂ (ml/l), epibenthic oxygen concentration.

St.	Deployment time (hour/date)	Recovering time (hour/date)	Dh	TS	C/24	Dm	T	O ₂
1	22:30 / 02 April	17:30 / 04 April	43	7	3.9	1,150	3.9	0.60
2	06:00 / 03 April	12:30 / 04 April	30	23	31.3	850	5.3	0.28
3	14:00 / 03 April	05:00 / 04 April	15	39	9.2	1,435	3.0	1.15

Table 2. Previous records for *Myxine circifrons* in the Gulf of California based on material held at the Scripps Institution of Oceanography (Wisner and McMillan, 1995) (Fig. 1, open circles).

Collection voucher	Locality	Depth (m)	Number (Size Range mm)
SIO 68-59	23°07'N, 109°19'W	1,280	25 (133-510)
SIO 68-60	23°07'N, 109°11'W	1,830	6 (365-496)
SIO 68-118	25°37'N, 109°43'W	1,190	110 (125-490)
SIO 68-119	25°36'N, 109°45'W	1,490	25 (280-475)

third species that incidentally appeared in the traps was *Lebbeus scrippsi* Wicksten and Méndez, 1982, a small-size Hippolytidae shrimp. Capture of pandalids were low when hagfish were abundant, thus indicating that the presence of the fish on the trap walls might prevent the shrimp from gaining access to the entrance and the bait. Videos recorded near baits show that hagfish and pandalids are the first species to reach the remains of dead fish and competition among these two groups might be intense. Interestingly, a record of *M. circifrons* from off Colombia was recently reported from similar traps targeting a related species, *Heterocarpus hostilis* Faxon, 1893 (Rubio *et al.*, 2005). The co-occurrence of hagfishes with these targeted shrimp species indicates that development of these fisheries will need to take into account the interactions of hagfishes in the capture of these shrimp species.

Myxine circifrons is known from off San Francisco, USA, to Chile at depths between ca 700 and 1,860 m. Previous records for this species are provided by Wisner and McMillan (1995), and include four samples from the gulf of California obtained between

1,190 and 1,830 m depth (Table 2). Depth records obtained during this survey correspond to the known range. *Myxine hubbsi*, the second eastern Pacific species of the genus recorded in the northern hemisphere, is known from 33° N to 34° S, including two localities near Cabo San Lucas, Mexico, close to the western entrance of the gulf of California. The only other hagfish species recorded from the gulf of California are *Eptatretus sinus* (Wisner & McMillan 1990), known from the midriff islands area in depths of 198 to 1,330 m, and *Eptatretus mcconnaugheyi* Wisner and McMillan, 1990, recorded from near Isla Carmen in depths of 177-415 m (Wisner & McMillan, 1990).

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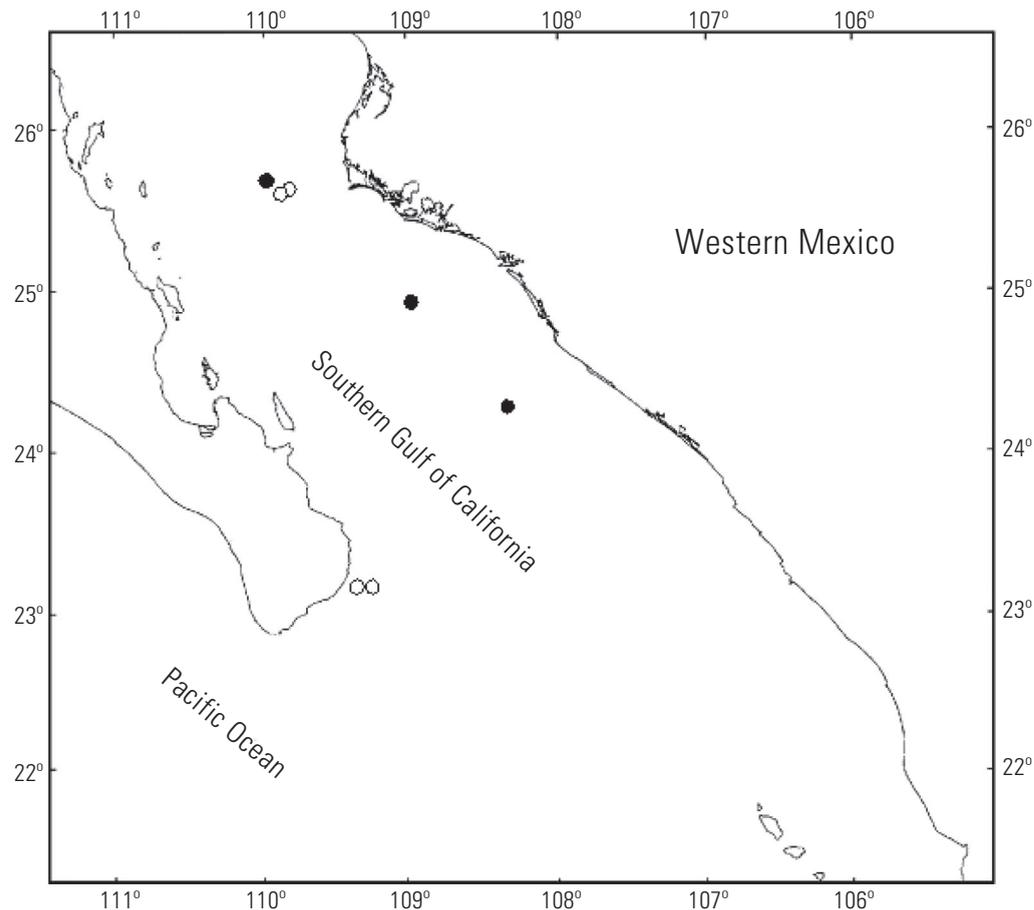


Figure 1. Previous (open circles) and new (solid circles) sampling localities for *Myxine circifrons* in the gulf of California, Mexico.

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