Mar Biodiv
DOI 10.1007/s12526-015-0404-y

SENCKENBERG CrossMark

SHORT COMMUNICATION

To knot or not? Novel feeding behaviours in moray eels

Shanta C. Barley[1,2] · **Rita S. Mehta**[3] · **Jessica J. Meeuwig**[1] · **Mark G. Meekan**[2]

Received: 16 March 2015 / Revised: 23 August 2015 / Accepted: 18 September 2015

Abstract We report observations of a novel feeding behaviour in the moray eel *Gymnothorax favagineus* (Bloch & Schneider, 1801) and a previously undocumented application of "knotting" behaviour in *G. fimbriatus* (Bennett, 1832). Moray eels were filmed by baited remote underwater video systems (BRUVS) at the Scott Reefs, a remote group of atoll-like reefs on the edge of the continental shelf in tropical, northwestern Australia. Two behaviours were observed as the moray eels tried to dislodge food from a bait bag: (1) *G. favagineus* used its tail as a "paddle" to gain leverage on the bag, and (2) *G. fimbriatus* tied a knot in its tail in order to extract food from the bag. Our observations suggest that morays have an extensive behavioural repertoire for manipulating and extracting large prey items from the interstices of the reefs where they typically hunt.

Keywords *Gymnothorax* · Feeding · Coral reef · Knotting · Baited remote underwater video systems · BRUVS

Communicated by R. Thiel

Electronic supplementary material The online version of this article (doi:10.1007/s12526-015-0404-y) contains supplementary material, which is available to authorized users.

✉ Shanta C. Barley
shanta.barley@gmail.com

1 School of Animal Biology and the Oceans Institute, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009 Perth, Australia

2 Australian Institute of Marine Science, The Oceans Institute, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009 Perth, Australia

3 Department of Ecology and Evolutionary Biology, Long Marine Lab, University of California, Santa Cruz, CA, USA

Introduction

Moray eels (Anguilliformes: Muraenidae) are important predators in many coral reef ecosystems (Carr and Hixon 1995), yet very little is known about their foraging behaviour (Mehta and Wainwright 2007a). There is evidence that muraenids use a very wide variety of hunting tactics, including cooperating with coral trout to flush prey from crevices in the reef (Vail et al. 2013) and "breaching," in which they leap out of rock pools in the intertidal zone to catch crabs (Graham et al. 2009). To consume prey that are too large to swallow whole, some species of moray eel rotate rapidly along their primary axes while holding the prey in their jaws, a feeding mode that has also been observed in anguillid eels and other eel-like fishes (Helfman and Clark 1986). Of the nearly 200 recognised species of moray eel (Böhlke et al. 1989; Smith 2012), 7 have also been observed to tie "knots" in their bodies in order to compress prey items that are too large to swallow or to anchor prey while the moray removes pieces (Miller 1987, 1989; Santos and Castro 2003). Unlike most other teleosts, which use suction to capture and swallow whole prey, moray eels rely on biting and have a highly mobile pharyngeal jaw used for transporting prey to their oesophagus, which may be an adaptation to hunting in the confined spaces of the reef (Mehta and Wainwright 2007a, b). Here, we report two novel behaviours used by two species of moray eels to obtain food.

Materials and methods

Baited remote underwater video systems (BRUVS) are an increasingly popular method to study fish behaviour (Fox and Bellwood 2008; Ebner et al. 2009), especially cryptic species such as moray eels (Weiss et al. 2006; Bassett and Montgomery 2011). Stereo-BRUVS were deployed at two

Published online: 08 October 2015

sites at the Scott Reefs, a remote coral reef system on the edge of the continental shelf in northwestern Australia. The rigs consisted of two HD digital video cameras in waterproof housings attached to a metal frame that held the cameras 30 cm above the sea floor. A bait bag made of stiff plastic mesh and containing 1 kg of crushed pilchards (*Sardinops spp*.) was suspended in front of the cameras at the end of a 1.5-m-long plastic tube, in order to attract carnivorous species. Deployments followed standard practices for BRUVS (Cappo et al. 2004). A total of 56 deployments were made across the two reef systems, and the video cameras recorded fishes approaching the bait bags for approximately 60 min.

Results

A fimbriated moray eel, *Gymnothorax fimbriatus* (Bloch & Schneider, 1801), was recorded grasping the mesh bag with its teeth and creating a loose overhand "knot" in its tail region (Fig. 1a). The knot slid rapidly up its body (Fig. 1b), over its head and was pushed forcefully against the bait bag (Fig. 1c). The knot was then unraveled and the process repeated (see video). The moray eel spent a total of 1 min and 35 s in the field of view of the camera, which was deployed at a depth of 51.7 m at 0807 hours on 28 February 2014 at South Scott Reef (14°8′43″S, 121°52′38″E) on a seabed characterized by a mixture of soft coral, rubble and hard coral (both foliose and tabulate). A second moray [*G. favagineus* (Bennett, 1832)] was observed gripping the bait bag in its mouth and using its tail as a paddle in order to open the bag and remove food (Fig. 1d–f), spending a total of 5 min 33 s in the field of view of the camera. This behaviour was observed at a depth of 39.1 m on 25 February 2014 at 0839 hours at North Scott Reef (13°56′8″S, 121°55′48″E) in a field of soft coral.

Discussion

We report the first observation of a novel feeding behaviour by a moray eel and a new application of an already documented

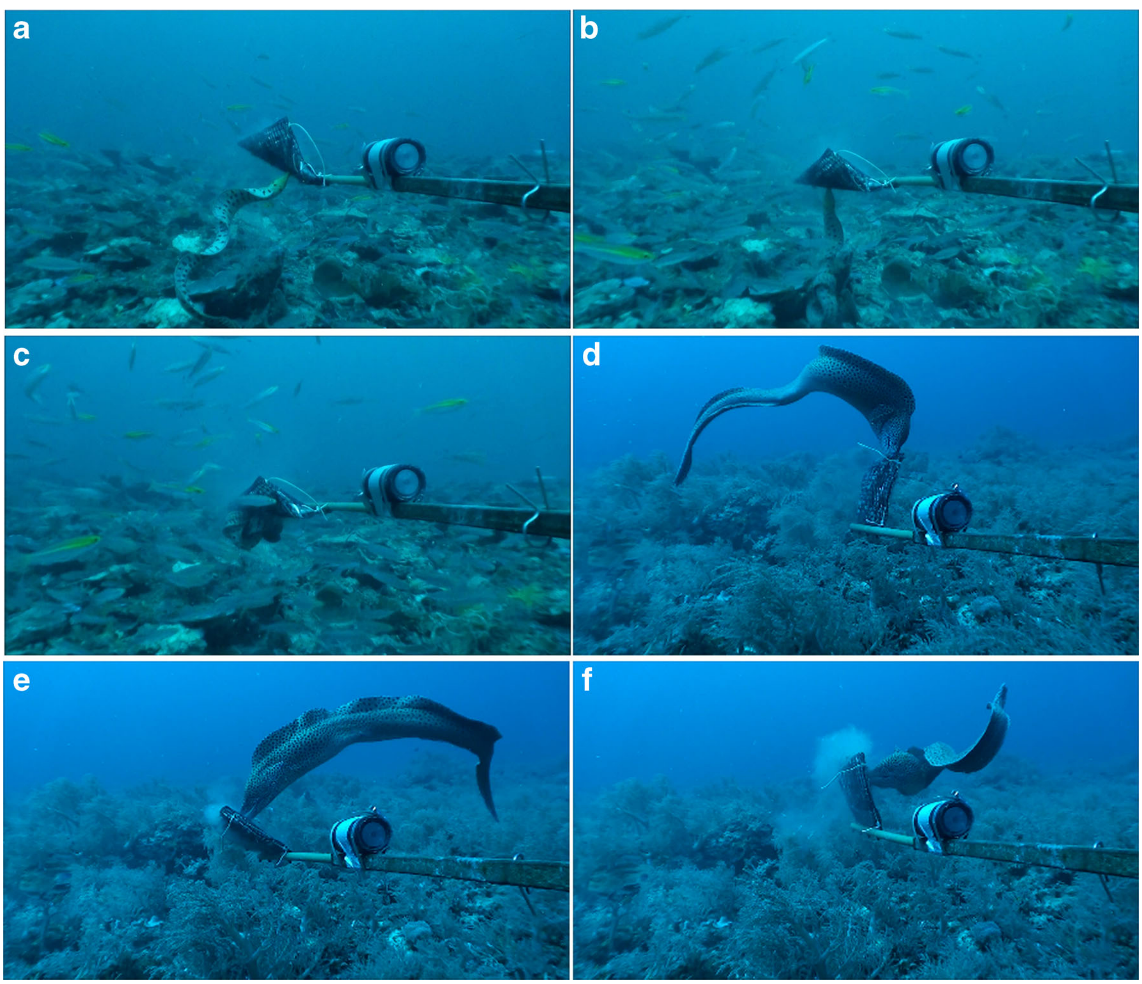

Fig. 1 *Gymnothorax fimbriatus* attacks the bait bag (**a**), forms a "knot" in its tail (**b**), and rapidly pushes the knot into the bait bag (**c**). A different moray eel, *Gymnothorax favagineus*, attacks the bait from two angles (**d**, **e**) before using its tail as a "paddle" to rip open the mesh bag (**f**)

behaviour, knotting, in a separate species. *Gymnothorax favagineus* grasped the bait bag in its mouth and used its tail to "paddle" water in the direction of the bait bag, providing it with leverage as it tried to rip open the bag's mesh. A second species, *G fimbriatus*, used a different behaviour to achieve the same objective. An individual of this species used a fast-moving knot initiated in its tail region to either break open the bait bag or force large food items through the mesh of the bag so that they could be consumed. This is the first report of knotting in *G. fimbriatus* and shows a novel application of this feeding behaviour. Laboratory studies (Miller 1987, 1989) and field observations in the Atlantic Ocean (Santos and Castro 2003) suggest that moray eels generally apply knots to large prey items, either to break them into smaller pieces, compress them into more manageable units until they can be swallowed or anchor them while the eel removes pieces. Our observations, however, suggest that knotting behaviour in morays serves a range of purposes beyond simply breaking up large prey items. Specifically, our observations suggest that knotting may also be useful for extracting large prey items from the interstices of the reefs where morays are commonly known to hunt.

It is likely that knotting and other unconventional feeding tactics observed in a relatively small number of morays are in fact pervasive among muraenids and, indeed, anguilliform animals in general (Helfman and Clark 1986; Helfman 1990). Hagfish, for example, have been observed to use knotting to provide leverage when pulling prey out of burrows (Zintzen et al. 2011). Caecilians, a group of subterranean, limbless amphibians, use rotational feeding to reduce the size of large prey items (Measey and Herrel 2006). The anguilliform body shape, regardless of taxon, may permit a range of versatile foraging tactics that are largely unavailable to conventionally shaped, fusiform fishes (Mehta et al. 2010). Ultimately, the ability to attack and consume prey much larger than themselves through the use of behaviours like knotting may, in part, explain both the ecological role of moray eels as significant mesopredators in reef systems (Parrish et al. 1986) and the evolution of cooperative hunting partnerships (Brose et al. 2006) with other large piscivores.

Acknowledgments We would like to thank the Australian Institute of Marine Science for the use of its research vessel, the *RV Solander*, and for the support of its crew. We also acknowledge the Department of Fisheries, the Department of Parks and Wildlife (DPaW) and the Department of Sustainability, Environment, Water, Population and Communities for arranging permits to conduct research at the Scott Reefs. Experimental protocols were approved by the University of Western Australia's Animal Ethics Committee (RA3/100/1279, RA3/100/1172), and were carried out in accordance with the approved guidelines.

References

Bassett DK, Montgomery JC (2011) Investigating nocturnal fish populations in situ using baited underwater video, with special reference to their olfactory capabilities. J Exp Mar Biol Ecol 409:194–199

Böhlke EB, McCosker JE, Böhlke JE (1989) Fishes of the Western North Atlantic. The Yale Peabody Museum. Yale University, New Haven

Brose U, Jonsson T, Berlow EL et al (2006) Consumer-resource body-size relationships in natural food webs. Ecology 87:2411–2417

Cappo M, Speare P, De'ath G (2004) Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. J Exp Mar Biol Ecol 302:123–152

Carr MH, Hixon MA (1995) Predation effects on early post-settlement survivorship of coral-reef fishes. Mar Ecol Prog Ser 124:31–42

Ebner B, Clear R, Godschalx S, Beitzel M (2009) In-stream behaviour of threatened fishes and their food organisms based on remote video monitoring. Aquat Ecol 43:569–576

Fox RJ, Bellwood DR (2008) Direct versus indirect methods of quantifying herbivore grazing impact on a coral reef. Mar Biol 154:325–334

Graham NAJ, Purkis SJ, Harris A (2009) Diurnal, land-based predation on shore crabs by moray eels in the Chagos Archipelago. Coral Reefs 28:397

Helfman G (1990) Mode selection and mode switching in foraging animals. In: Slater P, Rosenblatt J, Beer C (eds) Advances in the study of behavior, vol 19. Academic, San Diego, pp 249–290

Helfman GS, Clark JB (1986) Rotational feeding: overcoming gape-limited foraging in anguillid eels. Copeia 1986:679–685

Measey GJ, Herrel A (2006) Rotational feeding in caecilians: putting a spin on the evolution of cranial design. Biol Lett 2:485–487

Mehta RS, Wainwright PC (2007a) Raptorial jaws in the throat help moray eels swallow large prey. Nature 449:79–82

Mehta RS, Wainwright PC (2007b) Biting releases constraints on moray eel feeding kinematics. J Exp Biol 210:495–504

Mehta RS, Ward AB, Alfaro ME, Wainwright PC (2010) Elongation of the body in eels. Integr Comp Biol 1091–1105

Miller TJ (1987) Knotting: a previously undescribed feeding behavior in Muraenid eels. Copeia 4:1055–1057

Miller TJ (1989) Feeding behaviour of Echidna nebulosa, Enchelycore pardalis, and Gymnomuraena zebra (Teleostei: Muraenidae). Copeia 3:662–672

Parrish JD, Norris JE, Callahan MW et al (1986) Piscivory in a coral reef fish community. In: Simonstad CA, Cailliet GM (eds) Contemporary Studies on Fish Feeding: the Proceedings of the Gutshop, 1984. Dev Environ Biol Fish 7:285–298

Santos FB, Castro RMC (2003) Activity, habitat utilization, feeding behaviour and diet of the sand moray Gymnothorax ocellatus (Anguilliformes, Muraenidae) in the South Western Atlantic. Biota Neotrop 3:1–7

Smith DG (2012) A checklist of the moray eels of the world. Zootaxa 3474:1–64

Vail AL, Manica A, Bshary R (2013) Referential gestures in fish collaborative hunting. Nat Commun 4:1765. doi:10.1038/ncomms2781

Weiss HM, Lozano-Álvarez E, Briones-Fourzán P, Negrete-Soto F (2006) Using red light with fixed-site video cameras to study the behavior of the spiny lobster, panulirus argus, and associated animals at night and inside their shelters. Mar Technol Soc J 40:86–95

Zintzen V, Roberts CD, Anderson MJ et al (2011) Hagfish predatory behaviour and slime defence mechanism. Sci Rep 1:1–6