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A POSSIBLE CASE OF TRANSOCEANIC DISPERSAL OF A COMMONLY OCCURRING INDO-WEST PACIFIC PUFFERFISH TO THE SOUTH-WEST ATLANTIC

Juan Martín DÍAZ DE ASTARLOA [1,2], Daniel Enrique FIGUEROA [1] & Raúl RETA [1,3]

[1] *Departamento de Ciencias Marinas, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata. Funes 3350, B7602AYL Mar del Plata,* ARGENTINA

[2] *Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET),* ARGENTINA

[3] *Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP). Paseo Victoria Ocampo s/n, B7602HSB Mar del Plata,* ARGENTINA

ABSTRACT.- The unusual occurrence of the commonly Indo-west Pacific pufferfish *Arothron firmamentum* was reported for the first time off Mar del Plata, Argentina at a depth of ca. 45 m. As far as we know, the species has not been previously reported in American Atlantic waters. Some morphological and biological characteristics are given for the two specimens caught. A hypothesis of trans-oceanic migration from the eastern South Atlantic by means of marine Currents is discussed.

KEY-WORDS.- Transoceanic migration, Pufferfish, *Arothron firmamentum*, Argentina

RESUME.- Pour la première fois à notre connaissance, le poisson-globe *Arothron firmamentum*, espèce très commune dans les eaux de l'Océan Indien et de la partie ouest du Pacifique, a été signalé dans les eaux atlantiques américaines, au large de Mar del Plata, Argentine, à une profondeur de 45 m. Cette présence insolite pourrait hypothétiquement s'expliquer par une migration transocéanique qui, grâce à des courants marins, transiterait par le sud-est de l'Atlantique.

MOTS-CLES.- Migration transocéanique, Poisson-globe, *Arothron firmamentum*, Argentine

INTRODUCTION

In April 3 2000 two specimens of starry toadfish ("hoshifugu" in Japanese) *Arothron firmamentum* (Temminck and Schlegel), a species not previously recorded in American Atlantic waters, were collected with a commercial trawler off Mar del Plata (38° 20'S, 56° 30'W) at a depth of about 45 m on the Argentinean continental shelf.

Species of *Arothron* are widely distributed troughout the tropical regions of the Indo-west Pacific (MATSUURA, 1994). SMITH and HEEMSTRA (1995) listed about 10 species, with 7 occurring in South-African waters. Nine species were reported for the Japanese Archipelago (MASUDA *et al.*, 1984) and 15 nominal species were considered valid at present (MATSUURA, 2002). Although most species usually inhabit coastal waters, around coral reefs, the starry toadfish is a relatively deep-water in occurrence, frequently caught in a depth range of 30-80 m (HARDY, 1980). However, specimens of *A. firmamentum* were also recorded at deeper waters (GOMON *et al.*, 1994; MATSUURA & TYLER, 1997). The species is known from the southern part of Japan, the south China Sea, New Zealand and Australia (MASUDA *et al.*, 1984; PAULIN *et al.*, 1989; GOMON *et al.*, 1994; MATSUURA & TACHIKAWA, 1994; RANDALL *et al.*, 1997), and has recently

been found at Cape St. Francis and Sea Point in Cape Town, South Africa (HEEMSTRA, 1995), and also from New Caledonia (MATSUURA & TYLER, 1997).

The southwestern records constitute the first report of *Arothron firmamentum* in American Atlantic waters.

MATERIALS AND METHODS

The specimens were first fixed in formalin and subsequently transfered to alcohol and deposited in the fish collection of the Instituto Nacional de Investigación y Desarrollo Pesquero as INIDEP 713 and INIDEP 714. Proportional measurements expressed as per cent of standard length were taken using dial calipers. Fin ray counts were made by means of X-ray photographs. Measurements and color description were made from fresh specimens.

One of the specimens was eviscerated in order to investigate the diet and to establish sex and maturity. Small fragments of tissue were removed from the centre of each gonad, dehydrated in methanol, cleared in benzol, and embedded in paraffin. Tissues were cut into 4 μm sections, and stained with Harris's hematoxylin followed by eosin counterstain.

RESULTS

The distinguishing characteristics of the specimens caught are: the head and the body covered with prickles, except on posterior of caudal peduncle, around mouth, eye, gill opening and on fin bases; some random variation in prickles covering and density on caudal peduncle was found. INIDEP 714 specimen showed more spines than those observed in the other specimen. Each nostril with two fleshy flaps formed by bifurcation of a single base; many small circular light pale spots on head and body on a distinctive dark brown ground color on lateral and dorsal parts of head and body; ventral region becoming pale. Lateral lines on both specimens indistinct (Fig. 1).

Proportional measurements as % of standard length (SL): total length 125.5–125.8, head length (HL) 32.9–34.8, postorbital length 19.0–20.1, predorsal length 72.8–73.9, preanal length 74.5–74.8, snout to anus 67.7–69.5, bony interorbital width 16.1–16.4, depth of body 20.3–21.8, longest dorsal ray 20.3–23.1, longest anal ray 19,7–21.1, caudal fin length 24.8–26.8, pectoral fin length 14.2–16.1, caudal peduncle depth 10.6–10.7, caudal peduncle length 14.2–15.8, dorsal fin base length 10.7–11.3, anal fin base length 9.4–10.0. As % of HL: eye diameter 13.9–14.6, snouth length 28.5–31.3.

Meristics: dorsal-fin rays 14, anal-fin rays 13–14, pectoral-fin rays 15, caudal-fin rays 11, total vertebrae 20.

Both meristic and morphological features of the specimens correspond to those reported in the literature for this species (HARDY, 1980; MASUDA *et al.*, 1984; GOMON *et al.*, 1994; MATSUURA & TACHIKAWA, 1994; MATSUURA & TYLER, 1997). Microscopic examination of food remains adhering to the digestive tube walls (stomach and intestine measured 132 cm length overall) revealed the presence of Cnidaria (Hydrozoa), Nematodes, Polychaetes, Pelecypods (Nuculidae and Pectinidae), Gasteropods (Olividae), Echinoderms (Asteroidea and Ophiuroidea), Briozoa (Membraniporidae) and Crustaceans (Brachyura).

The dissected specimen was histologically sexed as a maturing female with few small previtellogenic oocytes scattered among vitellogenic oocytes.

DISCUSSION

The finding of tropical or subtropical fish species in coastal waters off northern Argentina, especially as a southern range extension of Brazilian ichthyofauna, has been considered as occasional reports at the end of summer and begining of autumn (COUSSEAU & FIGUEROA, 1989; FIGUEROA *et al.*, 1992; DÍAZ DE ASTARLOA *et al.*, 2000; FIGUEROA *et al.*, 2000). These sporadic occurrences have been attributed to the incursion of warm neritic waters to the Argentine continental shelf (DÍAZ DE ASTARLOA & FIGUEROA, 1995).

Reports on dispersal of fishes with tropical affinities into temperate waters are common in the literature. In the north-east Atlantic new records of tropical fishes extended the known area of fish distribution substantially farther north than their often area of occurrence (QUÉRO *et al.*, 1998). The winter warming of waters of the south-to-north current along the northern Spanish slope could explain the fishes distribution as a means of transport (QUÉRO, 1998). Other records of unusual fish occurrences were also reported in the Mediterranean Sea (MASSUTI & STEFANESCU, 1993; RAGONESE & GIUSTO, 1997 & 1999; PIZZICORI *et al.*, 2000; RAGONESE *et al.*, 2001). The possibility of recent climatic changes, particularly thermal increases, recorded in the Mediterranean, was suggested as indicative on the spreading of the fish fauna outside their typical distribution range (BETHOUX *et al.*, 1990; FRANCOUR *et al.*, 1994; ANDALORO & RINALDI, 1998; GUIDETTI & BOERO, 2001; CASTRIOTA *et al.*, 2002).

In the present study, the finding of two antitropical Indo-west Pacific Tetraodontid specimens of *Arothron firmamentum* long distance from their usual area of occurrence is of much interest because a different transport mechanism of fish fauna with tropical affinities to the south-west Atlantic should be addressed.

In a global scale, the marine currents allow the flow of the elements that characterize an ecosystem. Thus, fluxes of tracers such as heat, salt, nutrients, pollutants and also organisms are carried through different oceanic basins. The occurrence and widespread distribution of the starry toadfish *A. firmamentum* in the Indo-West Pacific might be related to such marine currents. The pufferfish has been recorded from Korea, around the southern half of Japan, Taiwan, south-eastern Australia, including Tasmania, and the northern half of New Zealand (HARDY, 1980). This wide area is interconnected via the Indonesian Through Flow (ITF) and the East Australian Current (EAC) (Fig. 2). The former is the only connection between basin at low latitude that connects Pacific and Indian Oceans. Large-scale observations-based studies reveal significant Pacific export of fresh water and heat into the Indian Ocean (GORDON, 2001). ITF current is associated with temperature of 24 °C and salinity of 34.5 psu. The EAC also flows Pacific water into the Indian Ocean along the Tasman Sea and southern coast of Australia (REID, 1997).

More recently findings extended the distribution range of *A. firmamentum* to South Africa, substantially further west from the typical area of occurrence (HEEMSTRA, 1995). Specimens of starry toadfish were recorded in Asvoel Point, Cannon Rocks, Kenton, and Cape St. Francis in South Africa (ANONYMOUS, 2000). Two main marine currents cross the Indian Ocean to the west, the North Equatorial Current of the Indian Ocean (NECIO) and the South Equatorial Current of the Indian Ocean (SECIO). A southern branch of the SECIO forms the East Madagascar Current (EMC), a small but well-defined western boundary current, that contributes to form the Agulhas Current (AC) (Fig. 2).

The occurrence of *A. firmamentum* on the southernmost eastern Atlantic might be explained by the injection of Indian water into the southeastern Atlantic via the Agulhas Current tending to add heat and salt to the South Atlantic. The AC is one of the strongest currents of the world ocean (RICHARDSON *et al.*, 2003). It flows westward

along the continental shelf of southern rim of Africa (GORDON, 2001). Rather than continuing into the South Atlantic, Agulhas water curls back to the Indian Ocean, feeding the eastward-flowing Agulhas Return Current (ARC) near 40° S (Fig. 2). However, not all of the Agulhas water turns back to the Indian Ocean. That part that does not turn back passes into the South Atlantic, in what is often called Agulhas leakage. Several eddies spun-off or detached from the main AC and may remain in the general area for extended periods (LUTJERHAMS & WALTERS, 1985). Most eddies are ejected into the Benguela Current (BeC) and drift away toward northwest (Fig. 2). These eddies are among the most energetic in the world ocean and are believed to have life spans of many years. Sometimes the generation of anticyclonic frontal vortices are responsible on the transport of thermophilic forms out of their usual area of occurrence (FIGUEROA *et al.*, 1998).

The BeC, with its Indian Ocean component, directly feeds the South Equatorial Current of the Atlantic Ocean (SECAO) which flows westward to South America. A branch of the SECAO goes northwestward forming the North Brazil Coastal Current (NBCC) and a southern part of the SECAO is carried by the warm southward flowing Brazil Current (BrC). The BrC, the western boundary current associated with the sub-tropical gyre in the South Atlantic Ocean, flows southward along the continental margin of South America and turns away from the coast at about 36-38° S (Fig. 2). After its confluence with the Malvinas Current (MC), the BrC separates from the shelf break and turns southeast towards deeper waters in a series of large amplitude meanders and eddies (OLSON *et al.*, 1988) (Fig. 2). It has been hypothetized that since some Agulhas rings can cross the full width of the South Atlantic Ocean relatively intact they will eventually reach the BrC, interact with it and modify its subsequent behaviour (CAMPOS *et al.*, 1999).

SOARES & MOLLER (2001) describe the current at Southern Brazilian Shelf (32-35° S) and suggest maximum along-shore transport in the austral autumn and winter, when downwelling favorable winds tend to spread river water in near shore bands. Local winds in this zone are very energetic in the few days periods band due to the atmospheric frontal systems. Therefore, low-frequency current variations should be expected to contain the combined influences of the seasonal and short-term wind variations, the seasonal Brazil-Malvinas Confluence migrations, the meso-scale processes of the Brazil Current (meanders and eddies), the seasonal cycles of La Plata river and Patos Lagoon runoffs and the short-term variations of the latter. Following these statements, *Arothron firmamentum* could be very near coast in autumn and/or winter time due to Ekman transport remaining in shelf water until summer time when the transport southwards is forced by the north winds on the north Argentinean coast (GUERRERO *et al.*, 1997).

According to the most recent species report from Sea Point in Cape Town (HEEMSTRA, 1995) and the transport mechanisms by means of marine currents, explained above, the unusual occurrence of the Indo-West Pacific *Arothron firmamentum* in the south-west Atlantic might be explained as a trans-oceanic migration from the eastern South Atlantic via the Agulhas leakage. Similar transport mechanisms have also been proposed for other fish species. The first and second reports of the mobulid *Mobula rochenbrunei* in the western Atlantic on an estuarine area of Paranagua bay, Brazil (25° 31'S, 48° 15' W) (BARLETTA *et al.*, 1989; CHAVERT, 1995) were considered as cases of trans-oceanic migration from the Eastern Atlantic, since the species is a common inhabitant of the African coast from Mauritania to Angola (MC EACHRAN & SÉRET, 1990). The presence of the Carangid *Seriola rivoliana* on the British coast of south Devon was also considered as a case of trans-oceanic fish dispersal, but from the Western Atlantic (WHEELER, 1986).

There are also some reports of unusual occurrences of marine mammals such as the sea lion *Arctocephalus tropicalis* in the southwestern Atlantic coast. It was suggested that the species makes long trophic migrations form their usual reproductive areas in Tristan da Cunha Island by means of Oceanic currents (RODRÍGUEZ, 1996). The recovery

of oceanographic cards released into the southeastern Atlantic confirmed some surface routes that could explain the sea lions' transportation from the eastern Atlantic to the southwestern Atlantic. Regarding the oceanographic cards recovered in South America it was suggested a potential route that includes a transportation from the southeastern Atlantic by means of the Benguela Current (BeC), the South Equatorial Current of the Atlantic Ocean (SECAO) and the Brazilian Current (BrC) (RODRÍGUEZ, 1996).

There would be another pathway in the South Ocean. The meridional gaps between the continents of the southern hemisphere and Antarctica allow for a free exchange of water among the Pacific, Atlantic and Indian basins. The Antarctic Circumpolar Current (ACC) is mainly a zonally flowing current carrying polar and subpolar waters from west to east through the Drake Passage (Fig. 2). A way of arrival of *A. firmamentum* to the south-west Atlantic by means of this current is unlikely since the species is antitropical in occurrence, with tropical affinitties.

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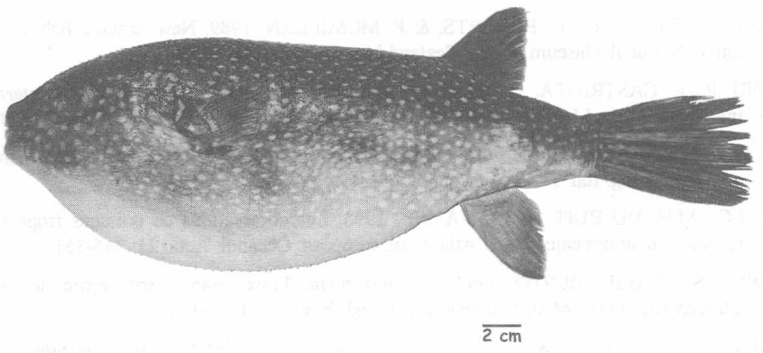

Fig. 1. *Arothron firmamentum*, INIDEP 714, 390 mm TL, off Mar del Plata, Argentina (photo by M. Tobío).

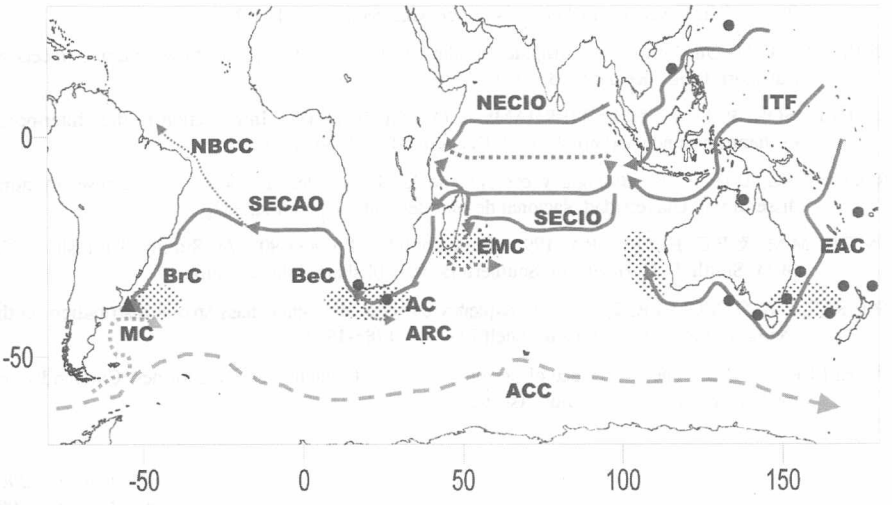

Fig. 2. Geographic distribution of *Arothron firmamentum* based on reported specimens in the literature (*circles*) and recent records (*triangles*), and main surface marine currents on the area of species distribution (*arrows*). **ACC**: Antartic Circumpolar Current; **EAC**: East Australian Current; **ITF**: Indonesian Through Flow; **NECIO**: North Equatorial Current (Indian Ocean); **SECIO**: South Equatorial Current (Indian Ocean); **EMC** : East Madagascar Current; **AC**: Agulhas Current; **ARC**: Agulhas Return Current; **BeC**: Benguela Current; **NECAO**: North Equatorial Current (Atlantic Ocean); **SECAO**: South Equatorial Current (Atlantic Ocean); **NBCC** : North Brazil Coastal Current; **BrC**: Brazil Current; **MC**: Malvinas Current. Shadow areas indicate high eddy energy.

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