VIE ET MILIEU - LIFE AND ENVIRONMENT, 2019, 69 (2-3): 153-157

NEW RECORDS OF BIRDS IN STOMACH CONTENTS OF MARINE APEX PREDATORS FROM THE NORTH ATLANTIC OCEAN AND MEDITERRANEAN SEA

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FEEDING ASSOCIATIONS
CORY'S SHEARWATER
BLUE SHARK
BLUEFIN TUNA
STOMACH CONTENTS
TOP-PREDATOR

ABSTRACT. – Predation on seabirds by sharks or other large predators is a poorly documented issue. The blue shark is a known generalist predator that feeds on seabirds, among other prey. Bluefin tuna is a well-studied species, but to date no species of seabird has been cited as being the prey of any species of Scombridae. The present study reports the first record of Atlantic bluefin tuna (*Thunnus thynnus*) predation on a seabird (Cory's shearwater *Calonectris borealis*). We also provide three new records of blue sharks (*Prionace glauca*) feeding on terrestrial and seabirds in the Northeast Atlantic Ocean and in the Mediterranean Sea. Seabirds can associate with other large marine predators, especially large tunas and marine mammals, in any oceanic region for the purpose of feeding. It is known that small pelagic fish try to flee from predators by approaching the surface of the sea, which is when seabirds take advantage of this situation by attacking them from the air to feed on them. Therefore, during the fishing frenzy, an individual bluefin tuna could have fed on the shearwater. This hypothesis is consistent with our observations. However, the case of seabirds found in the stomachs of blue sharks could imply the intentional and opportunistic predation by blue sharks on seabirds floating on the surface of the sea. On the other hand, exhausted migrating terrestrial birds (non-marine birds) could fall into the sea and thus become prey.

INTRODUCTION

Sharks are known generalist top predators and/or scavengers, of which the majority are white sharks (*Carcharodon carcharias*), blue sharks (*Prionace glauca*), and tiger sharks (*Galeocerdo cuvier*) (Randall *et al*. 1998, Bowman *et al*. 2000, Fergusson *et al*. 2000, Meyer *et al*. 2010). The tiger shark diet often includes birds (Dicken *et al*. 2017). Predation on seabirds by sharks or other large predators is a little documented issue, especially if we consider the different oceans of the world. Seabirds and terrestrial birds are not only predated by sharks, but also by some large teleosts, such as the hapuku (*Polyprion oxygeneios*), snapper (*Pagrus auratus*), and yellowtail kingfish (*Seriola lalandi*) (Duffy & Taylor 2015).

Due to the high proportion of blue sharks caught by commercial longliners worldwide, blue sharks are a well-studied species in terms of distribution, migration, and feeding habits (Vaske *et al*. 2009). This shark species is a known generalist predator that feeds on seabirds, among other prey (Stevens 1973, Compagno 1984, Carey & Scharold 1990). Bluefin tuna (*Thunnus thynnus*) is also a well-studied species, but to date no species of seabird has been cited as prey of any species of Scombridae. The present study reports the first record of Atlantic bluefin tuna predation on a seabird. Furthermore, we provide three new records of terrestrial and seabirds predated by blue sharks in the Northeast Atlantic Ocean and the Mediterranean Sea.

MATERIAL AND METHODS

The records of digested birds reported in the present article were obtained from scientific observer programs on different Spanish tuna and swordfish (*Xiphias gladius*) fishing vessels operating in the North Atlantic Ocean and Western Mediterranean Sea. The stomach content of a bluefin tuna was extracted from a specimen caught in the baitboat fishery targeting bluefin tuna near the Canary Islands during April 2018 (Fig. 1). The stomach contents of blue sharks came from specimens caught in the longline fishery targeting swordfish in the Atlantic Ocean in FAO areas 1.2, 2.0, and 3.2 (next to Cape Verde) between December 2017 and February 2018 (Fig. 1). Using a systematic approach, a scientific observer recruited by the Vigo Harbour Shipowners Collective (Spanish acronym: ARVI) in

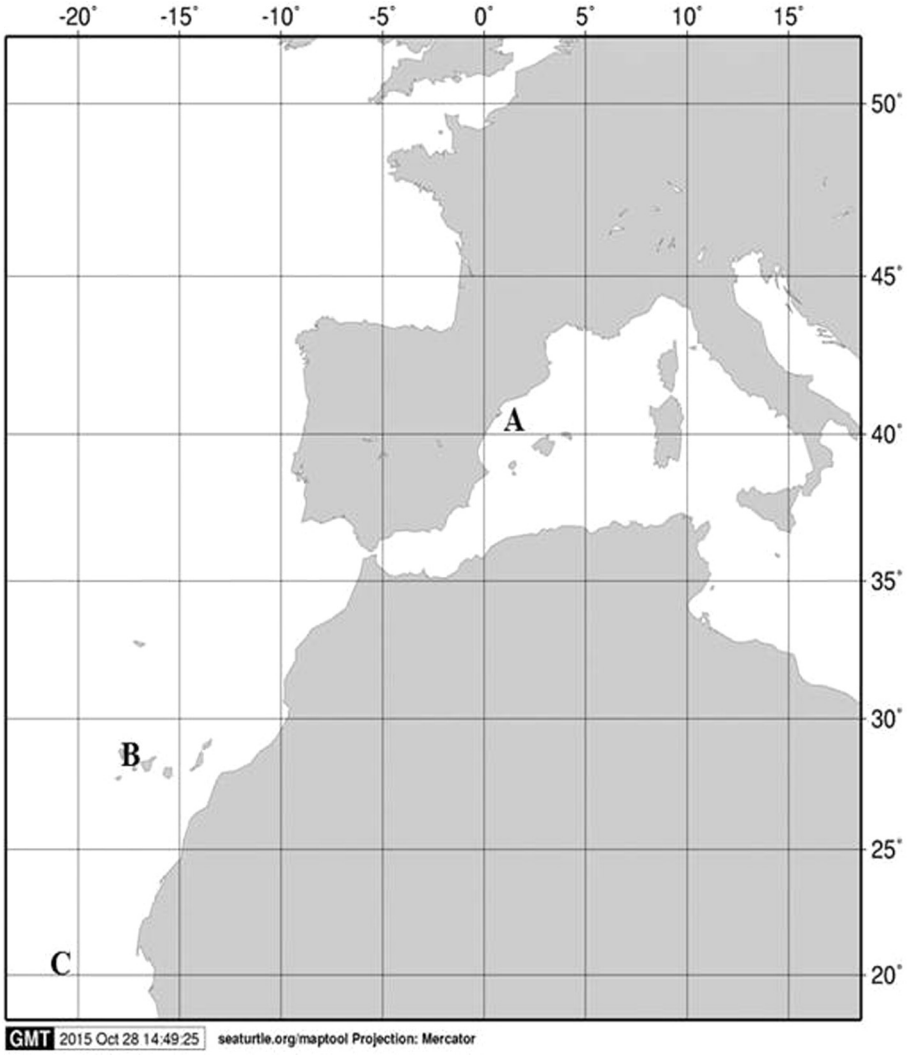

Fig. 1. – Map of the three sampling locations: Ebro delta (A), Canary Islands (B), and Cape Verde (C).

Vigo (Spain) visually checked the stomach contents of blue sharks caught during the trip. Since 1997, the Spanish Institute of Oceanography (Spanish acronym: IEO) has maintained an observer program on board the longline fleet targeting swordfish in the Mediterranean (García-Barcelona *et al*. 2010). The data collected by this program are used to comply with the requirements of various tuna-Regional Fisheries Management Organizations, the main one being the International Commission for the Conservation of Atlantic Tunas. One of the program observers was onboard a surface longliner from Tarragona (NE Spain) in waters over the continental shelf just north of the Ebro delta between January and May 2018 (Fig. 1). In contrast to the situation in the Atlantic Ocean, blue sharks are usually discarded alive in the Mediterranean Sea because of their low commercial value. In this case, some blue sharks were eviscerated on board for commercial use and their viscera were returned to the sea. As carried out in the Atlantic Ocean, the observer visually checked their stomach contents.

The birds found in the stomachs of the blue sharks caught by the Atlantic longliner were photographed and visually identified to genus level. In the case of the Mediterranean sharks, only loose feathers were found in a stomach. In this case, a genetic analysis was conducted to identify the species. The bird found in a bluefin tuna caught near the Canary Islands was frozen and subsequently dissected in a laboratory to determine its sex, age, and other relevant biological information.

DNA extraction, PCR amplification, and sequencing: Total DNA was extracted in a sterile DNA laboratory (i.e. the Laboratory of Molecular Biology – Doñana Biological Station). Several samples of single feathers were analyzed. Each feather unit was pulverized using steel balls after immersion in liquid nitrogen. Total DNA was extracted using the PowerSoil Kit (Qiagen, Hilden, Germany), and two different fragments of a mitochondrial marker (COI) were amplified using different combinations of primer set fragments of 350 bp and 380 bp of the cytochrome oxidase gene subunit I (COI) using primer sets mlCOI/HCO2198 (Leray *et al*. 2013) and COIPrey-FW/COIPrey-RW (Pastor-Beviá *et al*. 2014). Amplification products were sequenced in an ABI 3100 automated sequencer (PE Biosystems, Warrington, UK) following the manufacturer's protocols. Obtained sequences were visually checked using

Sequencher v. 4.9 (Gene Codes Corp, MI, USA). Subsequently, the Basic Local Alignment Search Tool (BLAST) was used to compare the obtained sequences with the available sequences in the GenBank database.

Dissection procedure: The procedure described by Van Franeker (2004) was followed to dissect the frozen bird. Its age and sex were determined by inspecting and measuring its sexual organs and the presence and size of the bursa of Fabricius (Broughton 1994). Standardized biometric measures were recorded: culmen length (CL: from bill-tip to feathering); head and culmen length (HCL: from the bill-tip to the lump of the supraoccipital region of the skull); bill depth at the base of the bill (BDBB); bill depth at nostril (BDN: distal edge of nares); bill depth at gonys (BDG); minimum bill depth (MBD: minimum distance between upper and lower parts of the rhamphotheca), and right tarsus length (RTL: from the middle tarsal joint to the distal length of the tarsometatarsus of the right leg). All measurements were taken using a digital caliper (accuracy ± 0.1 mm). The bird was refrozen after necropsy.

RESULTS

We report the first record of a Cory's shearwater *Calonectris borealis* in the stomach of a bluefin tuna (length 232 cm). It was found in April 2018 in waters off the Canary Islands during a baitboat survey targeting bluefin tuna. This was the first time that a bird was found in a stomach of bluefin tuna during 3 years of surveys in this area (2016, 2017, and 2018). During this period, we analyzed 114 stomachs. The corpse of the Cory's shearwater was relatively well preserved (Fig. 2), but the internal organs were partially deteriorated. Table I shows the biometric measurements. The most abundant fish species present in the stomach contents of the bluefin tuna was *Macroramphosus* spp.

A total of 37 fishing sets were observed (and 1252 blue shark sampling) by the ARVI observer during the longliner targeting swordfish trip in waters north of Cape Verde. The trip started on 26 December 2017 and finished on 20 February 2018. All blue sharks were checked by the observer, and a storm petrel of the genus *Oceanodroma* (probably *O. castro*) was found in the stomachs of two blue sharks. The first event occurred on 27 January 2018 at latitude 21º09'N and longitude 25º05'W, and the second occurred on 30 January 2018 at latitude 21º28'N and longitude 24º36'W. In both cases, the birds were in relatively good condition, although only one photograph was available for identification (Fig. 3). Unfortunately, the corpses were returned to the sea along with the viscera of the blue sharks.

An observer found feathers in the stomach of a blue shark caught by a longliner in the Mediterranean on 19 May 2018. Genetic analyses clearly showed that the feathers came from a common swift *Apus apus*.

Fig. 2. – Storm petrel (genus *Oceanodroma*) found in the stomach of a blue shark caught north of Cape Verde.

Fig. 3. – Cory's shearwater found in the stomach of a bluefin tuna caught in waters near the Canary Islands.

Table I. – Standardized biometric measures (mm) of the Cory's shearwater found in the stomach of the bluefin tuna caught in Canary Islands waters.

CL	HCL	BDBB	BDN	BDG	MBD	RTL
57.5	114.15	22.7	16.8	16.9	16.3	59.8

DISCUSSION

Interactions between large fish and seabirds are usually related to the presence of food near the surface (Hebshi *et al*. 2008). Many species of seabirds show a strong tendency to form multispecies feeding flocks (Ainley & Boekelheide 1983) that are strongly dependent upon prey driven to the surface by predatory fish, mainly tuna and marine mammals (Ashmole & Ashmole 1967, Evans 1986, Hebshi *et al*. 2008, Reyes-González & González-Solís 2016a). Moreover, it is also known that small pelagic fish species try to flee from predators by approaching the surface of the sea, which is when seabirds take advantage of this situation by attacking them from the air in the attempt to feed on them (Martin 1986, Morgan 1986, Clua & Grosvalet 2001). Therefore, the seabirds are at risk of being swallowed during the feeding frenzy. This risk is especially elevated in birds that can plunge to depths of several meters, such as Cory's shearwaters (Mougin & Mougin 1998, Paiva *et al*. 2010). It is thus possible for an individual large predator, like a bluefin tuna, to unintentionally swallow a seabird. In fact, *Macroramphosus* sp. was the most abundant prey of the bluefin tuna which swallowed the Cory's shearwater. This species, together with *Capros aper*, is very abundant in Macaronesian waters (Fock *et al*. 2002), and has also become the usual prey of Cory's shearwater around the Azores Islands (Granadeiro *et al*. 1998). Its association with tunas during these feeding episodes could be a natural source of seabird mortality. Thus, Xavier *et al*. (2011) highlighted the need for further research on the potentially negative impact on the Cory's shearwater population by tuna fisheries and fishing vessels. Such impacts can occur either directly, due to competition for prey, or indirectly, due to overfishing for tuna and the concomitant reduction in feeding associations between birds and tuna.

The sex and age of the Cory's shearwater could not be determined by inspection of the internal organs. However, the length of the right tarsus (RTL) and culmen length (CL) were within the range described for males (Reyes-González & González-Solís 2016b). The bird may have belonged to one of the following colonies: San Miguel (Portugal), Flores (Portugal), Corvo (Portugal), Faial (Portugal), the Azores (Portugal), Madeira (Portugal), Berlengas (Portugal), or Gran Canaria (Spain).

However, the case of *Oceanodroma* petrels found in the stomachs of blue sharks could be due to an intentional or opportunistic attack by the sharks when the seabirds were resting, injured, or dead on the sea surface (Kohler & Stillwell 1981). Blue sharks feed on a wide variety of prey, including fish, squid, birds, and the carrion of marine mammals (Cortés 1999). Stomachs often contain anthropogenic material, such as plastic debris and even dogs (McCord & Campana 2003, Vaske *et al*. 2009). Therefore, blue sharks could play an important role as scavenger in the global ocean ecosystem (Markaida & Sosa-Nishizaki 2010). The opportunistic prey of blue sharks includes different species of birds, such as pigeons, shearwaters, or mockingbirds (Vaske *et al*. 2009, Rivera *et al*. 2015). The two *Oceanodroma* specimens found in the stomach of blue sharks in waters north of Cape Verde were relatively fresh. This is first time that this species is found in the stomachs of blue sharks. Given that these two birds were eaten and then detected during a single trip of only 37 fishing sets, the number of predated *Oceanodroma* storm petrels could be relatively high, particularly if they were *O. castro*, which is a species with declining populations (BirdLife International 2016). The birds were not ringed and thus their geographical origin is unknown.

Finally, the consumption of birds by blue sharks in the Mediterranean Sea is very little documented, mainly because the remains of birds or feathers are usually left unidentified (e.g. Mendonça 2009, Markaida & Sosa-Nishizaki 2010). We decided to use genetic analysis to identify the species of bird to which the loose feathers belonged. As result, we identified a new species of terrestrial bird, the common swift, that had been swallowed by a blue shark. The common swift is a very abundant trans-equatorial migratory species in the Palearctic. As previously described (Dodrill 1977, Gallagher *et al*. 2011), exhausted swifts may fall into the sea during their migratory flight. This fact contributes to knowledge on the scavenger role of sharks in sea ecosystems and to a better understanding of the functioning of ocean food webs.

ACKNOWLEDGMENT. – We would like to thank Dr J Juste and the staff of the Laboratory of Molecular Ecology-Doñana Biological Station for their excellent work in identifying the common swift species via the remains of loose feathers. We would also like to acknowledge S Coxon for his professional proofreading services. The present study was supported by different projects of the Instituto Español de Oceanografía (IEO).

CONFLICT OF INTEREST. – On behalf of all authors, the corresponding author states that there is no conflict of interest.

REFERENCES

Ainley DG, Boekelheide RJ 1983. An ecological comparison of oceanic seabird communities of the South Pacific. *Stud Avian Biol* 8: 2-23.

Ashmole NP, Ashmole MJ 1967. Comparative feeding ecology of seabirds of a tropical oceanic island. *Peabody Mus Nat Hist Yale Univ Bull* 24: 1-131.

BirdLife International 2016. *Hydrobates castro*. The IUCN Red List of Threatened Species 2018: e.T132341128A132433305. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T132341128A132433305.en. Downloaded on 21 October 2019.

Bowman RE, Stillwell CE, Michaels WL, Grosslein MD 2000. Food of Northwest Atlantic fishes and two common species of squid. NOAA Technical Memorandum NMFS-NE-155, NOAA, USA: 149 p.

Broughton JM 1994. Size of the bursa of Fabricius in relation to gonad size and age in Laysan and black-footed albatrosses. *Condor* 96: 203-207.

Carey FG, Scharold JV 1990. Movements of blue sharks *Prionace glauca* in depth and course. *Mar Biol* 106: 329-342.

Clua E, Grosvalet F 2001. Mixed-species feeding aggregation of dolphins, large tunas and seabirds in the Azores. *Aquat Living Resour* 14: 11-18.

Compagno LJV 1984. FAO Species Catalogue. Vol 4: Sharks of the world, Part 2 – Carcharhiniformes. *FAO Fish Syn* 125, 4(2): 251-633.

Cortés E 1999. Standardized diet compositions and trophic levels of sharks. *ICES J Mar Sci* 56: 707-717.

Dicken ML, Hussey NE, Christiansen HM, Smale MJ, Nkabi N, Cliff G, Wintner SP 2017. Diet and trophic ecology of the tiger shark *Galeocerdo cuvier* from South African waters. *PLoS ONE* 12(6): e0177897.

Dodrill JW 1977. Land Birds in the stomachs of Tiger sharks *Galeocerdo cuvieri* Peron & Lesueur. *Auk* 95: 585-586.

Duffy CAJ, Taylor GA 2015. Predation on seabirds by large teleost fishes in northern New Zealand. *Bull Auckland Mus* 20: 497-500.

Evans PGH 1986. Associations between seabirds and cetaceans: a review. *Mammal Rev* 12: 187-206.

Fergusson IK, Compagno LJV, Marks MA 2000. Predation by white sharks *Carcharodon carcharias* Chondrichthyes: Lamnidae, upon chelonians, with new records from the Mediterranean Sea and a first record of the ocean sunfish *Mola mola* Osteichthyes: Molidae, as stomach contents. *Environ Biol Fish* 58: 447-453.

Fock H, Uiblein F, Koster F, Westerhagen H 2002. Biodiversity and species-environment relationships of the demersal fish assemblage at the Great Meteor Seamount subtropical NE Atlantic sampled by different trawls. *Mar Biol* 141:185-199.

Gallagher AJ, Jackson T, Hammerschlag N 2011. Occurrence of tiger shark *Galeocerdo cuvier*, scavenging on avian prey and its possible connection to large-scale bird die-offs in the Florida keys. *Fla Sci* 74: 264-269.

García-Barcelona S, Ortiz de Urbina JM, de la Serna JM, Alot E, Macías D 2010. Seabird by-catch in Spanish Mediterranean large pelagic logline fisheries, 1998-2008. *Aquat Living Resour* 23: 363-371.

Granadeiro JP, Monteiro LR, Furness RW 1998. Diet and feeding ecology of *Calonectris diomedea* in the Azores, northeast Atlantic. *Mar Ecol Prog Ser* 166: 267-276.

Hebshi AJ, Duffy DC, Hyrenbach KD 2008. Associations between seabirds and subsurface predators around Oahu, Hawaii. *Aquat Biol* 4: 89-98.

Kohler NE, Stillwell CE 1981. Food habits of the blue shark *Prionace glauca*, in the Northwest Atlantic. International Council for the Exploration of the Sea. Report CM 1981/H: 61 p.

Leray M, Yang JY, Meyer CP, Mills SC, Agudelo N, Ranwez V, Boehm JT, Machida RJ 2013. A new versatile primer set targeting a short fragment of the mitochondrial COI region for metabarcoding metazoan diversity: application for characterizing coral reef fish gut contents. *Front Zool* 10: 34.

Markaida U, Sosa-Nishizaki O 2010. Food and feeding habits of the blue shark *Prionace glauca* caught off Ensenada, Baja California, Mexico, with a review on its feeding. *J Mar Biol Ass UK* 90: 977-994.

Martin AR 1986. Feeding association between dolphins and shearwaters around the Azores Islands. *Can J Zool* 64: 1372-1374.

McCord ME, Campana SE 2003. A Quantitative assessment of the diet of the blue shark *Prionace glauca* off Nova Scotia, Canada. *J Northw Atl Fish Sci* 32: 57-63.

Mendonça A 2009. Diet of the blue shark, *Prionace glauca*, in the Northeast Atlantic. Master Thesis, Departamento de Biología, Faculdade de Ciências da Universidade do Porto: 36 p.

Meyer CG, Papastamatiou YP, Holland KN 2010. A multiple instrument approach to quantifying the movement patterns and habitat use of tiger *Galeocerdo cuvier*, and Galapagos sharks *Carcharhinus galapagensis,* at French Frigate Shoals, Hawaii. *Mar Biol* 157: 1857-1868.

Mougin JL, Mougin MC 1998. Les profondeurs maximums atteintes en plongée par le puffin cendré *Calonectris diomedea* au cours de ses voyages alimentaires de la période d'incubation. *Rev Ecol* 53: 69-76.

Morgan PG 1986. Cory's shearwater associating with dolphins. *Br Birds* 79: 87.

Paiva VH, Geraldes P, Ramírez I, Meirinho A, Garthe S, Ramos JA 2010. Foraging plasticity in a pelagic seabird species along a marine productivity gradient. *Mar Ecol Prog Ser* 398: 259-274.

Pastor-Beviá D, Ibáñez C, García-Mudarra JL, Juste J 2014. A molecular approach to the study of avian DNA in bat faeces. *Acta Chiropt* 16: 451-460.

Randall BM, Randall RM, Compagno LJV 1988. Injuries to jackass penguins *Spheniscus demersus*, evidence for shark involvement. *J Zool* 213: 589-599.

Reyes-González JM, González-Solís J 2016a. Pardela cenicienta mediterránea-*Calonectris diomedea*. *In* Salvador A, Morales MB Eds, Enciclopedia Virtual de los Vertebrados Españoles. Museo Nacional de Ciencias Naturales, Madrid. http://www.vertebradosibericos.org/. Accessed 25 Aug. 2018.

Reyes-González JM, González-Solís J 2016b. Pardela cenicienta atlántica-*Calonectris borealis*. *In* Salvador A, Morales MB Eds, Enciclopedia Virtual de los Vertebrados Españoles. Museo Nacional de Ciencias Naturales, Madrid. http://www.vertebradosibericos.org/. Accessed 25 Aug. 2018.

Rivera MJ, Hernández Vázquez S, Galván Magaña F, Leonardo Pérez EL 2015. A Mockingbird *Mimus polyglottos* Linnaeus, 1758, found in a stomach of a blue shark *Prionace glauca* Linnaeus, 1758. *CICIMAR Oceánides* 30: 53-54.

Stevens JD 1973. Stomach contents of the Blue Shark *Prionace glauca* L. off South-West England. *J Mar Biol Ass UK* 53: 357-361.

Van Franeker JA 2004. Save the North Sea Fulmar-Litter-EcoQO Manual Part 1: Collection and dissection procedures. Alterra-rapport 672. Alterra, Wageningen.

Vaske T Jr, Lessa RP, Gadig OBF 2009. Feeding habits of the blue shark *Prionace glauca,* off the coast of Brazil. *Biota Neotrop* 9: 55-60.

Xavier JC, Magalhães MC, Mendonça AS, Antunes M, Carvalho N, Machete M, Santos RS, Paiva V, Hamer KC 2011. Changes in diet of Cory's Shearwaters *Calonectris diomedea* breeding in the Azores. *Mar Ornithol* 39: 129-134.

Received on January 1, 2019
Accepted on October 21, 2019
Associate editor: J Michaux