

## Morphological and molecular identification of a new *Kudoa thyrsites* isolate in Mediterranean silver scabbardfish *Lepidopus caudatus*

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Table S1. Spore measurements (mean, standard deviation and range, in  $\mu\text{m}$ ) of different geographical isolates of *Kudoa thyrsites* and *Kudoa histolytica* (possible junior synonym of *K. thyrsites*; Whipps & Kent 2006). W1, Width1; W2, Width2; T1, Thickness1; T2, Thickness2; L, Length; LPCL, Length of large polar capsule; LPCW, Width of large polar capsule; IPCL, Length of intermediate polar capsule; IPCW, Width of intermediate polar capsule; SPCL, Length of small polar capsule; SPCW, Width of small polar capsule. (–) no data available.

Locality, no. of spores	Host species	Reference	Spore					Polar capsules					
			W1	W2	T1	T2	L	LPCL	LPCW	IPCL	IPCW	SPCL	SPCW
Alboran Sea, n = 60	<i>Lepidopus caudatus</i>	Present study	15.5 ± 1.0 (13.0–17.5)	14.5 ± 1.0 (12.0–17.0)	12.0 ± 1.0 (9.5–14.5)	10.0 ± 1.0 (8.5–12.5)	7.5 ± 1.0 (6.5–11.0)	5.0 ± 0.5 (4.0–6.5)	–	3.5 ± 1.0 (2.5–6.0)	–	3.0 ± 0.5 (1.5–4.5)	–
Norwegian Sea, n = 60	<i>Scomber scombrus</i>	Present study	15.5 ± 1.5 (13.0–18.5)	14.5 ± 1.5 (11.5–17.5)	12.0 ± 1.5 (9.5–17.5)	9.5 ± 1.0 (7.0–11.5)	7.0 ± 1.0 (5.5–8.0)	5.5 ± 1.0 (4.5–7.5)	–	4.0 ± 1.0 (2.5–5.5)	–	3.0 ± 0.5 (2.0–4.0)	–
North Sea, n = 30	<i>Scomber scombrus</i>	Levsen et al. (2008)	14.6 ± 0.7 (13.0–16.0)	–	7.9 ± 0.2 (7.5–8.1)	–	8.3 ± 0.6 (7.2–9.2)	5.8 ± 0.5 (5.0–7.0)	3.1 ± 0.2 (2.8–3.6)	4.7 ± 0.5 (3.7–5.7)	2.4 ± 0.1 (2.2–2.6)	3.7 ± 0.3 (3.2–4.2)	2.3 ± 0.2 (2.1–2.5)
England, n = 20	<i>Scomber scombrus</i>	Whipps & Kent (2006) <sup>a</sup>	14.3 ± 0.92 (13.0–16.3)	–	7.61 ± 0.51 (6.9–8.9)	–	7.40 ± 0.43 (6.8–8.2)	6.21 ± 0.32 (5.7–6.7)	3.33 ± 0.28 (2.8–3.8)	–	–	4.88 ± 0.24 (4.4–5.3)	2.68 ± 0.2 (2.3–3.0)
SW France, n = –	<i>Scomber scombrus</i>	Pérard (1928) <sup>a</sup>	(12.0–15.0)	–	–	–	(7.0–9.0)	(3.0–6.0)	–	–	–	–	–
South Africa, n = –	<i>Thyrsites autun</i>	Gilchrist (1924)	12.0	–	–	–	8.0	3.0	2.0	–	–	–	–
South Africa, n = 20	<i>Sardinops ocellatus</i>	Whipps & Kent (2006)	13.64 ± 0.77 (12.5–14.9)	–	7.00 ± 0.35 (6.4–7.5)	–	7.01 ± 0.38 (6.7–7.8)	5.93 ± 0.41 (5.3–6.7)	3.27 ± 0.26 (2.8–3.9)	–	–	4.83 ± 0.19 (4.6–5.3)	2.57 ± 0.2 (2.2–3.0)
South Africa, n = 20	<i>Beryx splendens</i>	Yokoyama & Itoh (2005)	12.6 (11.7–14.6)	–	10.1 (9.0–11.7)	–	6.8 (5.9–7.3)	4.6 (3.2–6.8)	2.6 (2.2–3.2)	–	–	2.0 (1.5–2.7)	1.3 (1.0–1.7)
British Columbia, n = 20	<i>Salmo salar</i>	Whipps & Kent (2006)	15.26 ± 0.84 (13.6–16.5)	–	7.57 ± 0.44 (6.7–8.2)	–	7.31 ± 0.51 (6.2–8.3)	5.06 ± 0.33 (4.6–5.7)	2.77 ± 0.23 (2.1–3.1)	–	–	3.98 ± 0.31 (3.5–4.7)	2.07 ± 0.16 (1.7–2.3)
British Columbia, n = 26	<i>Aulorhynchus flavidus</i>	Shaw et al. (1997)	14.25 ± 1.07 (12.7–17.9)	–	10.98 ± 0.21 (8.60–12.37)	–	7.07 ± 0.76 (5.6–8.5)	5.27 ± 0.56 (4.2–6.9)	3.18 ± 0.41 (2.4–3.7)	–	–	3.42 ± 0.36 (2.5–4.0)	2.38 ± 0.46 (1.5–3.3)
British Columbia, n = 70	<i>Merluccius productus</i>	Kabata & Whitaker (1981)	16.67 ± 1.24 (14–19)	–	12.73 ± 1.13 (10.0–14.0)	–	7.14 ± 0.80 (6.0–8.0)	5.43 ± 0.97 (4.90–5.88)	3.34 (2.84–3.92)	–	–	4.12 ± 0.82 (2.94–4.90)	2.41 (1.96–2.94)

Locality, no. of spores	Host species	Reference	Spore					Polar capsules					
			W1	W2	T1	T2	L	LPCL	LPCW	IPCL	IPCW	SPCL	SPCW
Oregon, n = 20	<i>Merluccius productus</i>	Whipps & Kent (2006)	16.71 ± 1.5 (14.9–19.6)	–	8.35 ± 0.60 (7.4–9.6)	–	7.73 ± 0.49 (6.6–8.6)	6.78 ± 0.65 (5.4–7.8)	3.62 ± 0.38 (2.7–4.3)	–	–	5.09 ± 0.55 (4.1–5.9)	2.76 ± 0.26 (2.3–3.2)
Oregon, n = 20	<i>Pholis ornata</i>	Whipps & Kent (2006)	14.95 ± 1.02 (13.0–17.1)	–	7.9 ± 0.42 (7.0–9.0)	–	7.41 ± 0.38 (6.7–7.9)	6.76 ± 0.43 (6.1–7.5)	3.77 ± 0.36 (3.1–4.5)	–	–	5.22 ± 0.35 (4.5–6.1)	2.75 ± 0.32 (2.1–3.4)
Oregon, n = 20	<i>Leptocottus armatus</i>	Whipps & Kent (2006)	14.23 ± 0.78 (12.5–16.0)	–	7.8 ± 0.39 (7.0–8.5)	–	7.14 ± 0.35 (6.4–7.7)	6.95 ± 0.41 (6.3–7.8)	3.95 ± 0.31 (3.3–4.4)	–	–	5.53 ± 0.28 (4.9–6.0)	3.06 ± 0.28 (2.4–3.7)
Western Australia, n = 20	<i>Coryphaena hippurus</i>	Langdon (1991)	14.0 ± 1.1 (12.3–16.3)	–	10.3 ± 0.7 (9.3–11.3)	–	(7.3–8.2)	6.3 ± 0.3 (5.8–6.9)	2.9 ± 0.2 (2.7–3.2)	5.1 ± 0.4 (4.2–5.5)	2.3 ± 0.1 (2.2–2.6)	4.3 ± 0.3 (3.8–4.8)	1.9 ± 0.4 (1.8–2.3)
Japan, n = 20	<i>Paralichthys olivaceus</i>	Yokoyama et al. (2004)	14.7 (12.9–17.8)	–	7.8 (6.9–8.9)	–	7.6 (6.9–7.9)	5.0 (4.0–5.9)	2.5 (1.5–3.0)	–	–	2.8 (2.0–4.0)	1.6 (1.5–2.5)
Japan, n = 12	<i>Thamnaconus modestus</i>	Kasai et al. (2016)	16.5 (14.8–18.2)	–	12.5 (10.8–13.5)	–	8.7 (8.5–9.0)	5.7 (5.2–6.2)	2.9 (2.6–3.2)	–	–	3.6 (2.3–4.6)	1.7 (1.1–2.6)

<sup>a</sup>Measurements of *K. histolytica*, possible junior synonym of *K. thyrsites* (Whipps & Kent 2006).

## LITERATURE CITED

- Gilchrist JDF (1924) A protozoal parasite *Chloromyxum thyrsites* sp. n. of the Cape sea-fish, the “snoek” (*Thyrsites atun* Euphr.). Trans R Soc S Afr 11:263–273
- Kabata Z, Whitaker DJ (1981) Two species of *Kudoa* (Myxosporea: Multivalvulida) parasitic in the flesh of *Merluccius productus* (Pisces: Teleostei) in the Canadian Pacific. Can J Zool 59:2085–2091
- Kasai A, Li YC, Mafie E, Sato H (2016) New host records of monacanthid fish for three *Kudoa* spp. (*K. septempunctata*, *K. thyrsites* and *K. shiomitsui*) prevalent in the olive flounder (*Paralichthys olivaceus*), with the description of *K. parathyrsites* n. sp. from a black scraper (*Thamnaconus modestus*). Parasitol Res 115:2741–2755
- Langdon JS (1991) Myoliquefaction post-mortem (“milky flesh”) due to *Kudoa thyrsites* (Gilchrist) (Myxosporea: Multivalvulida) in mahi mahi, *Coryphaena hippurus* L. J Fish Dis 14:45–54
- Levsen A, Jørgensen A, Mo TA (2008) Occurrence of postmortem myoliquefactive kudoosis in Atlantic mackerel, *Scomber scombrus* L., from the North Sea. J Fish Dis 31:601–611
- Pérard C (1928) Sur une maladie du maquereau (*Scomber scomber* L.) due à une myxosporidie: *Chloromyxum histolyticum* n. sp. C R Acad Sci 186: 108–110 (in French)
- Shaw RW, Hervio DML, Devlin RH, Adamson ML (1997) Infection of *Aulorhynchus flavidus* (Gill) (Osteichthyes: Gasterosteiformes) by *Kudoa thyrsites* (Gilchrist) (Myxosporea: Multivalvulida). J Parasitol 83:810–814
- Whipps CM, Kent ML (2006) Phylogeography of the cosmopolitan marine parasite *Kudoa thyrsites* (Myxozoa: Myxosporea). J Eukaryot Microbiol 53:364–373
- Yokoyama H, Itoh N (2005) Two multivalvulid myxozoans causing postmortem myoliquefaction: *Kudoa megacapsula* n. sp. from red barracuda (*Sphyraena pinguis*) and *Kudoa thyrsites* from splendid alfonso (*Beryx splendens*). J Parasitol 91:1132–1137
- Yokoyama H, Whipps CM, Kent ML, Mizuno K, Kawakami H (2004) *Kudoa thyrsites* from Japanese flounder and *Kudoa lateolabracis* n. sp. from Chinese sea bass: causative myxozoans of post-mortem myoliquefaction. Fish Pathol 39:79–85