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Records of the Ocean Sunfish (*Mola mola*, Tetraodontiformes) in the German Baltic Sea

Nachweise von Mondfischen (*Mola mola*, Tetraodontiformes) im deutschen Ostseegebiet

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Summary: Twenty-three records of ocean sunfish (*Mola mola*) have been recorded since 1860 in German waters of the Baltic Sea. Nineteen of them happened since 1978. In comparison to the maximum size of the species the respective individuals are rather small with only 59.3 cm body length in average. This could be the result of a common behaviour of smaller ocean sunfish specimens to aggregate in coastal waters. Thus smaller specimens are more likely to reach the Baltic Sea via the Belts. The common explanation of ocean sunfish being flushed into the Baltic Sea by major inflow events explains only part of the records. Many questions remain open: Why are ocean sunfish recorded almost exclusively around November when no major inflow events happened? Are they unable to survive for a longer time in this environment? If yes, due to which reason? Is there an accumulation of records of ocean sunfish during the last years? If yes, what could be the reason for this? Also future records of ocean sunfish from the Baltic Sea will answer some questions and pose new questions at the same time.

Keywords: Major inflow event, exotic species, Molidae

Zusammenfassung: Seit 1860 konnten 23 Nachweise von Mondfischen (*Mola mola*) in der deutschen Ostsee belegt werden. Neunzehn davon stammen aus den Jahren nach 1978. Mit durchschnittlich 59,3 cm Länge sind die Individuen, auf die maximale Körperlänge der Art bezogen, eher klein. Möglicherweise ist dafür das Verhalten verantwortlich, dass sich kleinere Mondfische oft küstennah und dann zuweilen in größeren Ansammlungen aufhalten. Somit könnten kleinere Exemplare eher durch die Belte in die Ostsee gelangen. Die übliche Erklärung, dass Mondfische durch größere Salzwassereinbrüche in die Ostsee geschwemmt werden, passt nur auf einen Teil der Nachweise. Viele Fragen bleiben jedoch offen: Warum treten Mondfische auch ohne größere Salzwassereinbrüche praktisch immer im November in der Ostsee auf? Können sie dort nicht länger überleben? Und wenn ja, warum genau? Gibt es eine Häufung von Mondfischnachweisen in den letzten Jahren? Und wenn ja, was ist hier die Ursache? Auch weiterhin werden die seltenen Nachweise von Mondfischen aus der Ostsee einige Fragen beantworten und weitere aufwerfen.

Schlüsselwörter: Salzwassereinströme, Irrgäste, Molidae

1. Introduction

For most of its area and volume the Baltic Sea represents a brackish environment. Excluding the Kattegat 112 fish species have been recorded which permanently live in the Baltic Sea (HELCOM 2012). But there is about the same amount, 105 species, of 'exotic' fishes recorded in that area (HELCOM 2012). They may be introduced by humans, entering from the freshwater influents or migrating via the Belt Sea from the marine environment of the North Sea. Marine exotic species are for example various shark and ray species, bass (*Dicentrarchus labrax*), striped red mullet (*Mullus surmuletus*), several species of the family Sparidae and also very conspicuous species like opah (*Lampris guttatus*), swordfish (*Xiphias gladius*) or ocean sunfish (*Mola mola*) (fig. 1; Winkler & Schröder 2003; HELCOM 2012).

With 2.3 tons weight sunfishes are considered to be the heaviest bony fish of the world (Pope et al. 2010). Plural was used here, as recent studies suggest that indeed there is more than one species in the genus *Mola* (Bass et al. 2005; Pope et al. 2010; Nyegaard et al. 2017; Sawai et al. 2018). The present data proposes that so far in the North and Baltic Seas only the nominal species *Mola mola* (Linnaeus, 1758) has been reported (Sawai et al. 2018). Besides occasional records in South Africa, Australia and New Zealand, this species inhabits mainly tropical and temperate areas of all oceans in the northern hemisphere (Sawai et al. 2018). Sunfishes are not only famous for their size and weight, but also for their curious body shape, resulting from a reduction of the tail and forming of a "new" posterior end, the so called clavus, derived from parts of the dorsal and anal fin (Johnson & Britz 2005).

2. Material and Methods

Actual and historical data on records of ocean sunfish (*Mola mola*) from German waters in the Baltic Sea were compiled from the zoological collection of the University of Rostock and the Deutsches Meeresmuseum. Furthermore information from scientific publications and local newspapers about location of the record and body length were collected, summarized and critically evaluated. For the understanding of the occurrence of the sunfish records were related to the major inflow events in the Baltic Sea known from oceanographic detections.

3. Results and Discussion

3.1. Records of ocean sunfish

With quite some confidence we know of 23 sunfish records in German waters of the Western Baltic Sea since 1860 (tab. 1, figs 1-2). Nineteen of them were found since 1978. For 15 of the latter there are at least estimations on their size, and of 12 we have assured measurements. The body size of the latter ranged from 45 to 67.5 cm length with an average of 54.1 cm. Including the rough size estimations up to 100 cm length reported only in newspapers the average rises to about 59.3 cm. Regarding a maximum size of assured 2.7 m (Pope et al. 2010) and probably more than 3 m (Froese und Pauly 2017) is seems remarkable that apparently only small sunfish enter the Baltic Sea. The only well documented report of a larger specimen is given by Mohr (1929), which was found in the Great Belt at Korsør in 1862. This specimen was noted with 180 cm length. But on the other hand due to the geographic situation of the Baltic Sea its connection to the North Sea can be regarded as bottleneck of coastal environment. Thus, open ocean species first have to enter coastal areas, before they may enter the Baltic Sea via the Belts. For ocean sunfish there are several studies indicating that smaller specimens, i.e. individuals below 1 m length, often stay close to coasts, sometimes forming large aggregations (e.g., Houghton et al. 2006; Pope et al. 2010 for further references). This could explain the limited size range of *Mola* recorded in the Baltic Sea as well as occasional records of several specimens within a short time span.

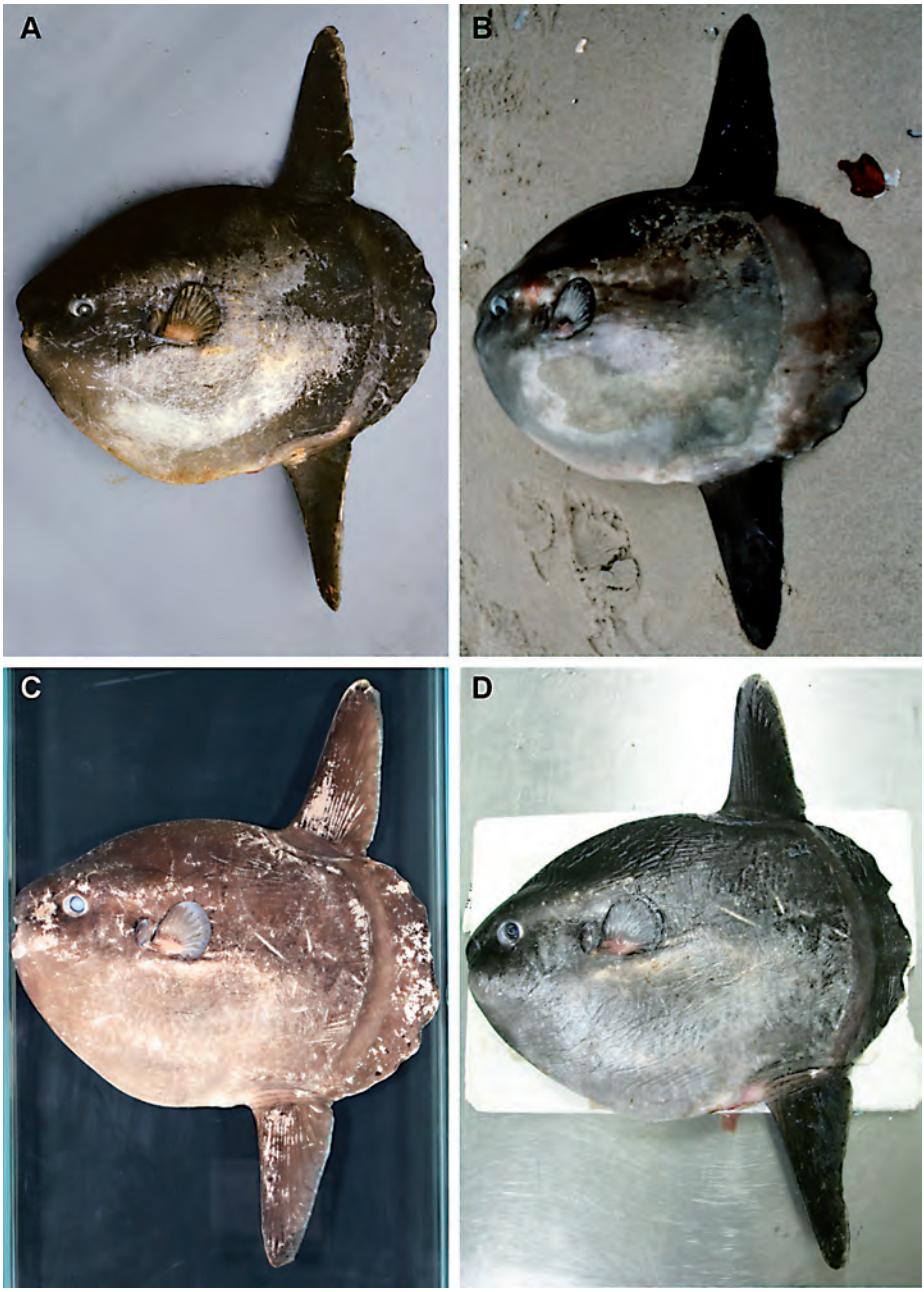

Fig. 1: Ocean sunfish (*Mola mola*) specimens found in the Baltic Sea. **A** Shortly after catching (cast of the specimen as DMM IE/724), 11.04.1978, north of Stubbenkammer, Rügen. **B** On the beach, 27.11.1982, Markgrafenheide. **C** Displayed specimen in the OZEANEUM Stralsund, DMM IE/4748, 06.12.2009 off Dranske, Rügen. **D** Shortly after catching, DMM IE/13801, 13.11.2012, off Sassnitz, Rügen. **Abb. 1:** Mondfische (*Mola mola*) aus der Ostsee. **A** Direkt nach dem Fang (Replik des Tieres unter DMM IE/724), 11.04.1978, nördlich von Stubbenkammer, Rügen. **B** Am Strand von Markgrafenheide, 27.11.1982. **C** Exponat im Ozeaneum Stralsund, DMM IE/4748, vom 06.12.2009, vor Dranske, Rügen. **D** Direkt nach dem Fang, DMM IE/13801, vom 13.11.2012, vor Sassnitz, Rügen.

Tab. 1: Records of ocean sunfish (*Mola mola*) from the Baltic Sea in Germany.
Tab. 1: Nachweise von Mondfischen (*Mola mola*) aus der deutschen Ostsee.

date	location	length (in cm)	type of record	remarks
12/04/2015	Markgrafenheide	52	stranded	reported by press, ZSRO
12/04/2015	Scharbeutz, Mecklenburg Bight	56	caught	reported by press
14/12/2014	Fehmarn, Bojendorf	-	stranded	pers. comm. R. Lemcke
13/11/2012	Off Sassnitz, Rügen	46	caught	specimen at DMM
12/10/2009	Off Rügen	49	caught	
12/06/2009	Off Dranske	46	caught	
25/11/2009	Sehlendorf, Plön	~80	stranded	reported by press
25/11/2009	Heilgenhafen	~100	stranded	reported by press
24/11/2007	Elmenhorst	52	stranded	pers. comm. B. Mattis, parts in ZSRO
10/12/2000	North of Cap Arkona, Rügen		caught	pers. comm. H. Schröder
01/12/1999	Eastern Schwansee	65	?	pers. comm. H. Schröder
11/08/1995	Ahrenshoop	45	stranded	pers. comm. H. Schröder
02/09/1989	Wismar	-	caught	pers. comm. H. Schröder
15/11/1985	Markgrafenheide	65		pers. comm. H. Schröder
02/11/1984	Warnemünde, Rostock	-	stranded	pers. comm. H. Schröder
12/01/1982	Ahrenshoop	~60	stranded	Busching & Pagel (1982)
27/11/1982	Markgrafenheide	67,5	stranded	Busching & Pagel (1982)
24/10/1979	Off Hiddensee	49	caught	replica at DMM; Busching & Pagel (1982)
11/04/1978	North off Stubbenkammer	57	caught	replica at DMM; Busching & Pagel (1982)
1964	Graal Müritz	-	stranded	Busching & Pagel (1982), Martinköwitz (1969)
11/05/1941	Börgerende, Heiligendamm	-	stranded	
08/01/1936	Wustrow, Fischland	54	stranded	Busching & Pagel (1982), in ZSRO
1860/64	Flensburg	-		Mohr (1929)

DMM – Deutsches Meeresmuseum
ZSRO- Zoologische Sammlung Universität Rostock

3.2. Reasons for ocean sunfish to enter the Baltic Sea

The usual explanation for records of *Mola mola* in the Baltic Sea was that they were rather passively driven be saltwater inflow events via the Belts. Such major inflow events of saltwater to the Baltic occur irregularly, usually during winter, depending on wind conditions over several days (Lass & Matthäus 1996). Since the beginning of the 1980s the amount of inflow events has drastically declined (Mohrholz et al. 2015). Major inflows happened in December 2014 (Mohrholz et al. 2015), November 2015 and January/February 2016 (Naumann et al. 2016). The 2015 event apparently is responsible

Fig. 2: Ocean sunfish (*Mola mola*) records in the German Baltic Sea area.
Abb. 2: Nachweisen von Mondfischen (*Mola mola*) im Gebiet der Deutschen Ostsee.

for the subsequent record of at least three ocean sunfish in November and December of the same year (tab. 1, fig. 3). Many other records, however, do not fit in this scheme of inflow events flushing *Mola* specimens into the Baltic Sea (fig. 3). An explanation could be that major inflow events are recorded as such only if fresh saline water reaches the depth of the central Baltic Sea. Minor inflow events, however, may be sufficient to enhance sunfish translocation through the Belts. Once arrived in the Western Baltic Sea they may spread independent of inflow events towards the more eastern Baltic areas. Studies using

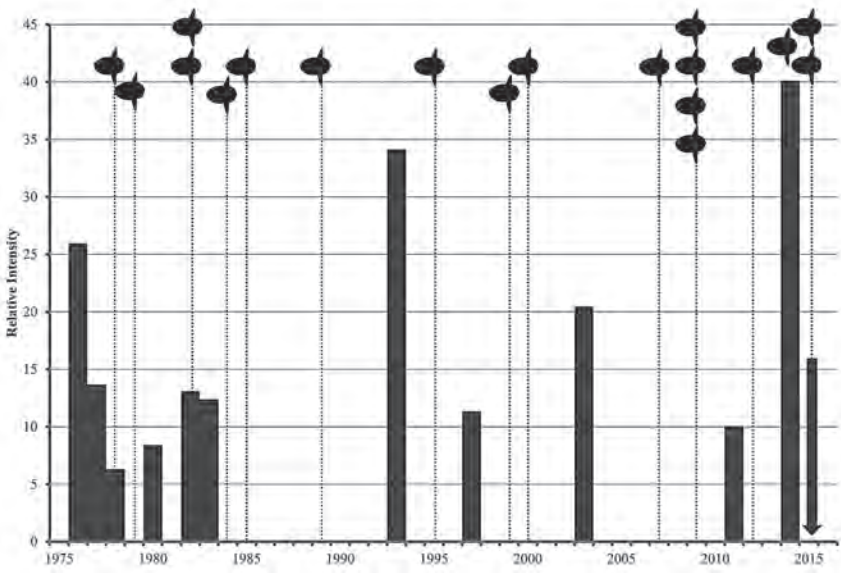

Fig. 3: Major inflow events into the Baltic (modified, after Mohrholz et al. 2015) and records of Ocean sunfish (*Mola mola*) in German waters of the Baltic Sea; arrow – inflow event without detailed data available.
Abb. 3: Größere Salzwassereinbrüche in die Ostsee (verändert nach Mohrholz et al. 2015) und Nachweise von Mondfischen (*Mola mola*) in der deutschen Ostsee; Pfeil – Salzwassereinbruch (genaue Daten nicht verfügbar).

satellite tracking showed that *Mola mola* is not a more or less passive drifting organism, as proposed in former times, but in contrast able to move quickly over large distances and also independent of currents (Cartamil & Love 2004; Watanabe & Sato 2005; Sims et al. 2009). But it is remarkable that also the records not directly coinciding with major inflow events all but two happened around November (at least where exact dates are available). This is congruent with the finding of Muus & Nielsen (1999) that sunfish occurrence in the neighbouring North Sea is usually recorded in autumn. Also from other areas the occurrence of *Mola* was reported only during a certain part of the year, e. g. for California where it may be related to warm water currents (Hahlbeck et al. 2017).

3.3. Survival of ocean sunfish under conditions of the Baltic Sea

An unresolved question is, why ocean sunfish are apparently all deemed to die in the Baltic Sea. Busching & Pagel (1982, 1983) speculated that the lower salinity causes damage to this open ocean species. In recent press articles (Dec. 2015) it was also speculated that the species quickly dies in the Baltic environment due to food shortage and cold temperatures. In general it seems that in the Baltic Sea plenty of food is available for sunfish even if planktonic cnidarians abundances such as *Aurelia aurita* are low during winter times (unpublished data C. Augustin) and fish stocks are partly overfished. While stocks for cod (*Gadus morhua*) and herring (*Clupea harengus*) remained rather low, sprat (*Sprattus sprattus*) stocks appeared with high peaks in 1996 and 2016 in the southwestern Baltic Sea (FishSec 2016). As recent studies showed that smaller individuals mainly feed on small crustaceans and teleost fish (Sousa et al. 2016) there should be enough prey organisms available for the size of *Mola* specimens recorded in the Baltic Sea. Unfortunately no stomach analyses of specimens from the Baltic Sea are known.
Salinity, food shortage and temperature altogether may indeed influence stranding events of *Mola*, but it remains difficult to say if this species might be able to survive longer periods in the Baltic Sea, as half of these records are catches from fishermen and not strandings (tab. 1). Nevertheless, we postulate that the most negative environmental factor indeed is the low temperature during the Baltic Sea winter as Sims et al. (2009) showed that even if ocean sunfish dive to colder depth below 400 m and even stay certain times in depth of more than 200 m, they avoid temperatures below 10 °C.
And finally the question remains if the increased records since 2009 (fig. 3, tab. 1) indicate a new trend, maybe driven by change of environmental factors, as e. g. climate change, or if these records are just an incidental accumulation of events. Observing future records of *Mola mola* in the western Baltic Sea may allow evaluating such hypotheses.

Literature

Bass, A.L., H. Dewar, T. Thys, J.T. Streelman, & S.A. Karl. 2005. Evolutionary divergence among lineages of the ocean sunfish family, Molidae (Tetraodontiformes). Marine Biology 148, 405-414.

Busching, W.-D., & H.J. Pagel. 1982. Fund eines Mondfisches (*Mola mola*) am Strand in Rostock. Natur und Umwelt, Rostock Kulturbund 4, 30.

Busching, W.-D., & H.J. Pagel. 1983. Mondfische in der Ostsee. Poseidon 226, 41.

Cartamil, D.P., & C.G. Lowe, 2004. Diel movement patterns of ocean sunfish *Mola mola* off southern California. Marine Ecology Progress Series 266, 245-253.

Fish Sec. 2016. Summary of ICES advice on the exploitation of Baltic Sea fish stocks in 2017, ICES, https://www.fishsec.org/app/uploads/2016/06/2016-FishSec-Summary-ICES-advice-for-Baltic-2017.pdf

Froese, R., & D. Pauly. 2017. FishBase. www.fishbase.org, version (10/2017)

Hahlbeck, N., K. Scales, H. Dewar, S. Maxwell, S. Bograd, & E. Hazen. 2017. Oceanographic determinants of ocean sunfish (*Mola mola*) and bluefin tuna (*Thunnus orientalis*) bycatch patterns in the California large mesh drift gillnet fishery. Fisheries Research. 191. 154-163. 10.1016/j.fishres.2017.03.011.

HELCOM. 2012. Checklist of Baltic Sea macrospecies. Baltic Sea Environment Proceedings No. 130. Helsinki Commision, Helsinki.

Houghton, J. D., T.K. Doyle., J. Davenport, & G.C. Hays. 2006. The ocean sunfish *Mola mola*: insights into distribution, abundance and behaviour in the Irish and Celtic Seas. Journal of the Marine Biological Association of the United Kingdom 86, 1237-1243.

Johnson, G.D., & R. Britz. 2005. Leis' conundrum: homology of the clavus of the ocean sunfish. 2. Ontogeny of the median fins and axial skeleton in *Ranzania laevis* (Teleostei, Tetraodontiformes, Molidae). Journal of Morphology 266, 11-21.

Lass, U., & W. Matthäus. 1996. On temporal wind variations forcing salt water inflows into the Baltic Sea. Tellus 48A, 663-671

Lübbert H., & E. Ehrenbaum (eds). 1936: Handbuch der Seefischerei Nordeuropas. Bd. II Schweitzerbartsche Verlagsbuchhandlung, Stuttgart.

Mohr, E. 1929. Die Tierwelt der Nord- und Ostsee: Teleostei, Physoclisti, 3. Plectognathi. Akademische Verlagsgesellschaft, Leipzig.

Mohrholz, V., M. Naumann, G. Nausch, S. Krüger, & U. Gräwe. 2015. Fresh oxygen for the Baltic Sea – an exceptional saline inflow after a decade of stagnation. Journal of Marine Systems 148, 152-166.

Muus, B.J., & J.G. Nielsen. 1999. Kosmos Naturführer – Die Meeresfische Europas. Kosmos, Stuttgart.

Naumann, M., G. Nausch, & V. Mohrholz. 2016. A succession of four major Baltic inflows in the period 2014-2016 – an overview of propagation and environmental change, p. 27. In: Multiple drivers of earth system changes in the Baltic Sea region. International Baltic Earth Secretariat Publication No. 9 (Reckermann, M., & S. Köppen, eds). International Baltic Earth Secretariat, Geesthacht.

Nyegaard, M., E. Sawai, N. Gemmell, J. Gillum, N.R. Loneragan, Y. Yamanoue, & A.L. Stewart. 2017. Hiding in broad daylight: molecular and morphological data reveal a new ocean sunfish species (Tetraodontiformes: Molidae) that has eluded recognition. Zoological Journal of the Linnean Society, in press (online since July 2017).

Pope, E.C., G.C. Hays, T.M. Thys, T.K. Doyle, D.W. Sims, N. Queiroz, V.J. Hobson, L. Kubicek, & J.D.R. Houghton. The biology and ecology of the ocean sunfish *Mola mola*: a review of current knowledge and future research perspectives. Reviews in Fish Biology and Fisheries 20, 471-487.

Sawai, E., Y. Yamanoue, M. Nyegaard, & Y. Sakai. 2018. Redescription of the bump-head sunfish *Mola alexandrini* (Ranzani 1839), senior synonym of *Mola ramsai* (Giglioli 1883), with designation of a neotype for *Mola mola* (Linnaeus 1758) (Tetraodontiformes: Molidae). Ichthyological Research, 65, 142-160.

Sims, D.W., N. Queiroz, N.E. Humphries, F.P. Lima, & G.C. Hays. 2009. Long-term GPS tracking of ocean sunfish *Mola mola* offers a new direction in fish monitoring. PLoS ONE 4(10): e7351.

Sousa, L.L., R. Xavier, V. Costa, N.E. Humphries, C.Trueman, R. Rosa, D.W. Sims, & N. Queiroz. 2016. DNA barcoding identifies a cosmopolitan diet in the ocean sunfish. Scientific Reports 6, Article number: 28762

Watanabe, Y., & K. Sato. 2005. Functional dorsoventral symmetry in relation to lift-based swimming in the ocean sunfish *Mola mola*. PLoS ONE 3(e3446), 1-7.

Winkler, H.M., & H. Schröder. 2003. Die Fischfauna der Ostsee, Bodden und Haffe, pp. 25-35. In: Fische und Fischerei in Ost- und Nordsee. Meer und Museum Band 17 (Benke, H., ed.). Deutsches Meeresmuseum, Stralsund.

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