Biodiversity Journal, 2023,14 (1): 61–164 https://doi.org/10.31396/Biodiv.Jour.2023.14.1.61.164

Orca, *Orcinus orca* (Linnaeus, 1758) (Mammalia Cetacea), interactions with ocean sunfishes (Family Molidae, genus *Mola* Kölreuter, 1766 and *Masturus* Gill, 1884): A global review

Ingrid N. Visser[1*], Marianne Nyegaard[2,3] & London Fletcher[1,4]

[1]Orca Research Trust, P.O. Box 402043, Tutukaka, 0153, New Zealand
[2]Auckland War Memorial Museum Tamaki Paenga Hira, Natural Sciences, The Domain, Private Bag 92018, Victoria Street West, Auckland 1142, New Zealand - ORCID 0000-0002-9920-2862
[3]Ocean Sunfish Research Trust, Auckland, New Zealand
[4]Aquatic Research Conservancy, Blaine, Washington State, USA - ORCID 0000-0002-8078-4962
[*]Corresponding author, e-mail: info@orcaresearch.org - ORCID 0000-0001-8613-6598

ABSTRACT To better understand the interactions between orca, *Orcinus orca* (Linnaeus, 1758), killer whale (Mammalia Cetacea Delphinidae) and the large species of ocean sunfish (molids), *Mola* spp. and *Masturus lanceolatus* (Tetraodontiformes Molidae Actinopterygii), we searched for published and unpublished records of contact between these taxa. We reviewed a total of 73 interactions between 1961 and 2022, with social media in recent decades clearly facilitating dissemination of records. The interactions were primarily clustered in hotspots in Oceania (*n*=17), the eastern Pacific Ocean off Central and North America (*n*=33), and the South Atlantic off South Africa (*n*=10). We assessed predation risk for the molids by distinguishing between non-predation (*n*=29) and predation (*n*=42) interactions (the status of two interactions could not be established). We document what we believe to be the first confirmed predation by orca on *M. alexandrini* (*n*=3) and we reaffirm that predation occurs on *M. mola* and *Ma. lanceolatus*. Both non-predation and predation interactions involved orca who had previously been documented feeding on fish (elasmobranch and teleost) (*n*=9) and mammals (pinnipeds and cetaceans) (*n*=19). The most common orca group size was a single orca (*n*=27) and where molid numbers could be established (*n*=65), all but one interaction involved a single molid. During interactions the orca exhibited cooperative hunting and food sharing and learning/teaching may have been occurring. The relatively low number of interactions found for these two sympatric and charismatic species is surprising. Explanations may include prey-selection specificity by some orca and/or reflect the opportunistic nature of human documentation. However, our findings suggest that molids are potentially a localized food source for some orca in Oceania and the eastern Pacific, as predation was documented for 65% and 58% of interactions within those regions respectively.

KEY WORDS Foraging behaviour; killer whale *Orcinus orca*; predator prey interaction; sunfish; molid.

Received 08.10.2022; accepted 22.11.2022; published online 16.02.2023

INTRODUCTION

Within their global distribution, orca *Orcinus orca* (Linnaeus 1758), also known as killer whales, fall into a wide range of 'ecotypes'; i.e., ecologically distinct populations, which are adapted to the

local environment and show variations of, *inter alia*, morphology, genetics, acoustics and behaviour, including social structure, foraging strategies and diet (e.g., see Barrett-Lennard et al., 1996; Matkin et al., 2007; Ford & Ellis, 2014; Ford, 2019). Therefore, although the species as a whole has been documented foraging on a wide range of prey types such as invertebrates, elasmobranchs, teleost fishes, birds, reptiles, pinnipeds and cetaceans (Song, 2018; Ford, 2019), when focused on a single ecotype the prey list is typically much narrower. For example, in the Northern Pacific the ecotype known as 'Transient' or 'Bigg's' forages predominantly on marine mammals (e.g., Ford & Ellis, 1999) whilst the sympatric 'Resident' ecotype forages predominantly on teleosts (e.g., Ford, 2018). In the Southern Pacific, the 'Coastal' ecotype found around New Zealand forages predominantly on elasmobranchs (e.g., Visser, 1999) and the 'Pelagic' ecotype forages predominantly on cetaceans (Visser & Cooper, 2020).

A somewhat overlooked pelagic teleost group, which has also been confirmed as prey for orca (e.g., Ryan & Holmes, 2012), are the large species of ocean sunfish (genus *Mola* Kölreuter, 1766 and *Masturus* Gill, 1884 Family Molidae). Currently, four species are recognised; *Mola mola* (Linnaeus 1758), *M. alexandrini* (Ranzani 1839), *M. tecta* Nyegaard, Sawai, Gemmell, Gillum, Loneragan, Yamanoue et Stewart, 2017 and, *Masturus lanceolatus* (Liénard, 1840) – hereafter referred to as 'molids'. Due to a history of taxonomic confusion, these species are not uncommonly mistaken for each other (e.g., Nyegaard et al., 2018a). As a group, they are ubiquitous in tropical and temperate seas (Phillips et al., 2017; Caldera et al., 2020; Sawai et al., 2020), overlapping completely with the distribution of orca, which are found not only in these waters, but also in polar regions (Dahlheim & Heyning, 1999; Visser et al., 2008). A peculiar feature of the molids is their complete lack of a true tail; in its place, elements from the dorsal and anal fins form a rudder-like structure termed the 'clavus' (Fraser-Brunner, 1951; Johnson & Britz, 2005). Molids are well known for their large sizes, with at least three species (*Ma. lanceolatus, M. mola* and *M. alexandrini*) able to reach > 3 m total length (TL) (Sawai & Nyegaard, 2022) and the latter is known to reach at least 2.7 ton in body weight (Gomes-Pereira et al., 2022). Molid behaviour includes time spent at or near the surface for thermoregulation purposes after deep dives (Cartamil & Lowe, 2004; Nakamura et al., 2015; Nakamura & Yamada, 2022) as well as to seek parasite removal by seabirds (Abe et al., 2012). Combined with these sea-surface basking habits, such large sizes would presumably increase their potential as prey for orca.

Although orca are well studied in several parts of the world (Baird, 2002) and their predation methods are described for a wide range of prey types [e.g., marine mammals (Jefferson et al., 1991); elasmobranchs (Visser, 2005) and fish (Similä & Ugarte, 1993)], accounts of orca predating on molids are scarce in the literature. When available, detailed descriptions are typically examined from the point of view of the orca (e.g., Gladstone, 1988), but not from the point of view of the molids as prey.

In this study we reviewed the published literature and collated unpublished records to provide the first comprehensive review of orca interactions with, and predation on, molids. We aimed to examine how prevalent orca-molid interactions may be around the globe and better understand their nature. To achieve this, we developed a method for categorising interactions based on both orca and molid behaviour within a framework of non-predation versus predation interactions. Further, we hypothesized that molid predation would be conducted by fish- (elasmobranch or teleost) eating ecotypes and if interactions occurred with mammal- (pinniped or cetacean) eating ecotypes, they would be of a non-predation type.

MATERIAL AND METHODS

Sources

To find documentation of orca-molid interactions we; (i) reviewed the literature using standard scientific reference search engines; (ii) searched online media, video platforms and social media and, (iii) accessed data from our own databases and networks. All searches were conducted in English.

For inclusion in this study, an account had to; (a) unambiguously show and/or identify and/or mention both taxa and, (b) report that an interaction had taken place, either through a description or shown on imagery (video and/or photos) and, (c) the account had to specify a location to at least

country level. Consequently, accounts with ambiguous taxa identities (e.g., Alava et al., 2013) and/or where molids were listed as prey without account details or references (e.g., Foster, 2019) and/or where molids were mentioned in general terms as a food item for orca (e.g., Perrin et al., 2002), were not included. For the purpose of this study an 'interaction' included not only situations with clear reciprocal reactions, but also where both taxa were present within close proximity (i.e., likely to be visible to each other), but where no external reactions were evident (e.g., Jefferson et al., 1991), to acknowledge that internal reactions may be taking place.

Sources were categorised into; (1) 'Published' sources (scientific and grey literature), (2) 'Video' (unpublished interactions captured on video) and, (3) 'Narrated' (unpublished descriptions with or without photos, such as social media posts and personal communications). 'Published' sources were categorized into primary (describing the interaction for the first time) and secondary (citations of the primary source) levels, with only primary sources included here. Where a source described more than one interaction, we separated each out. Relevant data (e.g., date, location, descriptions etc) were extracted from all sources. Where interactions were reported more than once (by the same or different sources), we conflated these into a meta record in order to consolidate as much data as possible for each interaction.

Where feasible, we contacted the original observers of the unpublished accounts, to obtain further information and/or original imagery from the interaction. Where the date could not be ascertained, we assigned the date as prior to the date of publication or posting.

Interaction assessment

Location

All interactions were reviewed for geographic location and assigned an Ocean Basin adapted from Conkright et al. (2002). We used an additional 'Equatorial Zone' (between 10º N and 10º S of the equator) and used this as a sub-divider of the Pacific, Atlantic and Indian Oceans.

Taxa details

For each interaction, where possible, details for both taxa were established based on the information provided and/or from the available imagery.

Orca

The number of orca present and the number of orca involved in the interaction were noted for each interaction. Descriptions and imagery typically focused on the orca involved in the interaction (rather than all orca present). Therefore, if it was not stated if the group size given referred to those involved or not, we presumed it did. When a range was given, we used the lowest number stated.

Orca age/sex classes were; (i) determined as reported in the original source or, (ii) estimated visually from photos/video based on; (a) comparison to familiar objects (such as a snorkeler) to gauge relative size (and thereby age-class groupings) and, (b) using morphological indicators, e.g., adult orca are sexually dimorphic (Heyning & Dahlheim, 1988; Ford, 2018). Age classes (calf/juvenile, sub-adult or adult) were defined as described in Visser (2000a). Based on this information, the compositions of the orca involved in the interaction were categorised following the definitions in Table 1.

Molids

The species, size and number of molids involved in each interaction were noted. Where imagery was available, we identified the molid to the lowest possible taxonomic level based on morphology, following Sawai et al. (2020). Size was estimated as TL; anterior-most to posterior-most point, following Sawai et al. (2020), based on; (i) a subjective judgement of the molid morphology [*Mola* spp. change morphology with growth (Watanabe & Sato, 2008; Sawai et al., 2017; Nyegaard et al., 2018b; Sawai et al., 2018)] as well as, (ii) size relative to the orca.

Interaction Types

We assessed the interactions from the point of view (POV) of both orca and molids, using the interaction categories defined in Table 2. This table was constructed as part of the current study, based

Term	# of Orca Involved	Definition of Composition
Single adult male	One	Individual confirmed as an adult male.
Single adult female	One	Individual confirmed as an adult female.
Calf/juvenile	One or more	Individual(s) confirmed as calf/calves and/or juvenile(s).
Dyads	At least two	At least one individual confirmed as an adult female *and* at least one individual confirmed as calf/juvenile.
Other	One or more	Some or all orca could be assigned an age/sex class *and* the composition based on the known data does not fit into any of the above categories (e.g., two adult males).
Unknown	One or more	None of the individuals could be assigned age/sex/ class, or insufficient information available to categorise the composition into one of the above categories (e.g., one juvenile + an orca of unknown age/sex).

Table 1. Definitions of compositions of the orca involved in an interaction.

on our expectations of behaviours of the respective taxa, combined with an iterative process of video analysis focusing on the specific behaviours of each taxa. Detailed descriptions of molid 'Evade' behaviour are provided separately in Nyegaard et al. (2023).

Orca POV

From the orca POV the interactions were categorised as 'Non-predation' or 'Predation'. 'Non-predation' denoted interactions where the molid survived and contained the orca behavioural sub-categories; 'No Reaction', 'Interest', 'Disturb', 'Play/Harass' and 'Persecute' (Table 2). These were listed in the order that we believe (approximately) represents an escalation of risk to the molids. For example, a brief nudging ('Play/Harass') likely causes little (if any) harm, compared to hitting ('Persecute'), which could potentially result in contusions, or, if the molid is hit with enough force, may cause injuries such as internal blunt-force trauma (e.g., as has been documented in orca attacks on humans and conspecifics; Parsons, 2012). The 'Persecute' category would also include instances of minor consumption, where a piece of the molid (e.g., a part of the clavus) may be bitten off and consumed by the orca, with the molid itself escaping and surviving (e.g., Nyegaard et al., 2019).

The 'Predation' category denoted interactions leading to fatal injuries to the molid, regardless of consumption, and contained the sub-categories 'Kill (unknown)', 'Kill & Abandon' and 'Kill & Feed'. 'Kill (unknown)' denoted interactions, where the molid was killed, but the subsequent orca actions could not be ascertained. 'Kill & Abandon' included interactions, where the orca abandoned the molid carcass without consuming any of it. 'Kill & Feed' included interactions where consumption occurred, regardless of the amount consumed.

Each interaction was assessed to establish the highest ranked sub-category in Table 2 that the interaction escalated to. For some interactions, this was evident from the available information and/or imagery and these were noted as 'Confirmed'. For example, 'Kill & Feed' was categorized as 'Confirmed' when consumption was specifically stated (e.g., "*feeding on*" and "*ate the sunfish*") and/or where imagery clearly showed the orca feeding. Where the information strongly suggested (but did not explicitly confirm) a certain escalation, the sub-category was noted as 'Suspected'. For example, during an interaction where the molid was missing dorsal and/or anal fins, but consumption was not specifically documented, we presumed ('Suspected') that this was the result of the interaction. In the absence of clear statements, we used subjective judgement and a line-of-evidence approach to conservatively gauge to which level an interaction was suspected to escalate to.

For interactions where the molid was already dead when the observation began, we presumed it had been killed by the orca (rather than found dead by the orca). This assumption was made as there are limited records of orca scavenging, and these are

predominantly associated with whaling vessels (Whitehead & Reeves, 2005) or discards of fish from trawlers (Couperus, 1994; van Opzeeland et al., 2005).

Molid POV

Interactions from the molid POV were categorised as either 'Alive' or 'Fatally-wounded' (Table 2) according to the state of the molid at the beginning of the observation. 'Alive' were further categorized according to the reported and/or observed molid behaviour, namely; 'No-response', 'Evade', 'Confront' and 'Flee', listed in the approximate order that we believe corresponded to a potential predation sequence. This ranking is tentative, as antipredator behaviour in molids is not well understood (e.g., Nyegaard et al., 2023). For example, it is not known if molids potentially become catatonic (i.e., non-responsive to external stimuli) or display thanatosis ('playing dead'). Should molids exhibit thanatosis, we would consider this a higher ranked behaviour in terms of escalation, than 'Evade' and 'Confront', in line with the definition of thanatosis as an "…*anti-predator strategy adopted by diverse prey late on in the predation sequence, and frequently following physical contact by the predator.*" (Humphreys & Ruxton, 2018).

The category 'Fatally-wounded' included severely injured molids to the point where survival was deemed unlikely. For example, where a molid was missing dorsal and/or anal fin(s), survival was deemed unlikely, as these fins are critical for the lift-based swimming method of molids (Watanabe & Sato, 2008). The 'Fatally-wounded' category was further categorized into the sub-categories 'Dying' or 'Expired' (Table 2).

Other orca behaviour

As predation techniques (and prey selection) may be culturally transmitted in orca (Rendell & Whitehead, 2001; Ford, 2019) we assessed the interactions for; (i) cooperative hunting and food sharing [as these have been correlated with intergenerational cultural transmission (Copello et al., 2021)] and, (ii) involvement of Dyads (see Table 1) [as these have been associated with training/learning for younger orca (Guinet, 1991; Baird, 2000)].

Predation on molids by different ecotypes

To examine if molids are preyed upon by orca which otherwise target particular prey types, we established – where possible – the diet of the orca involved in the interactions.We used broad categories of prey type as follows; cephalopods, reptiles, fish (elasmobranch and teleost), birds and mammals (pinnipeds and cetaceans). Dietary specialisations are currently one of the key aspects used in the field to identify/define orca ecotypes, including sympatric populations (Ford et al., 1998). However, tying diet to ecotype is not trivial; e.g., (i) the diets of only a small number of ecotypes are well documented and, (ii) for those ecotypes, either fish or mammals are the most common prey (e.g., Baird, 2002) and, (iii) even for those ecotypes, their diet is typically broader than just one taxa e.g., the 'Resident' ecotype, which is known to forage predominantly on salmon, has also been documented feeding on squid (Ford et al., 1998; Hanson & Walker, 2014) and, (iv) if mixed prey types are documented the proportions may not be established.

As one of the aims of this study was to establish whether both Fish-eating and Mammal-eating orca predate on molids, we concentrated on those prey categories. Therefore, where the diet included fish or mammals – regardless of other prey types documented – the orca were categorised as such. Where prey type included both fish and mammals, we categorised the orca as multi-prey eaters, i.e., Fish+Mammal-eater. Where the diet included neither fish nor mammals, the orca were categorised as 'Other'.

Prey types were established from; (a) the source description and/or, (b) photo-identified individuals (where these could be linked to an ecotype for which prey type was known) and/or, (c) the geographic location (if the prey-type for the orca from that location was known and only one orca population was known from that location) and/or, (d) the prey the orca was documented feeding on prior to/after the interaction with the molid. Furthermore, as the wearing down of the coronal apex of orca teeth has been associated with the prey type of various ecotypes (e.g., Ford et al., 2011) we noted; (e) the state of the orca's teeth. We followed Jett et al. (2017) by assessing if the visible teeth were either worn near to, or to, the gum line, (i.e.,

POV (Category)	Interaction type	Definition	Final status of molid
Orca (Non-predation)	'No Reaction'	Both species present, but the orca takes no obvious interest in the molid.	Survived
	'Interest'	The orca shows interest in, but does not disturb or make contact with, the molid.	
	'Disturb'	The orca alters behaviour of the molid indirectly (i.e., no physical contact) by (one or more); **(i)** blowing bubble blasts at the molid, **(ii)** 'rushing at' or using tail flukes nearby molid (underwater or at surface), **(iii)** by startling the molid in some non-contact way (e.g., opening mouth and exposing teeth or making a loud vocalization).	
	'Play/Harass'	Orca play with and/or harasses the molid through direct contact by; **(i)** Nudging (briefly touching), **(ii)** Pushing (through the water or lifting partially or fully from the water). Does not maim, bite or kill.	
	'Persecute'	The orca physically harms the molid by (one or more); **(i)** Hitting, headbutts or uses tail flukes with direct strike (e.g., may be hard enough to lift the molid out of the water), likely to cause contusions, **(ii)** 'Body slamming' (either breaches or porpoises onto the molid), **(iii)** the orca carries the molid in its mouth, **(iv)** Maims or bites (non-fatally). Note that minor consumption may occur, e.g., a bite out of the clavus, with the molid escaping and surviving.	
Orca (Predation)	'Kill (unknown)'	The orca injures the molid so extensively that the molid will not survive. Neither abandonment nor consumption can be confirmed.	Dead
	'Kill & Abandon'	The orca injures the molid so extensively that the molid will not survive. The orca swims off, abandoning the molid (which is injured and will die or is already dead). No consumption occurs.	
	'Kill & Feed'	The molid is fatally wounded or dead and consumption occurs.	
Molid (Alive)	'No response'	The molid offers no visible response to the presence of the orca. Exhibits no or slow fin movements; remains in 'basking' (horizontal) position at the sea surface; is motionless.	Survived or dead
	'Evade'	The molid exhibits one or more evasive manoeuvres; **(i)** is stationary (effectively) at the sea surface with the head angled slightly up ('Seek surface') and actively keeps the clavus towards the orca ('Clavus-to-orca'), **(ii)** abruptly obtains a near-vertical position with the head at the surface or above water ('Head-up'), **(iii)** from 'Head-up', pivots to quickly change direction; or, while upright, quickly changes direction on the spot ('Pivot'), **(iv)** from 'Head-up', inverts completely so the ventral area is at the surface or above water ('Ventral-up'), **(v)** thrashes at the surface with the dorsal and/or anal fins, without moving forwards ('Thrash'), **(vi)** while parallel to the surface, spins rapidly ('Spin'), **(vii)** propels itself partially (at least half of the body) or fully out of the water ('Breach'), **(viii)** Actively positions itself near a vessel (i.e., is not herded towards the vessel by orca), at a distance less than the length of the approaching orca ('Shelter').	
	'Confront'	The molid confronts the orca by (one or more); **(i)** deliberately turning towards the orca, **(ii)** deliberately moving towards the orca, **(iii)** deliberately bumping or pushing the orca.	
	'Flee'	The molid actively attempts to flee during the interaction by swimming away rapidly and/or diving (may or may not be successful).	
Molid (Fatally wounded)	'Dying'	The molid is clearly dying and/or is fatally wounded (e.g., missing one/both dorsal/anal fin). May (sluggishly) exhibit Evade behaviours.	Dead
	'Expired'	The molid is dead.	

Table 2. Definitions of orca-molid interaction categories from the Point of View (POV) of the orca and molids. The molid Categories refer to the state of the molid at the start of the observation. The interaction type is listed in order of approximate escalation of the most invasive behaviour of the orca and the most significant reaction by, or risk to, the molid, within each POV category. 'Evade' behaviours are taken from Nyegaard et al. (2023).

they showed extreme coronal wear, with 76–100% of the tooth missing) or if the teeth appeared 'normal' (no wear, 0–9%; or minor coronal wear, 10–25%). We also noted, (f) the presence of tassel barnacles (*Xenobalanus globicipitis* Steenstrup, 1852) attached to the orca as these may help to elucidate ecotype and therefore diet (Visser et al., 2020).

RESULTS

Overview of interactions

We identified a total of 73 different orca-molid interactions between 1961 and 2022 (Fig. 1). These consisted of 20 interactions from 'Published' sources (Sup Mat S–1) and 53 from unpublished sources. The latter consisted of (*n*=21) interactions documented on 'Video' (Sup Mat S-2), and (*n*=32) 'Narrated' accounts, with and without photos (Sup Mat S–3). For unpublished accounts, we were able to contact one or more observers for (*n*=50) interactions and obtained further information and/or original imagery for (*n*=27) of these.

Between Jan 1961 and Dec 2003 (i.e., 43 years), all interactions originated from 'Published' sources (Fig. 1), and averaged *ca*. 0.2 interaction per year. From Jan 2004 to Dec 2022 (i.e., 18 years), where interactions consisted of 'Published', 'Video' and 'Narrated' accounts, the average increased to 3.4 interactions per year. Most of these (83%) originated from 'Video' and 'Narrated' sources. Overall, during the 61 years spanning the records we collated, the average number of interactions was approximately one per year.

Geographic location of interactions

Orca-molid interactions were documented in the Atlantic, Indian and Pacific Ocean basins, and the western Mediterranean (Fig. 2). They clustered in 'hotspots' in the eastern Pacific Ocean off North and Central America [British Columbia, California, Costa Rica, the Galápagos Islands (Ecuador) and Mexico (*n*=33)] where 45% of the interactions were documented, in Oceania [eastern Australia, Indonesia, Malaysia, New Zealand and Papua New Guinea (*n*=17)] where 23% of the interactions were documented, and in the South Atlantic off South Africa (*n*=10) where 14% of the interactions were documented. Additionally, one interaction was reported from captivity, from an orca captured off California.

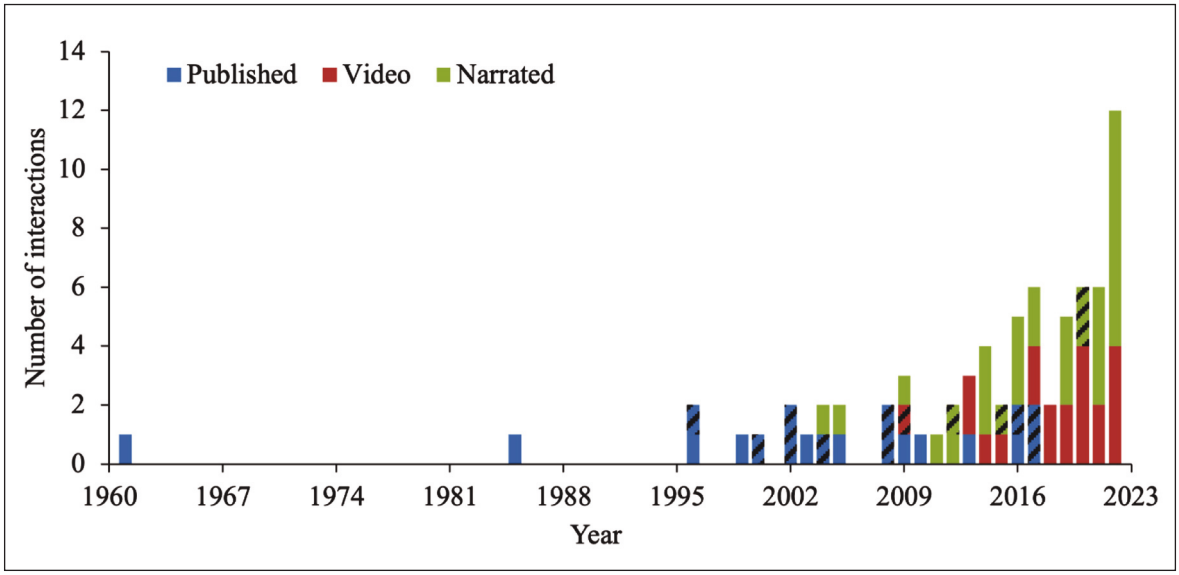

Figure 1. Number of individual orca-molid interactions (*n*=73) by year (1961-2022) identified in this study, according to the source of the information. Hashed bars indicate records, where the year refers to the year of publication. For further details see Sup Mat S-1 - Sup Mat S-3.

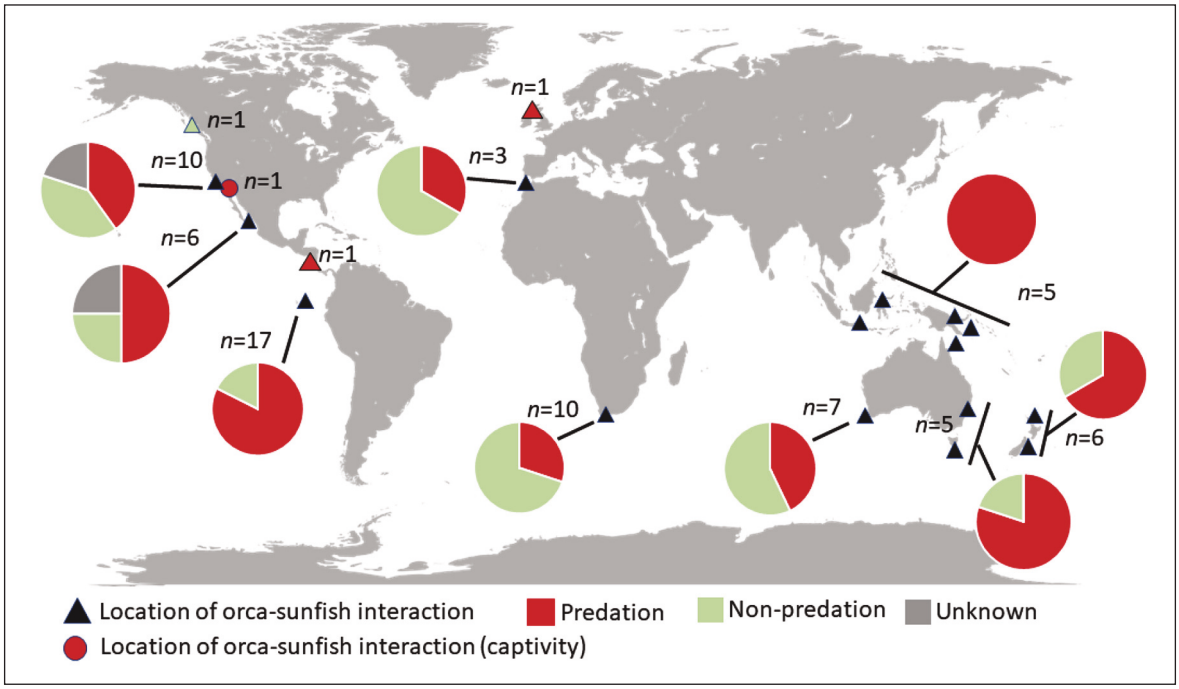

Figure 2. Locations of orca-molid interactions (*n*=73) observed in the wild (triangles) or in captivity (circle). In the four locations where only one interaction was documented a pie chart is not given and the symbol colour indicates the category of interaction. See text and Table 2 for determination of 'Non-predation' and 'Predation' interactions and see Sup Mat S-1 - S-3 for further details.

Taxa details

Orca

The number of orca involved could be determined for (*n*=52) interactions, and ranged between 1–7 individuals, with single individuals most commonly reported (Fig. 3).

Orca age/sex classes could be assigned to one or more orca involved in (*n*=41) interactions. The most common composition of individuals was single adult males (*n*=16) (Figs. 3, 4). However, six of these interactions were undertaken by the same male orca within hours of each other (Fig. 4). The second most common composition was Dyads (*n*=11), followed by calves/ juveniles (both sexes and undetermined sexes) (*n*=7) and single females (*n*=4) (Fig. 4). Of all interactions, where more than one individual was involved (*n*=26), at least 44 % consisted of Dyads (Fig. 3). However, when only including interactions where the composition could be established (i.e., excluding 'Unknowns'), this increased to 73%.

For (*n*=40) interactions, both the number of orca present and the number directly involved could be established (Table 3). When a single male was involved, just over half of them were travelling alone. The only single female involved was held as a solitary animal in captivity. When only calves/juveniles were involved in an interaction, there were always other orca present (Table 3), i.e., they were not solitary.

Molids

The number of molids involved in each interaction could be established, or reasonably presumed, for (*n*=53) and (*n*=12) interactions, respectively. In all but one of these, a single molid was present. The only exception was an interaction near the Galápagos Islands, where a single male orca swam past two *M. alexandrini* who were at a fish 'cleaning station' (i.e., a specific zone on a reef where small fish remove ectoparasites, dead skin etc from fishes, see Losey (1979) for a review).

Across all accounts, three different molid species were confirmed from imagery, namely *Ma. lanceolatus* (*n*=4), *M. mola*, (*n*=5) and *M. alexandrini* (*n*=8). A further (*n*=19) individuals were identified

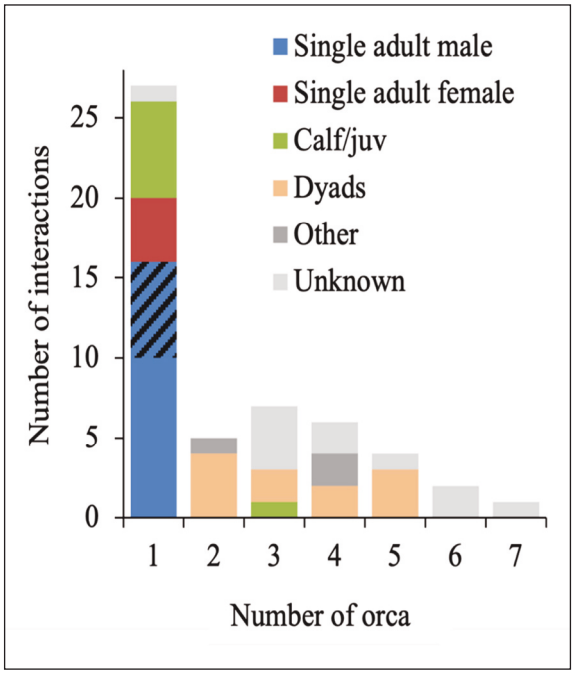

Figure 3. Frequency of group size for orca involved in interactions (where this could be established; *n*=52), according to the age/sex group categories (Table 1) (where this could be established, i.e., excluding 'Unknowns'; *n*=41). Hashed records indicate interactions which occurred within hours of each other, all by the same adult male (*n*=6).

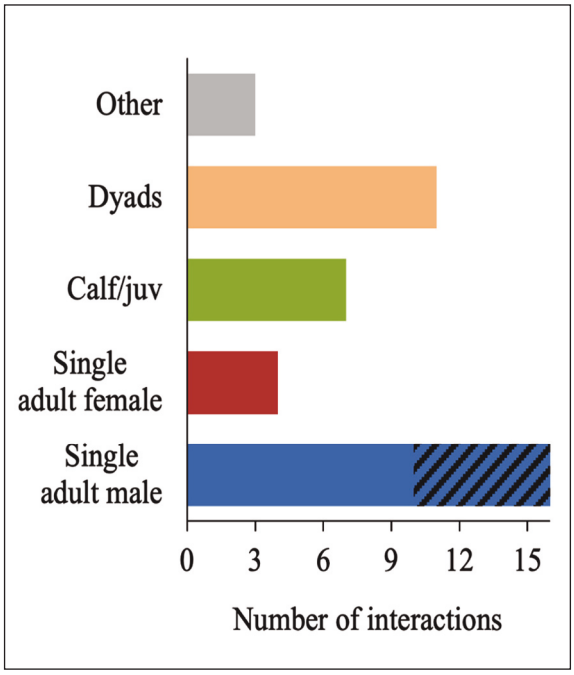

Figure 4. Number of interactions (*n*=41) where the involved orca group could be categorised according to age/sex group constellations. Hashed records indicate interactions, which occurred within hours of each other, all by the same adult male (*n*=6). See Table 1 for definitions and Sup Mat S-1 - S-3 for further details.

Total orca *present*	**Compositions of orca *involved***				
	Dyads	**Calf/juvenile**	**Single F**	**Single M**	**Other**
1			1*	12**	
2		1		2	1
3	2	1		1	
4	1	2			2
5	2	1		1	
6	2		2		
7	2				
8	1				
12		1			
14	1				
15					
20		1			
TOTAL	11	7	3	16	3

Table 3. For (*n*=40) interactions, both the number of orca present and the number directly involved could be established and categorised according to the definitions in Table 1. *Denotes a female orca in captivity. ** Six of these interactions occurred within hours of each other, all by the same adult male.

as *Mola* sp., and (*n*=3) as 'large molids'. Molid size estimates based on imagery (*n*=35) or provided by the source (*n*=6) collectively revealed a broad range from *ca*. 0.3 m TL to *ca.* 2–2.5 m TL, with most individuals (*n*=30) estimated to be 1 – 2 m TL.

Orca POV

The interaction type from the POV of the orca could be determined for 71 interactions, with 'Non-predation' (i.e., where the molid survived) and 'Predation' (i.e., fatal to the molid) occurring in 40% and 58% of the interactions respectively (Fig. 5).

Non-predation

The majority of 'Non-predation' interactions escalated to 'Play/Harass', with only a small number of 'No-reaction', 'Interest', 'Disturb' and 'Persecute' interactions (Fig. 5). Examples of orca behaviours during 'Play/Harass' included pushing the molid underwater (Fig. 6) and along the sea surface (Fig. 7) and lifting the molid completely out of the water (Figs. 8, 9). Examples of orca behaviours during 'Persecute' included knocking a small molid out of the water (Fig. 10), hurtling a small molid through the air by hitting it with the flukes (Fig. 11) and the carrying of a molid using the pectoral fin (Fig. 12), as well as narratives such as "*tossed it* [the molid] *around twice before letting it go*" and "*surfaced with sunfish in its mouth*".

Predation

The majority of 'Predation' interactions escalated to 'Kill & Feed' (*n*=34, Fig. 5), where some consumption occurred. However, in many cases it was not possible to establish the extent of consumption due to truncated video and/or a lack of specific information in this regard. Five interactions clearly documented the consumption of internal organs and/or the majority/entire carcass by the orca (e.g., see the Case Study below). 'Kill & Abandon' occurred during three interactions, however, two of these were only suspected (Fig. 5). The only confirmed case was in captivity where the molid was killed but not consumed.

Molid POV

The state of the molids at the start of each interaction could be established in (*n*=65) cases, with similar proportions being 'Alive' and 'Fatally Wounded' (Fig. 13). Of the 'Alive' group, most doc-

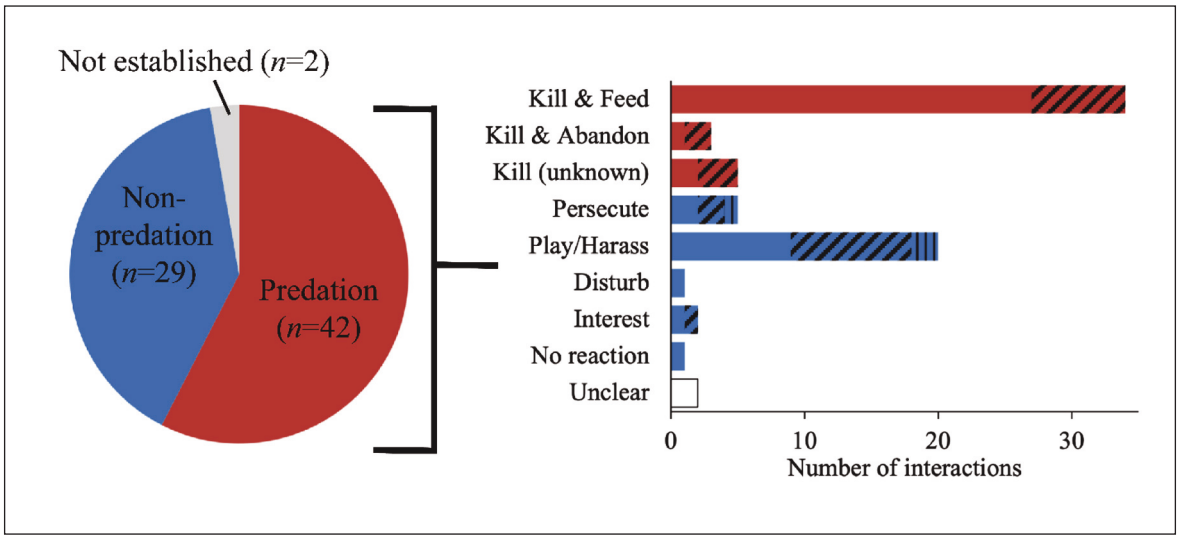

Figure 5. Assessment of orca-molid interactions (*n*=73) from the orca point-of-view, according to the orca interaction categories (left) and behavioural sub-categories (right) as defined in Table 2. The highest escalation of the interaction, as defined by the sub-category, was either confirmed (solid) or suspected (hashed). In a small number of cases (vertical stripes) insufficient evidence was available to assess further escalation. For further details see (Sup Mat S-1 - S-3).

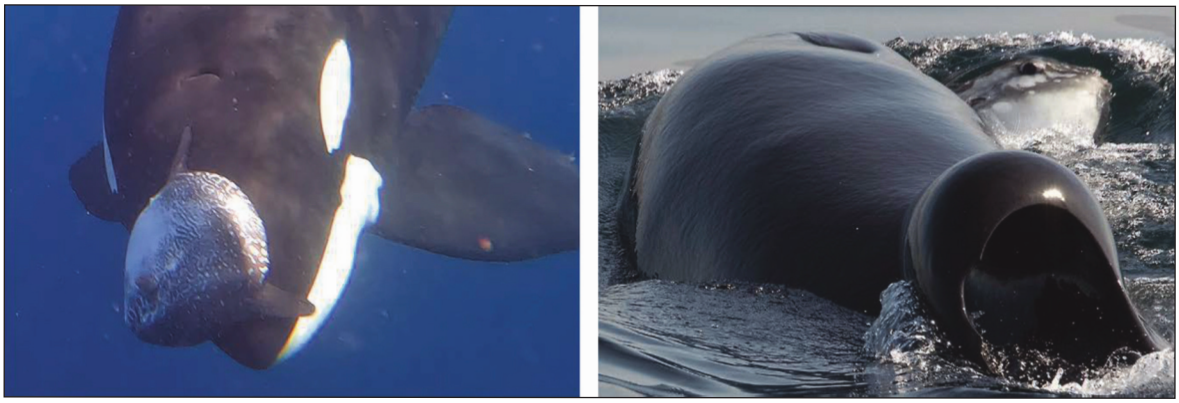

Figure 6 (left). 'Play/Harass' category. An adult female orca pushes a molid (*Mola* sp.) underwater. Frame from video by Bill Bain, Australia. Figure 7 (right). 'Play/Harass' category. An adult male orca pushes a molid (*Mola* sp.) along the surface. Note the dorsal fin of the orca is collapsed to his left; photo by Dave Hurwitz, Simon's Town Boat Company, South Africa.

Figure 8 (left). 'Play/Harass' category. A young female orca balances a *Mola* sp. on the top of its rostrum, whilst another orca surfaces nearby; photo by Daniel Bianchetta for Monterey Bay Whale Watch, USA. Figure 9 (right) 'Play/Harass' category. Two juvenile orca balance a *Mola* sp. between them (note the dorsal fin of the molid is bent over and trapped by the juvenile orca on the right), whilst an adult female orca watches; photo Jade Sharp for Whale Watch Western Australia, Australia.

Figure 10 (left). 'Persecute' category. A young orca hits a *Mola* sp. with enough force that the molid is propelled out of the water; photo by Machi Yoshida for Naturaliste Charters, Australia. Figure 11 (right). 'Persecute' category. An inverted adult female orca hits a *Mola* sp. with its tail flukes, which hurtles the molid (arrow) into the air. Frame from video by Mike Kaufman, for Monterey Bay Whale Watch, USA.

umented/evident responses did not escalate past 'Evade', which occurred during interactions of orca 'Play/Harass', 'Persecute' and 'Kill' (Fig. 13). Molid 'No-response' behaviours were seen in three interactions, during orca 'No-reaction' and 'Interest', respectively. A further three molids were reported to attempt to 'Flee' (unsuccessfully) by swimming rapidly across the surface (i.e., not diving), while no 'Confront' behaviours were seen or reported during any interactions.

All molid 'Evade' behaviours identified in this study originated from analysis of imagery (i.e., 'Video' and 'Narrated' accounts with photos). Limited information was available from all other accounts, as narratives and comments tended to focus on orca behaviour. Exceptions included descriptions such as "*…the sunfish bolted across the surface*" (B. Bain pers. comm. 2022), i.e., 'Flee' behaviour, and "*…the Sunfish may have been small, but he was feisty and would turn to face the Orca every time they approached and duck his backside towards them, protecting his face from the Orca teeth*" (Whale Watch Western Australia, 2020) i.e., 'Clavus-to-orca' behaviour.

Molid behaviours were naturally easiest to determine from 'Video' accounts, where motion aided in deciphering the interaction (e.g., see frames from a video in Figs. 14, 15). However, 'Evade' behaviours were evident on a subset of photos from 'Narrated' accounts, including 'Head-up' (Fig. 16), 'Ventral-up' (Fig. 17), and 'Thrash' (Fig. 18) (see Nyegaard et al. (2023) for details regarding molid behaviours). Combining all detected 'Evade' behaviours across all accounts, the most commonly documented were 'Seek-surface' and 'Clavus-to-orca', followed by 'Head-up' and 'Thrash' (Fig. 13). Naturally, more than one 'Evade' behaviour could be exhibited by the same molid during an interaction (e.g., Nyegaard et al., 2023).

Figure 12. 'Persecute' category. An adult female orca carries a *Mola* sp. by its pectoral fin. She is accompanied by her offspring (a 1.5-year-old male) who had, less than 1 minute earlier, carried the molid to her. Frame from video by Evan Brodsky for California Killer Whale Project, USA.

In a small number of cases (n=3), despite video being available, it was not possible to ascertain the behaviour of the molids, nor their state. In one case, a small molid which was pushed vigorously through the water by an orca (Fig. 6), exhibited no movements. However, after dislodging, the molid appeared to subtly right itself while the orca were close by but not engaging. It is not clear if the molid was 'playing dead' (i.e., thanatosis), or was simply in poor condition. The observer reported the molid died sometime after the interaction, so the latter seems plausible. In a second case, a molid was pushed vigorously along the sea surface, barely moving. Again, the reason for the lack of movement is not clear, as molids can certainly 'Thrash' while being pushed along the sea surface, as seen in other interactions. The observer reported the orca were "*… hunting and then feeding on…*" the molid, so it cannot be ruled out that the video was taken well into the interaction, when the molid was in poor condition. However, the possibility of thanatosis cannot be ruled out. In a third example, a small molid exhibited no discernible movements while hurtling high up in the air after being hit by the tail flukes of an orca (Fig. 11). It is possible the molid was alive but may have been stunned by the forceful blow from the orca tail.

In two instances, where the molids were 'Fatally wounded' and clearly 'Dying', 'Evade' behaviours were still evident. Specifically, a *Ma. lanceolatus* with the intestine removed by the orca (e.g., see Visser & Fletcher (2023) and the Case Study below), slowly assumed the 'Seek-surface' position (Fig. 19) and in another instance a bleeding *M. mola* sluggishly exhibited 'Seek-surface', 'Head-up', 'Pivot' and 'Clavus-to-orca' (Fig. 20).

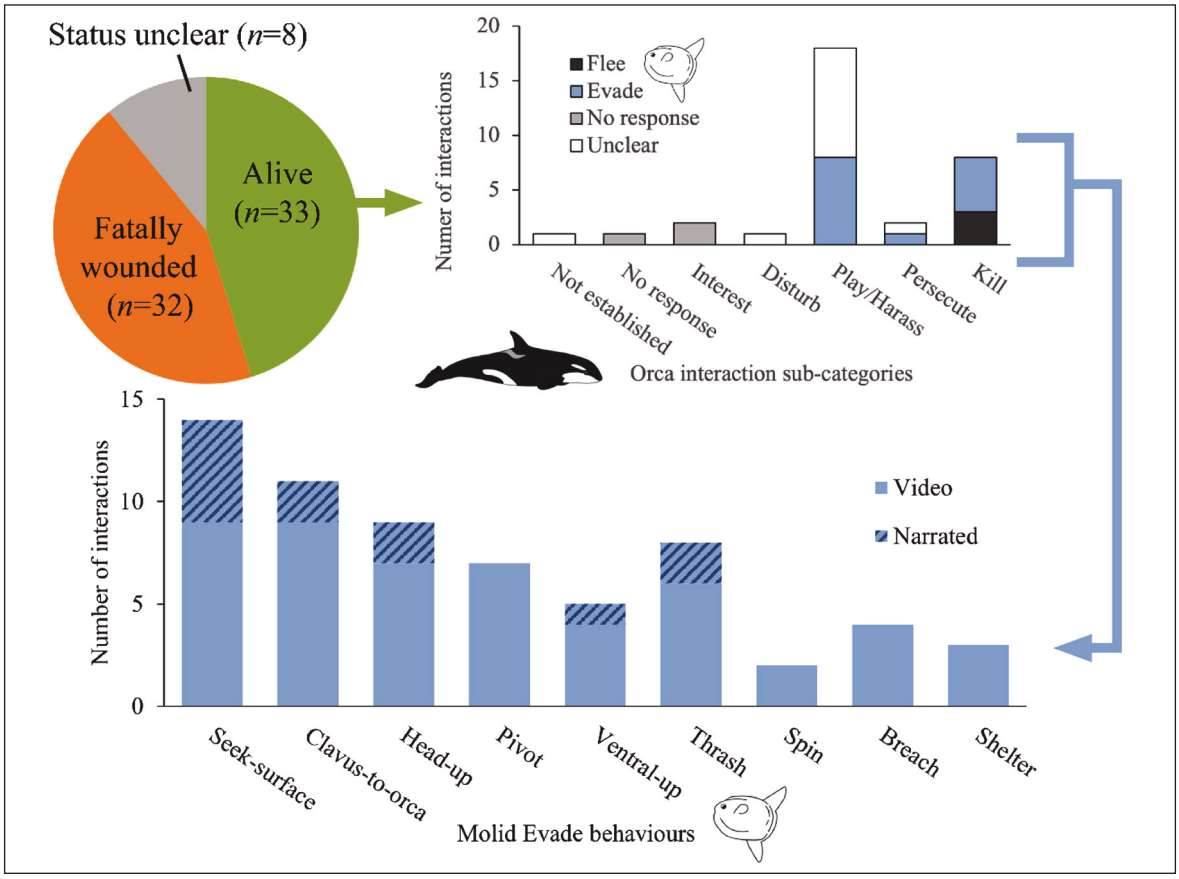

Figure 13. Assessment of orca-molid interactions (*n*=73) from the molid point-of-view. The pie chart shows the proportion of interactions according to the status of the molid at the start of the observation. Of the 'Alive' (*n*=33) interactions, the upper bar graph shows the highest ranked behavioural sub-category, as defined in Table 2, according to the highest escalation of orca behaviour. The lower bar graphs show the number of interactions, where each type of 'Evade' behaviour was observed at least once. An interaction could naturally include several behaviours for each taxa.

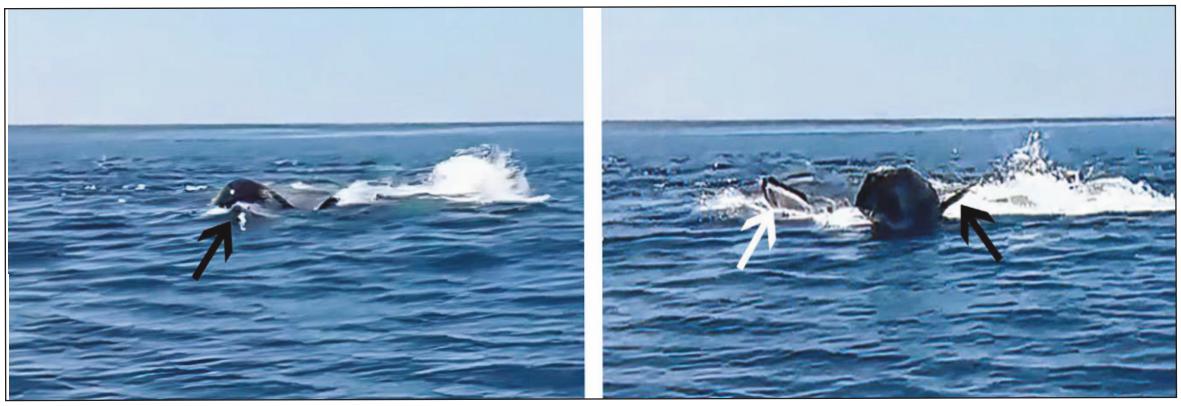

Figure 14 (left).'Evade' behaviour. An adult female orca approaches at speed, whilst a molid is just below the surface and has created a convex meniscus directly in front of the orca (arrow). Note the splashes created by the orca as it accelerates. Frame from a video by Francis Zavala, Eco Fishing, Galápagos Islands, Ecuador. Figure 15 (right). 'Evade' behaviour. The same orca and molid pair, two seconds after Fig. 14, where the molid has breached with its ventral surface (pale area on body) away from the orca and the anal fin (black arrow) clear of the water. Note the orca has turned away, showings its white chin (white arrow). Frame from a video by Francis Zavala, Eco Fishing, Galápagos Islands, Ecuador.

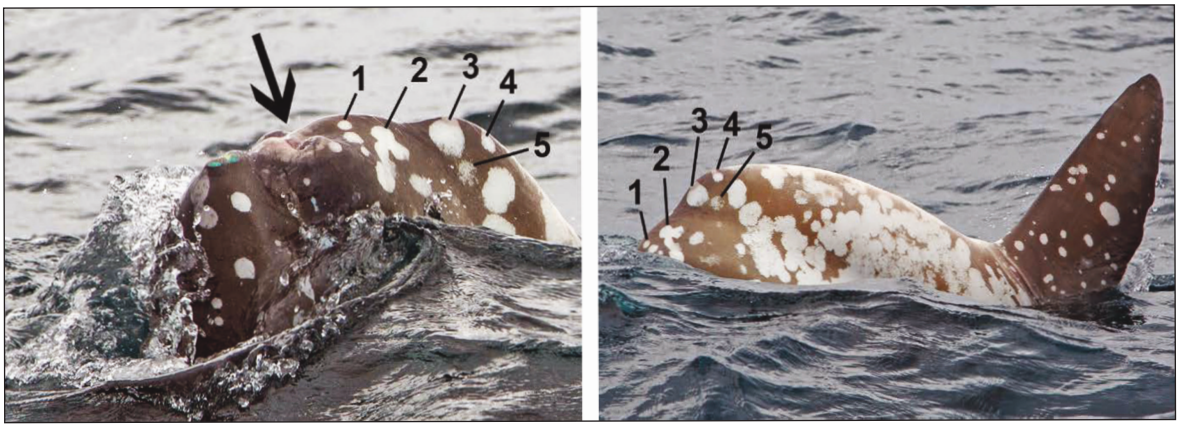

Figure 16 (left). Evade behaviour. Still photos of a molid (*M. alexandrini*) exhibiting 'Head-up' (arrow indicates mouth, numbers match spots in Fig. 17, illustrating the molid's orientation); photo by Marco Valentini, Galápagos Islands. Figure 17 (right). Evade behaviour. The same molid as in Fig. 16, now inverted ('Ventral-up') as the orca (out of frame) approached (numbers match spots in Fig. 16 and illustrate the molid's orientation); photo by Marco Valentini, Galápagos Islands.

Figure 18. 'Evade' behaviour. A molid thrashes ('Thrash') at the surface as an orca approached but did not make contact with the molid. Photo by Alex Vogel for Simon's Town Boat Company, South Africa.

Other orca behaviour

The orca appeared to be cooperatively hunting and/or food sharing during (*n*=11) interactions, and in all but one of these instances the orca were Mammal-eaters (the other instance involved Fish+Mammal eaters). Seven of these were 'Predation' interactions and in four of these, female-calf/juvenile Dyads were involved. Dyads were only involved in a single 'Non-predation' interaction. In this instance the calf first carried the molid towards the mother, then dropped it. The mother retrieved it and continued to carry it (Fig. 12) until the pair dove deeper and out of sight of the drone.

Orca by prey types

Orca could be categorised according to their prey type in (*n*=39) interactions. The prey included cephalopods, reptiles, elasmobranchs, teleosts, pinnipeds and cetaceans, as well as combinations of these (see Sup Mat S–1, S–4 for details).'Predation' events involving molid consumption was confirmed for Fish-, Mammal- and Fish+Mammal-eaters (Table 4).

Fish-eaters

Fish-eating orca were involved in molid interactions on (*n*=9) occasions, of which (*n*=4) were 'Predation' events (Table 4). Of those, one orca stranded and died in Ireland and was documented with molid bones in its stomach. It was genetically confirmed to be ecotype 'type 1' (Ryan & Holmes, 2012), which is a North Atlantic teleost-eating ecotype (Foote et al., 2009). In five accounts from New Zealand, the orca were potentially teleost-eating ecotypes based on the location of the interaction and the evidence previously gathered on the diet of orca in that area (Visser, 2000b). In another instance, an orca held in captivity was described based on "… *her pre-capture behavior, the animal was suspected to have fed on small fishes*…"; (p 133, in Caldwell & Brown, 1964), which together

with the capture location (and tooth wear, see below) indicates an 'Offshore' ecotype. This ecotype has been documented feeding on elasmobranchs (Ford et al., 2011) and teleosts (Heise et al., 2003).

Mammal-eaters

Mammal-eating orca were involved in molid interactions on (*n*=19) occasions, of which (*n*=9) were 'Predation' (Table 4). The orca in these interactions were observed four times hunting for/predating on marine mammals either before or after the molid interaction and in two of those interactions the orca were matched to known Bigg's (Mammal-eating) individuals. In another interaction, on the day prior to their predation of a molid, a group of orca in Costa Rican waters had been documented feeding on an unidentified hard-shelled turtle (Dario Nessi, pers. comm., details provided in Sup Mat S–4). However, as this same group of orca had also been observed feeding on a dolphin the day before (Dario Nessi, pers. comm.), they were included in the Mammal-eater category.

Fish+Mammal-eaters

In (*n*=10) interactions the orca involved were both Fish- (elasmobranch) and Mammal-eaters, of which (*n*=2) of the interactions were 'Predation' (Table 4). For one of the 'Non-predation' interactions, an orca had been observed predating on Cape fur seals (*Arctocephalus p. pusillus* Schreber, 1775) just three minutes prior to the interaction with the molid (Dave Hurwitz, pers. comm.) and this particular individual has previously been documented feeding on elasmobranchs (Towner et al., 2022).

Tooth wear

Tooth wear could be ascertained for (*n*=6) interactions (Table 4) and in all cases supported the determination of the diet of the respective orca. Specifically, the single orca described in captivity had "*excessive tooth wear*" (Caldwell & Brown, 1964 and see image Sup Mat S–5) indicative of an 'Offshore' ecotype, which, as noted above, are documented as both elasmobranch- and teleost-eaters. The orca which stranded and died in Ireland had "*significant apical tooth-wear*" (Ryan & Holmes, 2012 and see image in Sup Mat S–5) and was confirmed as a teleost-eater. The remaining four interactions all involved orca who had no, or minor, coronal wear (see Methods for definitions and Sup Mat S–5 for further details) and all were documented eating mammals (with two confirmed to also eat teleosts and reptiles). A clear example of Mammal-eating orca teeth puncture marks, in molid skin, is provided in Visser & Fletcher (2023).

Tassel barnacles

Tassel barnacles were documented for (*n*=10)

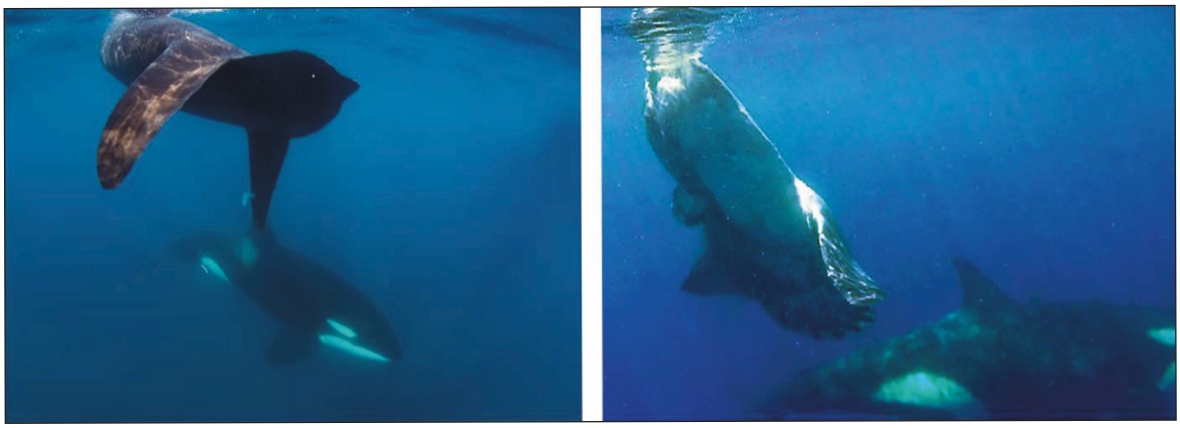

Figure 19 (left). 'Seek-surface' behaviour. A 'Fatally wounded' and 'Dying' *Ma. lanceolatus*; photo by Ryan Sault, Mexico.
Figure 20 (right). 'Seek-surface', 'Head-up' and 'Clavus-to-orca' behaviour by a 'Fatally wounded' and 'Dying' *M. mola*. Moments prior, the same individual (sluggishly) exhibited 'Pivot' as the orca passed. Frame from video by Rachel Barry, Papua New Guinea.

interactions. All tassel barnacles were documented during interactions which occurred in the Pacific Ocean; Australia (east coast) (*n*=1), Costa Rica (*n*=1), Galápagos Islands (*n*=3) and Mexico (*n*=5), see Sup Mat S–2, S–3 for details, and Sup Mat S-6 for images. The orca, where prey type could be established (*n*=4) were either Mammal-eaters or Fish+Mammal-eaters (Table 4, Sup Mat S–6).

Case Study

We present a case study from June 2022 in Mexican waters, in order to illustrate a range of behaviours from both the orca and the molid (*Ma. lanceolatus*), within a single interaction. Additional images and details are described in Visser & Fletcher (2023) and Sup Mat S–4.

On the 11 June 2022, when the photographers arrived on site, an orca was carrying a molid intestine (Fig. 21), which had been extracted from the side of a still-alive molid (Fig. 22). The molid, despite being fatally wounded, exhibited 'Evade' behaviours, including 'Seek-surface' (Fig. 23) and possibly 'Shelter' (Fig. 24), although we note this latter behaviour is not trivial to establish (Nyegaard et al., 2023). Despite the 'Fatally wounded' status of the molid, the orca exhibited caution, with slow approaches (Fig. 25) and targeted the pectoral fins of the molid (Fig. 26). After disarticulating the molid, an orca inserted its maxillae and mandibles into the body cavity of the molid (Fig. 27) and food sharing between members of the group was documented (Fig. 28). Further details of these and similar orca behaviours are described in Visser & Fletcher (2023).

DISCUSSION

On a global level, orca forage on a diverse range of prey types and species, with the latter being in excess of 175: Hoyt (1984); Song (2018); Ford (2019), Visser & Fletcher (2023); Visser unpublished data. Herein, we focused on the species of large molids (*Ma. lanceolatus* and *Mola* spp.) and provide the first confirmed consumption of *M. alexandrini*. Orca-molid interactions were documented in all Ocean Basins yet were concentrated in hotspots. They typically involved small numbers of orca with a single molid. Many of these interactions escalated to 'Play/Harass', with, a similarly high number of interactions escalating to 'Predation', and of these, many included adult female-calf/juvenile Dyads. All three categories of orca (as defined by their prey type) were documented preying on molids, confirming that both Fish-eating and Mammal-eating orca prey on molids.

Despite the wide-spread distribution of the large molids, the spatial overlap with orca, and the long-standing public and research interest in both taxa, we found relatively few accounts of interactions during this study, with an average of just one a year since 1961. This was unforeseen, as molids are presumably easy for orca to catch during their periods of sea surface basking, where they are relatively inactive (Nakamura et al., 2015). There may be several factors that contribute to this paucity of accounts, which are not necessarily mutually exclusive.

Firstly, it is possible orca avoid molids due to toxicity, although we find this unlikely. Molids were previously thought to accumulate the biotoxin tetrodotoxin (Halstead, 1967; Parsons, 1986) and be toxic to mammals (Halstead 1978 in Gladstone, 1988). However, this appears to be unfounded (Saito et al., 1991; Huang et al., 2011) and tetrodotoxin has, to date, not been found in Molidae (Baptista et al., 2020; Baptista et al., 2022). Further, human consumption, including the intestines, occurs in some Asian countries (Nyegaard et al., 2020). Consumption of molids by elasmobranchs and pinnipeds has also been described (Nyegaard et al., 2019) and in this study we noted a number of instances where birds, elasmobranchs and pinnipeds scavenged (i.e., consumed) molid parts during the orca 'Predation' events, indicating at least for these taxa, and orca, that molids are not toxic.

Another possible explanation is that molids are unpalatable and/or energetically inferior to other prey types and are not widely preyed on by orca. For instance, molid skin includes a thick layer of collagen tissue, comprised mainly of water (Davenport et al., 2018) and which constitutes an increasing proportion of the molid body mass as they grow (for example 44% in a 247–kg individual Watanabe & Sato, 2008). Furthermore, an estimated 79–83% of the red and white fin muscle of *M. mola* consists of water (Watanabe & Davenport, 2020).

Orca ecotype (as defined by prey type)	Total # of interactions where orca ecotype was established	Interaction type	# Interactions where teeth were assessed	# Individual orca where teeth were assessed	# Interactions with tassel barnacles present
Fish-eater	9	NP (*n*=5) P (*n*=4)	2	"*To the gums*" (*n*=1) "*Significant*" (*n*=1)	~
Mammal-eater	19	NP (*n*=9) P (*n*=9) NE (*n*=1)	3	No, or minor wear (*n*=6)	3
Fish+ Mammal-eater	10	NP (*n*=8) P (*n*=2)	1	No wear (*n*=2)	1

Table 4. Interactions, where the orca teeth and/or presence of tassel barnacles could be ascertained. Orca ecotype is defined by their prey (see text for details). See Sup Mat S-5 for details regarding tooth wear and Sup Mat S-6 for tassel barnacle presence. NP = 'Non-predation', P = 'Predation' and NE = Not established.

In addition, molid skin is armored with modified mineralised scales, creating a hard, rough surface (Fraser-Brunner, 1951; Gauldie, 1992) potentially causing tooth wear in predating orca, as has been speculated for the 'Offshore' ecotype, which is known to target elasmobranchs with rough skin (Ford et al., 2011). Overall, these properties potentially render molids less desirable prey compared with, for example tuna, as indicated by the difference in longline depredation rates (by unknown predator types) between molids (0.1 %) and various tuna and billfish species (4.1–7.4%) found in a study in the Atlantic (MacNeil et al., 2009). However, as extensive consumption of molids were seen in some interactions (e.g., where the entire molid was consumed), it seems unlikely that molid tissue is largely invaluable to orca. For example, the high water content of some molid tissues may be of value to orca (Visser & Fletcher, 2023), given that acquisition of fresh water for cetaceans is believed to be primarily reliant on metabolizing ingested food, although some seawater may be ingested (Ortiz, 2001; Rash & Lillywhite, 2019). Further, it is also possible that certain parts of the molid, e.g., the muscular intestines and the large liver, are energetically valuable to orca.

The low number of reported interactions may also reflect the patchy distribution of both taxa combined with the solitary or semi-solitary lifestyle of the molids, potentially resulting in relatively low encounter rates between these taxa. Likewise, the paucity of records may also reflect the opportunistic nature of human documentation of these types of events, with most interactions potentially taking place away from areas where human observers can readily and/or feasibly witness them. For example, not only are these species at times found offshore but given the diving abilities of both taxa (Thys et al., 2017; Towers et al., 2018) interactions may be happening well below the surface and therefore these would not be observed.

In addition, the apparent low rate of interactions may reflect that observers do not always disseminate their observations. For example, the increase in recent years in reported interactions likely reflects the increased availability of low-cost/compact cameras (as well as phone cameras) and the ability to share footage online, rather than an actual increase in the rate of interactions. This trend indicates that interactions are likely much more commonplace than the paucity of records in the published literature indicates.

Another surprising finding was that 'Predation' rates across all interactions were only slightly higher than 'Non-predation', which was unexpected when considering the energetic requirement for orca. For example, captive orca consume an aver-

age of 3.6% of their body weight per day (Kastelein et al., 2000), with higher food-intake requirements logically required for free-ranging individuals. It is therefore unclear why – when orca engage in interactions with molids and expend energy – a notable proportion did not escalate to 'Predation'. However, a similar lack-of-escalation by orca has been documented for other prey taxa; for example they have been observed 'playing' with jellyfish (Similä et al., 1996), birds (Williams et al., 1990) and pinnipeds (Norris & Prescott, 1961) although they have also been documented feeding on these same taxa (*Ibid.*). Within that framework, molids cannot be assumed to be invaluable prey, just because the orca at times play with them, or do not escalate all interactions to 'Predation'.

In a small number of interactions (n=3), the orca did not consume any of the molid after killing it. It is not clear why they would do this, but we note that one case was in captivity (Caldwell & Brown, 1964) and that the behaviour of captive orca is distorted (Marino et al. 2019). For the other two observations, it is possible that the presence of observers influenced orca behaviour. As such we recommend ethical and responsible interactions with wildlife (Valentine et al., 2004; Moor-

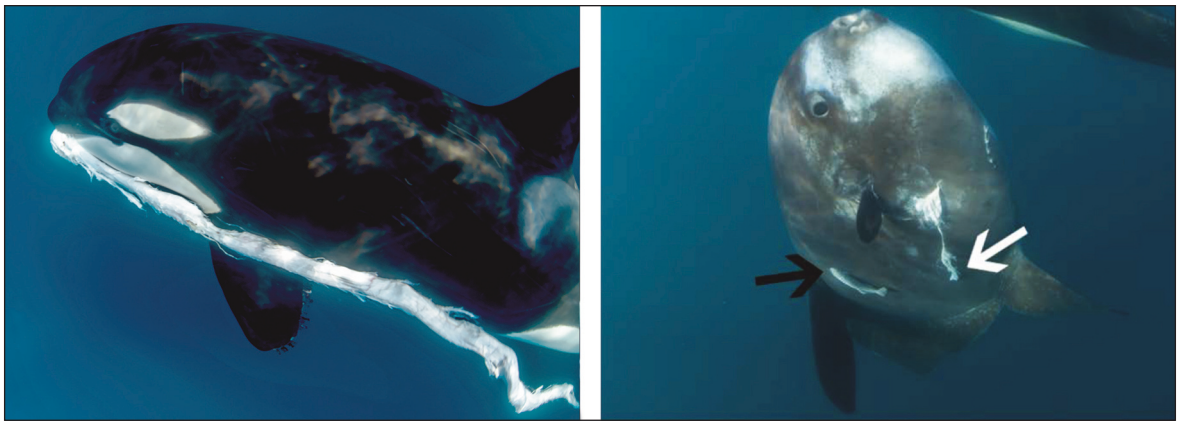

Figure 21 (left). When the photographer arrived, the orca were carrying (and consuming) the intestine of a sharptail sunfish (*Ma. lanceolatus*). Note the tassel barnacles on the left pectoral fin; photo by Ryan Sault. Figure 22 (right). The molid had an open wound along its right side and what appeared to be part of the intestine was protruding (white arrow). Note the remora attached to the side of the molid (black arrow); photo by Ryan Sault.

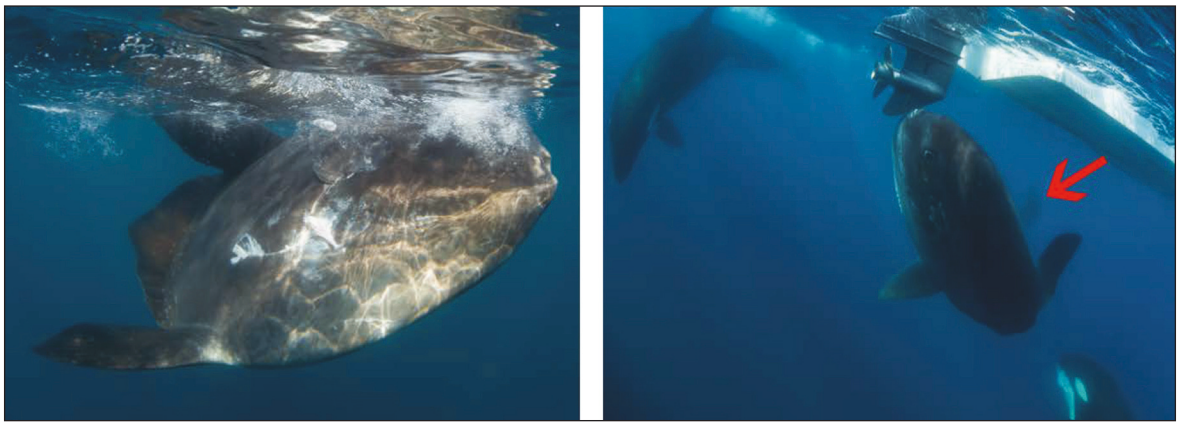

Figure 23 (left). Despite being fatally wounded, the molid still exhibited evade behaviours such as 'Seek-surface'; photo by Ryan Sault. Figure 24 (right). The molid also appeared to attempt to shelter under the boat ('Shelter'), although this behaviour is not trivial to establish. Note the blood in the water from the wound on its right side (red arrow); photo by Ryan Sault.

house et al., 2016; Pagel et al., 2020), especially during interactions which involve potential foraging.

The geographic clustering of interactions, and the high percentage of 'Predation' interactions in some of these, suggest that molids are potentially a localized food source for some orca. Specifically, within Oceania and the eastern Pacific, 'Predation' was documented for 65% and 58% of interactions, respectively. However, it can't be ruled out that these hotspots are generated due to the method of data collection, i.e., they may reflect observational and recording efforts, rather than be indicative of locations where higher occurrences of interactions occur.

Our study confirmed that orca ecotypes who predate on a range of prey also consume molids. When considering only the fish or mammal component of their diets (i.e., Fish-eaters, Mammal-eaters and Fish+Mammal eaters), there were a relatively higher number of interactions which involved Mammal-eating orca than we anticipated. Despite this, without further observations it is not possible to ascertain why orca who typically target mammals would also target molids. We can however speculate that such behaviour may be a 'safe'

Figure 25 (left). Although the molid was fatally wounded and slow to react, the orca used cautious approach behaviours and at no time rushed at the molid; photo by Ryan Sault. Figure 26 (right). The orca targeted the pectoral fins of the molid (white arrow indicates tip of the left fin). Frame from video by Tara Weberg.

Figure 27 (left). Eventually the molid was dissected by the orca into sections. At one point an orca placed its rostrum well into the body cavity of the molid, a feeding behaviour only recently documented for orca (Visser & Fletcher, 2022); photo by Ryan Sault. Figure 28 (right). Food sharing between an adult and a juvenile, where both orca have part of the molid in their mouths and are pulling it apart. Note the tassel barnacles on the flukes and dorsal fin of the juvenile. See Sup Mat S-6 for further details on the barnacles; photo by Giacomo Rossi.

way for younger animals to learn foraging techniques whilst utilizing a large-sized prey item, as molids do not have the ability to defend themselves with teeth, such as a pinniped or shark would. Many 'Predation' events indeed included female-calf/juvenile Dyads, where teaching/learning may have been occurring.

The sample size was small with regards to the teeth of the orca, i.e., only six interactions had video or photos that allowed for assessment. In the two individuals where the wear was significant, the orca were Fish- (teleost or teleost+elasmobranch) eaters. In contrast, the eight individuals with no or nominal wear to the teeth were all Mammal-eaters or Fish+Mammal-eaters, perhaps indicating a potential pattern that warrants further investigation. In a similar way, the sample size of tassel barnacles was too small to assist with categorising ecotypes. However, Ten et al. (2022) noted that documenting not only the presence, but also the absence of epizootics (including tassel barnacles) was of value. As such we highlight that tassel barnacles were only documented on orca in the Pacific Ocean. We are confident that this is not due to the distribution of tassel barnacles *per se*, as they have been documented attached to orca in other regions, e.g., the Atlantic Ocean (Siciliano et al., 2020; Visser et al., 2020). Therefore, tassel barnacles on orca who predate on molids may still provide an indicator of ecotype, if the data set was increased.

With just over half of the interactions escalating to 'Predation', when molids encounter orca the risk of predation for an individual is not insignificant. Given the similar behavioural responses from molids around the world, even when injured, 'Evade' behaviours may increase their chances of survival. Many of these appear to be attempts to keep the head and ventral areas away from the orca, and/or keep the clavus towards the orca (Nyegaard et al., 2023). As molids with significant portions of their clavus missing have survived presumed interactions with predators (Nyegaard et al., 2019), these behaviours may increase their chances of survival. However, the degree of success from these behaviours is unknown and not possible to establish from our study, but we do note that the molids were frequently successful at evading the orca in that moment (Nyegaard et al., 2023).

It has been suggested that quick and/or deep dives by molids observed during satellite tagging programs may represent predator avoidance behaviour (Cartamil & Lowe, 2004; Sims et al., 2009). Similarly, rare video of Lamalera whale hunters in Indonesia shows an attempt by a large molid (*M. alexandrini*) harpooned at the surface to dive straight down (Palička, 2016). Interestingly the molids in this study generally did not attempt to flee, even if the orca were several meters away and no attempts of escape by diving were observed. Of course, unobserved dive escape attempts may have occurred, or such attempts occurred but were not recorded in the information reviewed here. Alternatively, it may be a more favourable strategy for molids to 'wait out' orca interest while concurrently attempting to evade close approaches by the orca. Specifically, a reduced prey response may inhibit a predatory response from the orca, as has been documented for other predators (e.g., Lundgren & Moeller, 2017). We did not find any obvious evidence of thanatosis, as has been observed for some species of fishes such as the Brazilian seahorse (*Hippocampus reidi*) (Feret-Meurer et al., 2017). Neither did we find obvious evidence of tonic immobility (whereby a reflex causes a temporary state of inactivity in the fish), as has been suggested during an orca-shark predation event (Pyle et al., 1999). Although we did observe non-reactive molids in some interactions, the molids could have been in poor condition from the interactions, and we therefore err on the side of caution before assigning either thanatosis or tonic immobility behaviour.

Our results are semi-quantitative, as the interactions were documented not only in different ways (i.e., 'Published', 'Video' and 'Narrated' with and without photos), but also for different lengths of time, with differing point of view of the observer (top-side versus under water) and at different resolutions (quality of video/photographs). We relied on personal observations and data that were not collected as part of species-specific studies on either orca or molids. We are also aware of other interactions not included in this study, for which details were not available at the time of analysis. Nevertheless, our results indicate communalities in molid behaviour across species and Ocean basins, that molids are consumed by orca across the globe, and that interactions are likely to be more commonplace than what this review indicates. Overall, our study highlights the value of recording orca-molid inter-

actions in detail, including *inter alia* the escalation of orca behaviour, potential consumption, the state of the orca's teeth and the attachment of tassel barnacles as well as size and species of the molid and molid behaviours, to better understand the nature of interactions.

Despite the study limitations, we were able to ascertain that both Fish-eating and Mammal-eating orca predate on molids, and that learning/teaching is potentially occurring. We have illustrated that the predation risk to a molid, when discovered by orca, is not insignificant. Our review illustrated that meta-analysis of a diverse range of observations of orca-molid observation can provide insight into these types of interactions. As is so often the case with marine megafauna, our recommendation is that further research is conducted and we suggest that the identified hotspots for these interactions are likely areas where such work could be undertaken.

ACKNOWLEDGEMENTS

We acknowledge Māori as tangata whenua and Treaty of Waitangi partners in Aotearoa New Zealand. We thank Haze Sommer for her help with sourcing videos online. John Francis confirmed identification of the pinnipeds in the Galápagos Island video, Chris Gaskin confirmed identification of the birds in the Galápagos Island video, Chris Paulin confirmed identification of the fishes in the New Zealand video and we thank them all for their expertise. Tracy Cooper and Kirsta van der Linde provided helpful reviewers comments and we thank them for their attention to detail and suggested edits which improved the manuscript.

We also extend our thanks to the following individuals who kindly made video and contextual information available; Dani Abras, Daniela Alcarcón Ruales, Cristobal Alvarez, Bill Bain, Daniel Bianchetta, Evan Brodsky, Alfredo Barroso, Matthew Barry, Rachel Barry, Evans Baudin, Cecilie Benjamin, Nancy Black, Susanne Buetow, Damian Connor, Tracy Cooper, Karen Debler, Judith Denkinger, Jenny from Cabo Excursions, William Gladstone, Mrs. Haruka, David Hurwitz, Mik Jennings, Mike Kaufman, Frida Lara, Sandrine le Comte, Keith Lightbody, Vito Maffei, Pia Markovic, Shu Mei, Ryan Miller, Dario Nessi, David Parer, Daniel Parrazo, Breeanna Plater, Mazdak Radjainia, Giacomo Rossi, Ryan Sault, Gemma Sharp, Jade Sharp, Leanne Sharp, Adrian Stacey, Colleen Talty, Tierney Thys, Rob Torelli, Jared Towers, Marco Valentini, Michael Van den berg, Alex Vogel, Paul Vuchovich, Tara Weberg, Janet Wilson, Machi Yoshida, Francis Zavala. We also wish to thank the following companies and organisations for their contributions to the dataset; Apex Shark Expeditions, California Killer Whale Project, Cabowhale, Cetaceanfreedom, FunBaja, Galápagos Eco Fishing, Killer Whales Australia, MasterLive-Aboards, Monterey Bay Whale Watch, Naturaliste Charters, Ocean Sunfish Research Trust, Orca Research Trust, Roaring Earth, Scuba Diver Magazine, Scuba Junkie, Simon's Town Boat Company, Walindi Resort MV FeBrina, Whale Watch Western Australia and Wild Ocean Tasmania. Footage from the Gladstone (1988) publication, filmed by David Parer, for the program 'Seas Under Capricorn', was made available under license by the Australian Broadcasting Corporation (ABC Archives).

Ingrid thanks her Patreon supporters for their financial assistance during the preparation of this publication and thanks dodoland (Orca EUGY) and Uber Ultrafast Broadband for their continued support of the Orca Research Trust. We wish to add a special thanks to Jackie C. from Amsterdam for her interest in marine conservation (including watching sunfishes along the New Zealand coastline) and her financial support of the Orca Research Trust and this publication.

REFERENCES

Abe T., Sekiguchi K., Onishi H., Muramatsu K. & Kamito T., 2012. Observations on a school of ocean sunfish and evidence for a symbiotic cleaning association with albatrosses. Marine Biology, 159: 1173–1176. https://doi.org/10.1007/s00227-011-1873-6.

Alava J.J., Smith K.J., O'Hern J., Alarcón D., Merlen G. & Denkinger J., 2013. Observations of killer whale (*Orcinus orca*) attacks on Bryde's whales (*Balaenoptera edeni*) in the Galápagos Islands. Aquatic Mammals, 39: 196–201. https://doi.org/10.1578/AM.39.2.2013.196.

Baird R.W., 2000. The killer whale. Foraging specializations and group hunting. In: Mann J., Connor R.C., Tyack P.L. & Whitehead H. (Eds.), Cetacean Soci-

eties: Field studies of dolphins and whales. University of Chicago Press, Chicago, 127–153.

Baird R.W., 2002. Killer whales of the world - Natural history and conservation. Voyageur Press, Stillwater, MN, USA. Worldlife Discovery Guides, 132 pp.

Baptista M., Braga A.C., Rosa R. & Costa P.R., 2022. Does ocean sunfish *Mola* spp. (Tetraodontiformes: Molidae) represent a risk for tetrodotoxin poisoning in the Portuguese Coast? Marine Drugs. 20:e594 (591–97). https://doi.org/10.3390/md20100594.

Baptista M., Figueiredo C., Lopes C., Costa P.R., Dutton J., Adams D.H., Rosa R. & Raimundo J., 2020. Chapter 11 Biotoxins, trace elements and microplastics in the ocean sunfishes (Molidae) In: Thys T.M., Hays G.C. & Houghton J.D.R. (Eds.), The Ocean Sunfish: evolution, biology and conservation. CRC Press, Boca Raton, FL, USA, pp. 186–215.

Barrett-Lennard L.G., Ford J.K.B. & Heise K.A., 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. Animal Behavior, 51: 553–565. https://doi.org/10.1006/anbe.1996.0059

Caldera E., Whitney J.L., Nyegaard M., Ostalé-Valriberas E., Kubicek L. & Thys T.M., 2020. Chapter 3 Genetic Insights into the Taxonomy, Evolution and Development of the Ocean Sunfishes. In: Thys T.M., Hays G.C. & Houghton J.D.R. (Eds.), The Ocean Sunfishes Evolution, Biology and Conservation. 1st ed. CRC Press, Boca Raton, Florida, 310 pp.

Caldwell D.K. & Brown D.H., 1964. Tooth wear as a correlate of described feeding behavior by the killer whale; with notes on a captive specimen. Bulletin of the Southern California Academy of Sciences, 63: 129–140.

Cartamil D.P. & Lowe C.G., 2004. Diel movement patterns of ocean sunfish *Mola mola* off southern California. Marine Ecology Progress Series, 266: 245–253. https://doi.org/10.3354/meps266245

Conkright M.E., Locarniin R.A., Garcia H.E., O'Brien T.D., Boyer T.P., Stephens C. & Antonov J.I., 2002. World Ocean Atlas 2001. Objective Analyses, Data Statistics, and Figures. Ocean Climate Laboratory, National Oceanographic Data Center, Silver Spring, MD, USA, 17 pp.

Copello J.M., Bellazzi G., Cazenave J. & Visser I.N., 2021. Chapter 1. Argentinean orca (*Orcinus orca*) as an umbrella species: Conservation & management benefits. In: Carvelho Mocellin V (Ed.), Contributions to the global management and conservation of marine mammals. Editora Artemis, Curitiba, Brazil, pp. 1–27. https://doi.org/10.37572/EdArt_1003212861

Couperus A.S., 1994. Killer whales (*Orcinus orca*) scavenging on discards of freezer trawlers north east of the Shetland islands. Aquatic Mammals, 20: 47–51. https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1994/Aquatic_Mammals_20_1/20-01_Couperus.pdf

Dahlheim M.E. & Heyning J.E., 1999. Chapter 11 Killer whale *Orcinus orca* (Linnaeus, 1758). In: Ridgway S.H. & Harrison R.J. (Eds.), Handbook of Marine Mammals. Academic Press, London, pp. 281–322.

Davenport J., Phillips N.D., Cotter E., Eagling L.E. & Houghton J.D.R., 2018. The locomotor system of the ocean sunfish *Mola mola* (L.): role of gelatinous exoskeleton, horizontal septum, muscles and tendons. Journal of Anatomy, 233: 347–357. https://doi.org/10.1111/joa.12842

Feret-Meurer N., Fernandez T.C., Lopes D.A., Vaccani A.C. & Okada N.B., 2017. Thanatosis in the Brazilian seahorse *Hippocampus reidi* Ginsburg, 1933 (Teleostei: Syngnathidae). Acta Ethologica, 20: 81–84. https://doi.org/10.1007/s10211-016-0247-y

Foote A.D., Newton J., Piertney S.B., Willerslev E. & Gilbert T.P., 2009. Ecological, morphological and genetic divergence of sympatric North Atlantic killer whale populations. Molecular Ecology, 18: 5207–5217. http://dx.doi.org/10.1111/j.1365-294X.2009.04407.x

Ford J.K.B., 2018. Killer whale *Orcinus orca*. In: Perrin W.F., Würsig B. & Thewissen J.G.M. (Eds.), Encyclopedia of marine mammals. 3rd ed. Academic Press, San Diego, pp. 669–676.

Ford J.K.B., 2019. Chapter 11 Killer Whales: Behavior, social organization, and ecology of the oceans' apex predators. In: Würsig B. (Ed.), Ethology and Behavioral Ecology of *Odontocetes*. Springer, Switzerland, pp. 239–259. https://doi.org/10.1007/978-3-030-16663-2_11

Ford J.K.B. & Ellis G.M., 1999. Transients: Mammal-hunting killer whales. University of British Columbia Press, Vancouver, 96 pp.

Ford J.K.B. & Ellis G.M., 2014. You Are What You Eat: Foraging specializations and their influence on the social organization and behavior of killer whales. In: Juichi Y. & Karczmarski L. (Eds.), Primates and Cetaceans: Field Research and Conservation of Complex Mammalian Societies. Springer Japan, pp. 75–98. https://doi.org/10.1007/978-4-431-54523-1_4

Ford J.K.B., Ellis G.M., Barrett-Lennard L.G., Morton A.B., Palm R.S. & Balcomb K.C., 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology-Revue Canadienne de Zoologie, 76: 1456–1471. https://doi.org/10.1139/z98-089

Ford J.K.B., Ellis G.M., Matkin C.O., Wetklo M., H, Barrett-Lennard L.G. & Withler R.E., 2011. Shark predation and tooth wear in a population of northeastern

Pacific killer whales. Aquatic Biology, 11: 213–224. https://doi.org/10.3354/ab00307

Foster R.N., 2019. Fussy feeders or fallacy? Investigating the prevalence of prey preference in killer whales, globally and in the Southern Ocean. University of Canterbury, Christchurch, New Zealand, 35 pp. https://ir.canterbury.ac.nz/handle/10092/18588

Fraser-Brunner A., 1951. The ocean sunfishes (Family Molidae). Bulletin of the British Museum of (Natural History) Zoology, 1: 87–121.

Gauldie R.W., 1992. 'Plywood' structure and mineralization in the scales of the ocean sunfishes, *Mola mola* and *M. ramsayi*. Tissue and Cell, 24: 263–266. https://doi.org/10.1016/0040-8166(92)90099-S

Gladstone W., 1988. Killer whale feeding observed underwater. Journal of Mammalogy, 69: 629–630. https://doi.org/10.2307/1381360

Gomes-Pereira J., Pham C., Catarino D., Miodonski J., Aurélio M.A.R., Dionísio G., Nyegaard M., Sawai E., Carreira G. & Afonso P., 2022. The heaviest bony fish in the world: a 2744 kg giant sunfish *Mola alexandrini* (Ranzani, 1839) from the North Atlantic. Journal of Fish Biology. https://onlinelibrary.wiley.com/doi/10.1111/jfb.15244

Guinet C., 1991. Intentional stranding apprenticeship and social play in killer whales (*Orcinus orca*). Canadian Journal of Zoology. 69: 2712–2716.

Halstead B.W. 1967. Poisonous and venomous marine animals of the world. Vol. II. Vertebrates. United States Government Printing Office, Washington DC, 1070 pp.

Hanson B.M. & Walker W.A., 2014. Trans-Pacific consumption of cephalopods by North Pacific killer whales (*Orcinus orca*). Aquatic Mammals. 40: 274–284.

Heise K., Barrett-Lennard L.G., Saulitis E., Matkin C. & Bain D.E., 2003. Examining the evidence for killer whale predation on Steller sea lions in British Columbia and Alaska. Aquatic Mammals, 23: 325–334. https://www.zoology.ubc.ca/~consort/pdfs/heise2003.pdf.

Heyning J.E. & Dahlheim M.E. 1988. *Orcinus orca*. Mammalian Species, 304: 1–9.

Hoyt E., 1984. Orca: The whale called killer. 3rd ed. Camden House Publishing Ltd, Ontario, 291 pp.

Huang K.-M., Liu S.-M., Huang Y.-W., Huang K.-L. & Hwang D.-F., 2011. Food poisoning caused by sunfish *Masturus lanceolatus* in Taiwan. Journal of Food and Drug Analysis, 19: 191–196. https://doi.org/10.38212/2224-6614.2243

Humphreys R.K. & Ruxton G.D., 2018. A review of thanatosis (death feigning) as an anti-predator behaviour. Behavioral Ecology and Sociobiology, 72. https://doi.org/10.1007/s00265-017-2436-8

Jefferson T.A., Stacey P.J. & Baird R.W., 1991. A review of killer whale interactions with other marine mammals: Predation to co-existence. Mammal Review, 21: 151–180. https://doi.org/10.1111/j.1365-2907.1991.tb00291.x

Jett J., Visser I.N., Ventre J., Waltz J. & Loch C., 2017. Tooth damage in captive orcas (*Orcinus orca*). Archives of Oral Biology, 84: 151–160. https://doi.org/10.1016/j.archoralbio.2017.09.031

Johnson G.D. & Britz R., 2005. Leis' conundrum: Homology of the clavus of the ocean sunfishes. 2. Ontogeny of the median fins and axial skeleton of *Ranzania laevis* (Teleostei, Tetraodontiformes, Molidae). Journal of Morphology, 266: 11–21. https://doi.org/10.1002/jmor.10242

Kastelein R.A., Walton S., Odell D., Nieuwstraten S.H. & Wiepkema P.R., 2000. Food consumption of a captive female killer whale (*Orcinus orca*). Aquatic Mammals, 26: 127–131. https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/2000/AquaticMammals_26-02/26-02_Kastelein.pdf.

Losey G.S., 1979. Fish cleaning symbiosis: Proximate causes of host behaviour. Animal Behaviour, 27: 669–685. https://doi.org/10.1016/0003-3472(79)90004-6

Lundgren E. & Moeller K. 2017. Anti-Predator strategies of, and possible thanatosis in, juvenile collared peccaries (*Pecari tajacu*). The Southwestern Naturalist, 62: 253–237. https://doi.org/10.1894/0038-4909-62.3.235

MacNeil A.M., Carlson J.K. & Beerkircher L.R. 2009. Shark depredation rates in pelagic longline fisheries: a case study from the Northwest Atlantic,708–719. https://doi.org/10.1093/icesjms/fsp022

Marino L., Rose N.A., Visser I.N., Rally H.D., Ferdowsian H.R. & Slootsky V., 2019. The harmful effects of captivity and chronic stress on the well-being of orcas (*Orcinus orca*). Journal of Veterinary Behavior, 35: 69–82. https://doi.org/10.1016/j.jveb.2019.05.005

Matkin C.O., Barrett-Lennard L.G., Yurk H., Ellifrit D.K. & Trites A.W., 2007. Ecotypic variation and predatory behavior among killer whales (*Orcinus orca*) off the eastern Aleutian Islands, Alaska. Fishery Bulletin, 105: 74–87. https://www.zoology.ubc.ca/~barrett/documents/MatkinetalEcotypicvariationinkwLBL2888.pdf

Moorhouse T.P., D'Cruze N.C. & Macdonald D.W., 2016. Unethical use of wildlife in tourism: What's the problem, who is responsible, and what can be done? Journal of Sustainable Tourism, 1–12. https://doi.org/10.1080/09669582.2016.1223087

Nakamura I., Goto Y. & Sato K., 2015. Ocean sunfish rewarm at the surface after deep excursions to forage for siphonophores. Journal of Animal Ecology, 84: 590–603. https://doi.org/10.0.4.87/1365-2656.12346

Nakamura I. & Yamada M., 2022. Thermoregulation of ocean sunfish in a warmer sea suggests their ability to prevent heat loss in deep, cold foraging grounds. Journal of Experimental Marine Biology and Ecology. 546 e151651. https://doi.org/10.1016/j.jembe.2021.151651

Norris K.S. & Prescott J.H., 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University of California Publications in Zoology, 63: 291–402.

Nyegaard M., Andrzejaczek S., Jenner C.S. & Jenner M.-N.M., 2019. Tiger shark predation on large ocean sunfishes (Family Molidae) - two Australian observations. Environmental Biology of Fishes, 96: 1–8. http://doi.org/10.1007/s10641-019-00926-y

Nyegaard M., Garcia-Barcelona S., Phillips N.D. & Sawai E. 2020. Chapter 12 Fisheries interactions, distribution modeling and conservation issues of the ocean sunfishes. In: Thys T.M., Hays G.C. & Houghton J.D.R. (Eds.), The Ocean Sunfish: evolution, biology and conservation. CRC Press, Boca Raton, pp. 216–242.

Nyegaard M., Loneragan N.R., Hall S., Andrew J., Sawai E. & Nyegaard M. 2018a. Giant jelly eaters on the line: species distribution and bycatch of three dominant sunfishes in the Southwest Pacific. Estuarine, Coastal and Shelf Science, 207: 1–15. https://doi.org/10.1016/j.ecss.2018.03.017

Nyegaard M., Sawai E., Gemmell N., Gillum J., Loneragan N.R., Yamanoue Y. & Stewart A.L., 2018b. 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, 182: 631–658. https://doi.org/10.1093/zoolinnean/zlx040

Nyegaard M., Visser I.N. & Fletcher L.A., 2023. Ocean sunfish, genus *Mola* Kölreuter, 1766 (Pisces Molidae), exhibit surprising levels of agility during interactions with orca, *Orcinus orca* (Linnaeus, 1758) (Mammalia Delphinidae). Biodiversity Journal, 14: 3–17. https://doi.org/10.31396/Biodiv.Jour.2023.14.1.3.17

Ortiz R.M., 2001. Osmoregulation in marine mammals. The Journal of Experimental Biology, 204: 1831–1844. https://doi.org/10.1242/jeb.204.11.1831

Pagel C.D., Orams M.B. & Lück M., 2020. #BiteMe: Considering the potential influence of social media on in-water encounters with marine wildlife. Tourism in Marine Environments, 1–22. https://doi.org/10.3727/154427320X15754936027058

Palička J., 2016. Video. "The Whale Hunters from Lamalera - Part 6 Hunting *Mola Mola*" Posted on YouTube on 17 March 2016. Last accessed 10 December 2022. https://www.youtube.com/watch?v=Hxxu5xxzkXo

Parsons C., 1986. Dangerous Marine Animals of the Pacific Coast. Helm Publishing, San Luis Obispo, California, USA.

Parsons E.C.M., 2012. Killer whale killers. Tourism in Marine Environments, 8: 153–160. https://doi.org/10.3727/154427312X13491835451494

Perrin W.F., Reeves R.R., Dolar M.L.L., Jefferson T.A., Marsh H., Wang J.Y. & Estacion J., 2002. Second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman University, Dumaguete City, Philippines, 24–26 July, 2002, Bonn, Germany, 161 pp.

Phillips N.D., Reid N., Thys T.M., Harrod C., Payne N.L., Morgan C.A., White H.J., Porter S. & Houghton J.D.R., 2017. Applying species distribution modelling to a data poor, pelagic fish complex: the ocean sunfishes. Journal of Biogeography, 44: 2176–2187. https://doi.org/10.1111/jbi.13033

Pyle P., Schramm M.J., Keiper C. & Anderson S.D., 1999. Predation on a white shark (*Carcharodon carcharias*) by a killer whale (*Orcinus orca*) and a possible case of competitive displacement. Marine Mammal Science, 15: 563–568. https://doi.org/10.1111/j.1748-7692.1999.tb00822.x

Rash R. & Lillywhite H.B., 2019. Drinking behaviors and water balance in marine vertebrates. Marine Biology. 166:e122 (1–21). https://doi.org/10.1007/s00227-019-3567-4

Rendell L. & Whitehead H.P., 2001. Culture in whales and dolphins. Behavioral and Brain Sciences, 24: 309–382. https://doi.org/10.1017/S0140525X0100396X

Ryan C. & Holmes J.M.C., 2012. Killer whale *Orcinus orca* predation on sunfish *Mola mola*. Marine Biodiversity Records, 5(e10): 1–2. http://doi.org/10.1017/S1755267211001187

Saito T., Noguchi T., Shida Y., Abe T. & Hashimoto K., 1991. Screening of tetrodotoxin and its derivatives in puffer-related species. Nippon Suisan Gakkaishi, 57: 1573–1577. https://doi.org/10.2331/suisan.57.1573

Sawai E. & Nyegaard M., 2022. A review of giants: examining the species identities of the world's heaviest extant bony fishes (ocean sunfishes, Family Molidae). Journal of Fish Biology, 100: 1345–1364. https://doi.org/10.1111/jfb.15039

Sawai E., Nyegaard M. & Yamamoto Y., 2020. Phylogeny, taxonomy and size records of ocean sunfishes. In: Thys T.M., Hays G.C. & Houghton J.D.R, (Eds.), The Ocean Sunfish: evolution, biology and conservation. CRC Press, Boca Raton, FL, USA.

Sawai E., Yamanoue Y., Jawa L., Al-Mamry J. & Sakai Y., 2017. Molecular and morphological identification of *Mola* sunfish specimens (Actinopterygii:

Tetraodontiformes: Molidae) from the Indian Ocean. Species Diversity, 22: 99–104. https://doi.org/10.12782/sd.22_99

Sawai E., Yamanoue Y., Nyegaard M. & Sakai Y., 2018. Redescription of the bump-head sunfsh *Mola alexandrini* (Ranzani 1839), senior synonym of *Mola ramsayi* (Giglioli 1883), with designation of a neotype for *Mola mola* (Linnaeus 1758) (Tetraodontiformes: Molidae). Ichthyological Research. 65: 142–160. https://doi.org/10.1007/s10228-017-0603-6

Siciliano S., Cardoso J., Francisco A., De Souza S.P., Hauser-Davis R.A. & Iwasa-Arai T., 2020. Epizoic barnacle (*Xenobalanus globicipitis*) infestations in several cetacean species in south-eastern Brazil. Marine Biology Research, 16: 1–13. https://doi.org/10.1080/17451000.2020.1783450

Similä T., Holst J.C. & Christensen I.,1996. Occurrence and diet of killer whales in northern Norway: seasonal patterns relative to the distribution and abundance of Norwegian spring-spawning herring. Canadian Journal of Fisheries and Aquatic Sciences, 53: 769–779. https://doi.org/10.1139/f95-253

Similä T. & Ugarte F., 1993. Surface and underwater observations of cooperatively feeding killer whales in northern Norway. Canadian Journal of Zoology, 71: 1494–1499. https://doi.org/10.1139/z93-210

Sims D.W., Queiroz N., Doyle T.K., Houghton J.D.R. & Hays G.C., 2009. Satellite tracking of the World's largest bony fish, the ocean sunfish (*Mola mola* L.) in the North East Atlantic. Journal of Experimental Marine Biology and Ecology, 370: 127–133. https://doi.org/10.1016/j.jembe.2008.12.011

Song Y., 2018. Feeding habits of different killer whale (*Orcinus orca*) ecotypes and populations BSc Thesis. Wuhan, Hubei, China: Wuhan University, 43 pp.

Ten S., Raga J.A. & Aznar F.J., 2022. Epibiotic fauna on cetaceans worldwide: A systematic review of records and indicator potential. Frontiers in Marine Science. 9:e846558 (846551–846555). https://doi.org/10.3389/fmars.2022.846558

Thys T.M., Hearn A.R., Weng K.C., Ryan J.P. & Peña-herrera-Palma C., 2017. Satellite tracking and site fidelity of short ocean sunfish, *Mola ramsayi*, in the Galapagos Islands. Journal of Marine Biology, Article ID 7097965: 1–10. https://doi.org/10.1155/2017/7097965

Towers J.R., Tixier P., Ross K.A., Bennett J., Arnould J.P.Y., Pitman R.L. & Durban J.W. 2018. Movements and dive behaviour of a toothfish-depredating killer and sperm whale. ICES Journal of Marine Science, 76: 1–14. https://doi.org/10.1093/icesjms/fsy118

Towner A.V., Watson R.G.A., Kock A.A., Papastamatiou Y.P., Sturup M., Enrico G., Baker K.C., Booth T., L D.M., Chivell W., Elwyn S., Kaschke T., Edwards D.E. & Smale M.J., 2022. Fear at the top: killer whale predation drives white shark absence at South Africa's largest aggregation site. African Journal of Marine Science, 44: 139–152. https://doi.org/10.2989/1814232X.2022.2066723

Valentine P.S., Birtles A., Curnock M., Arnold P. & Dunstan A., 2004. Getting closer to whales—passenger expectations and experiences, and the management of swim with dwarf minke whale interactions in the Great Barrier Reef. Tourism Management, 25: 647–655. https://doi.org/10.1016/j.tourman.2003.09.001.

van Opzeeland I.C., Corkeron P.J., Leyssen T., Similä T. & Van Parijs S., 2005. Acoustic behaviour of Norwegian killer whales, *Orcinus orca*, during carousel and seiner foraging on spring-spawning herring. Aquatic Mammals, 31: 110–119. http://dx.doi.org/10.1578/AM.31.1.2005.110.

Visser I.N., 1999. Benthic foraging on stingrays by killer whales (*Orcinus orca*) in New Zealand waters. Marine Mammal Science, 15: 220–227. https://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1999.tb00793.x

Visser I.N., 2000a. Orca (*Orcinus orca*) in New Zealand waters PhD Thesis. Auckland: University of Auckland. Available from www.orcaresearch.org, 194 pp.

Visser I.N., 2000b. Killer whale (*Orcinus orca*) interactions with longline fisheries in New Zealand waters. Aquatic Mammals, 26: 241–252. https://www.bmis-bycatch.org/system/files/zotero_attachments/library_1/SSB9KRBP%20-%20Visser%20Killer%20Whales%20NZ.pdf

Visser I.N., 2005. First observations of feeding on thresher (*Alopias vulpinus*) and hammerhead (*Sphyrna zygaena*) sharks by killer whales (*Orcinus orca*), which specialize on elasmobranchs as prey. Aquatic Mammals, 31: 83–88. AM.31.1.2005.83. http://dx.doi.org/10.1578/AM.31.1.2005.83

Visser I.N. & Fletcher L.A., 2023. First records of orca, *Orcinus orca* (Linnaeus, 1758) (Mammalia Cetacea), predation on sharptail ocean sunfish, *Masturus lanceolatus* (É. Liénard, 1840) (Pisces Molidae), with novel components of foraging behaviour discovered through social media.Biodiversity Journal, 14: 19–60. https://doi.org/10.31396/Biodiv.Jour.2023.14.1.19.60

Visser I.N. & Cooper T.E., 2020. It's not black and white: Orca ecotypes in New Zealand. 5th World Conference on Marine Biodiversity; 13–16 December 2020; Auckland, New Zealand. Available from www.orcaresearch.org.

Visser I.N., Cooper T.E. & Grimm H., 2020. Duration of pseudo-stalked barnacles (*Xenobalanus globicipitis*) on a New Zealand Pelagic ecotype orca (*Orcinus*

orca), with comments on cookie cutter shark bite marks (*Isistius* sp.); can they be used as biological tags? Biodiversity Journal, 11: 1067–1086. https://doi.org/10.31396/Biodiv.Jour.2020.11.4.1067.1086

Visser I.N., Smith T.G., Bullock I.D., Green G.D., Carlsson O.G.L. & Imberti S., 2008. Antarctic Peninsula killer whales (*Orcinus orca*) hunt seals and a penguin on floating ice. Marine Mammal Science, 24: 225–234. http://dx.doi.org/10.1111/j.1748-7692.2007.00163.x.

Watanabe Y. & Davenport J., 2020. Chapter 5 Locomotory systems and biomechanics of the ocean sunfish. In: Thys T.M., Hays G.C. & Houghton J.D.R. (Eds.), The Ocean Sunfish: Evolution, biology and conservation. CRC Press Boca Raton, FL, USA, pp. 72–86.

Watanabe Y. & Sato K., 2008. Functional dorsoventral symmetry in relation to lift-based swimming in the ocean sunfish *Mola mola*. PLoS ONE. 3(e3446): 1–7. https://doi.org/10.1371/journal.pone.0003446

Whale Watch Western Australia, 2020. Video. "Orca play with sunfish" and accompanying comments. Posted to YouTube on 06 March 2020, from interaction on 03 March 2020. Last accessed 10 December 2022. https://www.youtube.com/watch?v=wxio3TMNmWI

Whitehead H.P. & Reeves R.R., 2005. Killer whales and whaling: the scavenging hypothesis. Biology Letters, 1: 415–418. https://doi.org/10.1098/rsbl.2005.0348.

Williams A.J., Dyer B.M., Randall R.M. & Komen J., 1990. Killer whales *Orcinus orca* and seabirds: "play", predation and association. Marine Ornithology, 18: 37–41. http://www.marineornithology.org/PDF/18/MO_1990_06.pdf

Supplemental Material S-1. Published sources.

Table S-1.1 Published sources of orca interactions with large species of molids (*Mola* spp. and *Masturus lanceolatus*). Although we are aware of extensive secondary citations, we only list the primary. The number of orca present and involved in the interaction, age class/size/sex and the ecotype of the orca, sunfish species identity and size are given as per the Primary source or from details supplied in subsequent pers. comm. See Table 2 for Interaction definitions. Abbreviations: # (number), ~ (approximately), btw (between), est. (estimated), TL (total length).

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
Night btw 19611118 - 19611119	(North Pacific), USA, California, Newport Beach, Captivity[1]	[1] (1) Adult, Female, Unknown	Predation	[1] *Mola mola* Not stated	Expired	Page 137. "*...placed into the 100- by 50- by 19-foot oval fish tank ... the following morning, the whale was observed holding a newly-killed ocean sunfish, Mola mola (Linnaeus) in her mouth. This fish was not consumed ….*"	Caldwell & Brown (1964)
19850330	(South Pacific), Coral Sea, Australia, Raine Island	[1] (1) Adult, Male, Unknown	Predation	[1] *Mola mola* 1m	Dying	Page 629. "*…a solitary animal [orca] was seen to devour a sunfish (Mola mola) ...*" … "*Underwater visibility was about 15 m*" … "*whale surfaced ... and was immediately surrounded by seabirds*." Page 630. "*…the whale held a struggling sunfish in its jaws and was biting it. The sunfish was about 1 m in length; it was still alive but the whale appeared to have no difficulty holding the sunfish in its jaws*" … "*Eating occurred only underwater. The whale dived to depths of 5-6 m, stopped, and began biting the sunfish. Jaw movements were visible and biting sounds clearly audible. Pieces of white flesh drifted away from the whale's mouth. We recovered one large piece (about 40 by 30 cm; weight about 3 kg) ripped away by the whale; it looked like a thick layer of skin. There were several conical-shaped holes in the piece. Sharks (Carcharhinus albimarginatus and C. amblyrhynchus)* [sic] *frequently circled the whale and sunfish, and swallowed the smaller pieces of flesh, but made no movements toward either the sunfish or the*	Gladstone (1988)

[1] Held at "Marineland of the Pacific" [public aquarium at Palos Verdes Estates, California, USA, closed permanently 11 Feb 1987].

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
						whale."… "*After 2 h the whale either had eaten the sunfish completely, or abandoned it. It left the vicinity of the reef and swam seaward; we abandoned our pursuit.*"	
Pre-1996	(South Pacific) Solomon Sea, Papua New Guinea, Milne Bay	[1] (1) Adult, Male, Unknown	Predation	[1] *Mola mola* Not stated	Expired	Page 143. "*A single large male, with an enormous dorsal fin, had killed and was eating an Ocean Sunfish (Mola mola). We decided to snorkel with him and, rather nervously, approached him on the calm, clear water. The whale was curious; he brought the dead sunfish towards us at the surface then he let it drop. As it was falling through the water the whale backed off and watched. We made no move towards his meal and, when the sunfish had almost sunk from sight, he dived for it, brought it back to the surface and dropped again. He did this several times before swimming away.*"	Halstead (1967)
19960114	(Equatorial Pacific) Ecuador, Galápagos Islands, Punta Flores	Not stated	Non-predation	[Not stated] *Mola mola* Not stated	Not established	Appendix 1, Table 1. "*Species attacked or harassed* [by orca] *(no evidence of physical contact made): Sunfish (Mola mola)*".	Merlen (1999)
19991024	(North Pacific) USA, California, Monterey Bay	[15] (Not Stated)	Predation	[1], *Mola (mola?)* Not stated	Expired	Page 31, Table 1, Entry 95. Number of killer whales = 15, ecotype = mammal-eater, behaviour = attack, prey killed = unknown, comments = "*Transient KWs apparently ate a sunfish*" Appendix S2, Page 26, Entry 95. "*24 October 1999; Monterey Bay, CA; D. Shearwater, unpublished notes. 15 transient killer whales "associated with 5–6 [humpback whales] and 2 [Pacific white-sided dolphins Lagenorhychus* [sic] *obliquidens]. Ate a Mola [mola]?*" Note that with the "?" placed after [mola], we have assumed it is the species, not the event, that is being questioned by Pitman et al 2017.	Pitman et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	**(Ocean Basin) Country, Location**	**[# of Orca present] (# involved) age class/size, sex, & Ecotype**	**Interaction Orca POV**	**[# sunfish present], species & size**	**Interaction Sunfish POV**	**Notes**	**Source**
Pre-2000	(South Pacific) New Zealand, Northland, The Rise	[3] (3) Not stated, Teleost eater	Predation	[1], *Mola mola*, Est. 2m TL	Dying	Page 130. "*…. a group of three orca were seen to attack and eat a sun-fish (Mola mola)…. Approximately 70 km offshore. As the water was clear (visibility was estimated at great* [sic] *than 20 m), surface observations of the attack clearly showed the sun-fish* [sic] *(estimated to be at least 2 m across) killed and consumed by the orca*". Page 125, Table 4.1. "*Prey taken in NZ, but also recorded elsewhere: …. Sunfish, Mola mola…"*	Visser (2000)
Pre-2002	(Mediterranean Sea) Western Mediterranean	Not Stated	Predation	[Not stated], *Mola mola* Not Stated	Expired	Page 12. "*Ten prey species have been recorded for the first time from New Zealand waters … sunfish, Mola mola;*" and "*In the Western Mediterranean Sea orcas were recorded between March and September 2001 feeding on … Ocean sunfish (Mola mola).*"	Whale and Dolphin Conservation Society et al. (2002)
Pre-2002	(Equatorial Pacific) Ecuador, Galápagos Islands	Not Stated	Predation	[Not stated], "Ocean Sunfish" Not Stated	Expired	Page 2. "*killer whales .... have been observed feeding* ...[on] *ocean sunfish ...* " Note that the Merlen, pers. comm. (2010) is the source, as the publications listed in this manuscript do not include any sunfish records.	Smith (2012)
20030110	(Equatorial Atlantic) Carvalho, São Tomé and Príncipe Islands	[3-5] (2) Adult, Juvenile, Female, Not Stated	Predation	[1], "Ocean Sunfish" Not Stated	Expired	Page 1605. "*… an adult–calf pair of killer whales was observed feeding on an ocean sunfish at the surface*". Page 1607, Table 2, Ref 3. "*A killer whale adult–calf pair observed feeding on an ocean sunfish at the surface. The other whales in the group did not participate*"… "*killer whale group size: 3-5*" … "*Water depth (m) 1,200."*	Weir et al. (2010)
Pre-2004	(South Pacific) Australia, Tasmania, St. Helens,	[20] (Not stated) Not stated	Non-Predation	[1], *Mola spp.* Not Stated	Not established	Page 27, Table 4. "*Marine wildlife associated with killer whales: "1 sunfish, location: St Helens Tasmania, 20 traveling orca*". Page 26. Additional notes "*Killer whales were observed to be associated with other wildlife species when hunting. These include species that are confirmed prey of killer whales…, as well as … sunfish (Mola spp.) …"*	Morrice (2004)
20050823	(Equatorial Atlantic)	[7] (7)	Predation	[1], *Mola*	Dying	Page 8. *"…witnessed by the tourist vessel M/V Polaris on 23 August 2005. This sighting indicated a pod of 7 orcas, 2*	Thys et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
	Ecuador, Galápagos Islands, Punta Vicente Roca	Adult, Juvenile, Not stated		*ramsayi* Ca. 2m		*adults and 5 juveniles, which attacked a mola* [M. ramsayi] *(approx. 2 m TL) at PVR. The pod repeatedly brought the fish to the surface. One adult orca first appeared to be using the mola as a prey-capture teaching tool for an accompanying juvenile orca before the mola was eventually eaten*."	
Pre-2008	(South Pacific) Australia, New South Wales, Eden	Not stated	Predation	[Not stated] *Mola ramsayi* Not Stated	Expired	Page 80. "*.... since 2002 Killer Whales have twice been observed feeding on Southern Ocean Sunfish* Mola ramsayi *off Eden NSW*"	Mustoe (2008)
Pre-2008	(South Pacific) Australia, New South Wales, Eden	Not stated	Predation	[Not stated] *Mola ramsayi* Not Stated	Expired	Page 80. "*.... since 2002 Killer Whales have twice been observed feeding on Southern Ocean Sunfish* Mola ramsayi *off Eden NSW*"	Mustoe (2008)
20090927	(North Pacific) USA, California, Monterey Bay	[6-7] (6) Not Stated	Predation	[1], *Mola mola* Est. 1 - 1.5m	Dying	Page 23, Table 1, Entry 96. Number of killer whales = 6-7, ecotype = mammal-eater, behaviour = attack, prey killed = unknown, comments = "*Transient KWs attacking a sunfish are "mobbed" by 3 HBs*" [humpbacks]. Appendix S2, Page 26, Entry 96. "*27 September 2009; Monterey Bay, CA, D. Shearwater, unpublished notes and A. Borker. ".. they appeared to be trying to kill an ocean sunfish, (Mola mola)!" "we spotted about 6–7 orcas and when we approached found them to be biting and presumably killing a sunfish. They dragged it through the water, but then lost interest. The orcas pod was rolling and breaching around the boat." "killer whales identified as Bigg's from photos by J. Durban"* *D. Shearwater, unpublished notes: "... this interaction of killer whales apparently killing an ocean sunfish, ... their*	Pitman et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
						behavior reminded me of every time I've ever seen them on a kill, or having just recently killed an animal. In this case, it was the mola." [DS estimated 5–6 killer whales]. [Length of the sunfish was estimated to be 1–1.5 m—]	
20101004	(North Atlantic) Ireland, Doohoma	[Not stated] (1) Adult, Female, Teleost eater	Predation	[Not stated] *Mola mola* Not Stated	Expired	Page 1. Description of stomach contents: "*Siphonostomatoid copepods were found in the stomachs and identified as Cecrops latreilli (Leach, 1816), an ectoparasite on the gills and skin of sunfish, (Mola mola (Linnaeus, 1758) and M. lanceolata (*Grabda, 1973)) [presumably referring to *Masturus lanceolatus* (Liénard, 1840)]. *Cecrops latreilli has a cosmopolitan distribution, following that of its host and has previously been recorded on the gill filaments of sunfish in Irish waters (Cooper et al., 1982). Partially digested bony structures consistent in shape and size with the modified toothless premaxilla and dentary of sunfish were also found in the stomachs. It was not possible to calculate the body size of the prey by allometric regression as the spongiform nature of sunfish bones means they are prone to shrinkage (Gregory & Raven, 1934).*"	Ryan & Holmes (2012)
Pre-2016	(South Indian) Australia, Western Australia, Bremer Canyon	[Not stated] (Not stated) Mammal eater	Unknown	[1], *Mola ramsayi* Not stated	Expired	Page 2. *"..... killer whales in southern Western Australia also potentially feed on the Southern Ocean sunfish (Mola ramsayi) (DR personal observation, unpublished)* " Page 11. "*There are other accounts of Bremer Sub-Basin killer whales potentially feeding on sunfish … (MB and DR personal observations, unpublished).*"	Wellard et al. (2016)
20130401	(Equatorial Atlantic) Ecuador, Galápagos Islands, Cerro	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are … occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo* Mola mola" (JD & DAR pers. comm.).	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
	Brujo, San Cristobal					NOTE: the quote in the publication states there were six predation events, one of those is separated out (above, dated 20050823) and of the remaining five interactions, dates and location details were supplied for three by Judith Denkinger & Daniela Alcarcón Ruales. These five are listed from here forward.	
20140226	(Equatorial Atlantic), Ecuador, Galápagos Islands, Isabela, Tagus	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo sunfish*" (JD & DAR pers. comm.). Note, this record is also listed in S-2 (Video).	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)
Pre-2016	(Equatorial Atlantic), Ecuador, Galápagos Islands	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." Note that no further details were available]	Thys et al. (2017)
Pre-2016	(Equatorial Atlantic), Ecuador, Galápagos Islands	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." Note that no further details were available]	Thys et al. (2017)
20160501	(Equatorial Atlantic) Ecuador, Galápagos Islands, "mar abierto", Banco Russo	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo sunfish*" (JD & DAR pers. comm.)	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)

Table S-1.2 Examples of excluded records.

Notes	Source (chronological by publication date)
Page 79. "*In Indonesia they feed on ocean sunfish (Mola mola), according to Kahn.*"	Perrin et al. (2002)
"*An attack of killer whales on an unknown prey species was observed by JO aboard the R/V BAE Orion in the Bolivar Canal on 6 October 2008. Four killer whales appeared to work cooperatively (often moving in pairs or in groups of 1 and 3) to surround another animal. The killer whales appeared to surround the animal and were observed forcing the forward section of the animal underwater, leaving the fluke of the animal to rest over the head of one of the killer whales. We speculate that the unknown prey was possibly a large shark or a sunfish (Masturus sp. or Mola mola) …*".	Alava et al. (2013)
Table 3. Listed as prey "*Sunfish (Mola mola)", "Southern sunfish (M. alexandrini)"* but no further data or sources given	Foster (2019)

References cited in Tables S-1.1 & S-1.2

Alava J.J., Smith K.J., O'Hern J., Alarcón D., Merlen G. & Denkinger J. 2013. Observations of killer whale (*Orcinus orca*) attacks on Bryde's whales (*Balaenoptera edeni*) in the Galápagos Islands. Aquatic Mammals. 39(2):196-201. doi:https://doi.org/10.1578/AM.39.2.2013.196.

Caldwell D.K. & Brown D.H. 1964. Tooth wear as a correlate of described feeding behavior by the killer whale; with notes on a captive specimen. Bulletin of the Southern California Academy of Sciences. 63(3):129-140.

Foster R.N. 2019. Fussy feeders or fallacy? Investigating the prevalence of prey preference in killer whales, globally and in the Southern Ocean. University of Canterbury, Christchurch, New Zealand. 35 pp. https://ir.canterbury.ac.nz/handle/10092/18588.

Gladstone W. 1988. Killer whale feeding observed underwater. Journal of Mammalogy. 69(3):629-630. doi:https://doi.org/10.2307/1381360.

Halstead B.W. 1967. Poisonous and venomous marine animals of the world. Vol. II. Vertebrates. United States Government Printing Office, Washington DC.

Merlen G. 1999. The orca in the Galápagos: 135 sightings. Noticias de Gálàpagos. 60(December):1-9. https://www.darwinfoundation.org/en/publications/galapagos-research/noticias-de-galapagos-60.

Morrice M.G. 2004. Killer whales (*Orcinus orca*) in Australian territorial waters. Deakin University, Warrnambool, Victoria, Australia. 50 pp.

Mustoe S. 2008. Killer Whale *Orcinus orca* sightings in coastal Victoria. Victorian Naturalist. 125(3):78-81.

Perrin W.F., Reeves R.R., Dolar M.L.L., Jefferson T.A., Marsh H., Wang J.Y. & Estacion J. 2002. Second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman University, Dumaguete City, Philippines, 24-26 July, 2002, Bonn, Germany. 161 pp.

S-1. Published sources.

Pitman R.L., Deecke V.B., Gabriele C.M., Srinivasan M., Black N., Denkinger J., Durban J.W., Mathews E.A., Matkin D.R., Neilson J.L., Schulman-Janiger A., Shearwater D., Stap P. & Ternullo R. 2017. Humpback whales interfering when mammal-eating killer whales attack other species: Mobbing behavior and interspecific altruism? Marine Mammal Science. 33(1):7-58. doi:https://doi.org/10.1111/mms.12343.

Ryan C. & Holmes J.M.C. 2012. Killer whale *Orcinus orca* predation on sunfish *Mola mola*. Marine Biodiversity Records. 5(e10):1-2. doi:http://doi.org/10.1017/S1755267211001187.

Smith K.J. 2012. Temporal and spatial analysis of killer whale sightings in the Galápagos Marine Reserve, Ecuador MSc Thesis. Texas A&M University, 88 pp.

Thys T.M., Hearn A.R., Weng K.C., Ryan J.P. & Peñaherrera-Palma C. 2017. Satellite tracking and site fidelity of short ocean sunfish, *Mola ramsayi*, in the Galapagos Islands. Journal of Marine Biology. Article ID 7097965:1-10. doi:https://doi.org/10.1155/2017/7097965.

Visser I.N. 2000. Orca (*Orcinus orca*) in New Zealand waters PhD Thesis. Auckland: University of Auckland. Available from www.orcaresearch.org, 194 pp.

Weir C.R., Collins T., Carvalho I. & Rosenbaum H.C. 2010. Killer whales (*Orcinus orca*) in Angolan and Gulf of Guinea waters, tropical West Africa. Journal of the Marine Biological Association of the United Kingdom. 90(8):1601-1611. doi:https://doi.org/10.1017/S002531541000072X.

Wellard R., Lightbody K., Fouda L., Blewitt M., Riggs D. & Erbe C. 2016. Killer whale (*Orcinus orca*) predation on beaked whales (*Mesoplodon* spp.) in the Bremer sub-basin, Western Australia. PLoS ONE.1-15. doi:https://doi.org/10.1371/journal.pone.0166670.

Whale and Dolphin Conservation Society, Dalla Rosa L., Hoyt E., Iñíguez M., Moreno M.M., Morrice M., Taylor M., Tossenberger V. & Visser I.N. 2002. *Orcinus orca* a species complex. Whale and Dolphin Conservation Society. 30 pp.

Supplemental Material S-1. Published sources.

Table S-1.1 Published sources of orca interactions with large species of molids (*Mola* spp. and *Masturus lanceolatus*). Although we are aware of extensive secondary citations, we only list the primary. The number of orca present and involved in the interaction, age class/size/sex and the ecotype of the orca, sunfish species identity and size are given as per the Primary source or from details supplied in subsequent pers. comm. See Table 2 for Interaction definitions. Abbreviations: # (number), ~ (approximately), btw (between), est. (estimated), TL (total length).

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
Night btw 19611118 - 19611119	(North Pacific), USA, California, Newport Beach, Captivity[1]	[1] (1) Adult, Female, Unknown	Predation	[1] *Mola mola* Not stated	Expired	Page 137. "*...placed into the 100- by 50- by 19-foot oval fish tank ... the following morning, the whale was observed holding a newly-killed ocean sunfish, Mola mola (Linnaeus) in her mouth. This fish was not consumed ….*"	Caldwell & Brown (1964)
19850330	(South Pacific), Coral Sea, Australia, Raine Island	[1] (1) Adult, Male, Unknown	Predation	[1] *Mola mola* 1m	Dying	Page 629. "*…a solitary animal [orca] was seen to devour a sunfish (Mola mola) ...*" … "*Underwater visibility was about 15 m*" … "*whale surfaced ... and was immediately surrounded by seabirds*." Page 630. "*…the whale held a struggling sunfish in its jaws and was biting it. The sunfish was about 1 m in length; it was still alive but the whale appeared to have no difficulty holding the sunfish in its jaws*" … "*Eating occurred only underwater. The whale dived to depths of 5-6 m, stopped, and began biting the sunfish. Jaw movements were visible and biting sounds clearly audible. Pieces of white flesh drifted away from the whale's mouth. We recovered one large piece (about 40 by 30 cm; weight about 3 kg) ripped away by the whale; it looked like a thick layer of skin. There were several conical-shaped holes in the piece. Sharks (Carcharhinus albimarginatus and C. amblyrhynchus)* [sic] *frequently circled the whale and sunfish, and swallowed the smaller pieces of flesh, but made no movements toward either the sunfish or the*	Gladstone (1988)

[1] Held at "Marineland of the Pacific" [public aquarium at Palos Verdes Estates, California, USA, closed permanently 11 Feb 1987].

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
						whale."… "*After 2 h the whale either had eaten the sunfish completely, or abandoned it. It left the vicinity of the reef and swam seaward; we abandoned our pursuit.*"	
Pre-1996	(South Pacific) Solomon Sea, Papua New Guinea, Milne Bay	[1] (1) Adult, Male, Unknown	Predation	[1] *Mola mola* Not stated	Expired	Page 143. "*A single large male, with an enormous dorsal fin, had killed and was eating an Ocean Sunfish (Mola mola). We decided to snorkel with him and, rather nervously, approached him on the calm, clear water. The whale was curious; he brought the dead sunfish towards us at the surface then he let it drop. As it was falling through the water the whale backed off and watched. We made no move towards his meal and, when the sunfish had almost sunk from sight, he dived for it, brought it back to the surface and dropped again. He did this several times before swimming away.*"	Halstead (1967)
19960114	(Equatorial Pacific) Ecuador, Galápagos Islands, Punta Flores	Not stated	Non-predation	[Not stated] *Mola mola* Not stated	Not established	Appendix 1, Table 1. "*Species attacked or harassed* [by orca] *(no evidence of physical contact made): Sunfish (Mola mola)*".	Merlen (1999)
19991024	(North Pacific) USA, California, Monterey Bay	[15] (Not Stated)	Predation	[1], *Mola (mola?)* Not stated	Expired	Page 31, Table 1, Entry 95. Number of killer whales = 15, ecotype = mammal-eater, behaviour = attack, prey killed = unknown, comments = "*Transient KWs apparently ate a sunfish*" Appendix S2, Page 26, Entry 95. "*24 October 1999; Monterey Bay, CA; D. Shearwater, unpublished notes. 15 transient killer whales "associated with 5–6 [humpback whales] and 2 [Pacific white-sided dolphins Lagenorhychus* [sic] *obliquidens]. Ate a Mola [mola]?*" Note that with the "?" placed after [mola], we have assumed it is the species, not the event, that is being questioned by Pitman et al 2017.	Pitman et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	**(Ocean Basin) Country, Location**	**[# of Orca present] (# involved) age class/size, sex, & Ecotype**	**Interaction Orca POV**	**[# sunfish present], species & size**	**Interaction Sunfish POV**	**Notes**	**Source**
Pre-2000	(South Pacific) New Zealand, Northland, The Rise	[3] (3) Not stated, Teleost eater	Predation	[1], *Mola mola*, Est. 2m TL	Dying	Page 130. "*…. a group of three orca were seen to attack and eat a sun-fish (Mola mola)…. Approximately 70 km offshore. As the water was clear (visibility was estimated at great* [sic] *than 20 m), surface observations of the attack clearly showed the sun-fish* [sic] *(estimated to be at least 2 m across) killed and consumed by the orca*". Page 125, Table 4.1. "*Prey taken in NZ, but also recorded elsewhere: …. Sunfish, Mola mola…"*	Visser (2000)
Pre-2002	(Mediterranean Sea) Western Mediterranean	Not Stated	Predation	[Not stated], *Mola mola* Not Stated	Expired	Page 12. "*Ten prey species have been recorded for the first time from New Zealand waters … sunfish, Mola mola;*" and "*In the Western Mediterranean Sea orcas were recorded between March and September 2001 feeding on … Ocean sunfish (Mola mola).*"	Whale and Dolphin Conservation Society et al. (2002)
Pre-2002	(Equatorial Pacific) Ecuador, Galápagos Islands	Not Stated	Predation	[Not stated], "Ocean Sunfish" Not Stated	Expired	Page 2. "*killer whales .... have been observed feeding* ...[on] *ocean sunfish ...* " Note that the Merlen, pers. comm. (2010) is the source, as the publications listed in this manuscript do not include any sunfish records.	Smith (2012)
20030110	(Equatorial Atlantic) Carvalho, São Tomé and Príncipe Islands	[3-5] (2) Adult, Juvenile, Female, Not Stated	Predation	[1], "Ocean Sunfish" Not Stated	Expired	Page 1605. "*… an adult–calf pair of killer whales was observed feeding on an ocean sunfish at the surface*". Page 1607, Table 2, Ref 3. "*A killer whale adult–calf pair observed feeding on an ocean sunfish at the surface. The other whales in the group did not participate*"… "*killer whale group size: 3-5*" … "*Water depth (m) 1,200."*	Weir et al. (2010)
Pre-2004	(South Pacific) Australia, Tasmania, St. Helens,	[20] (Not stated) Not stated	Non-Predation	[1], *Mola spp.* Not Stated	Not established	Page 27, Table 4. "*Marine wildlife associated with killer whales: "1 sunfish, location: St Helens Tasmania, 20 traveling orca*". Page 26. Additional notes "*Killer whales were observed to be associated with other wildlife species when hunting. These include species that are confirmed prey of killer whales…, as well as … sunfish (Mola spp.) …"*	Morrice (2004)
20050823	(Equatorial Atlantic)	[7] (7)	Predation	[1], *Mola*	Dying	Page 8. *"…witnessed by the tourist vessel M/V Polaris on 23 August 2005. This sighting indicated a pod of 7 orcas, 2*	Thys et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
	Ecuador, Galápagos Islands, Punta Vicente Roca	Adult, Juvenile, Not stated		*ramsayi* Ca. 2m		*adults and 5 juveniles, which attacked a mola* [M. ramsayi] *(approx. 2 m TL) at PVR. The pod repeatedly brought the fish to the surface. One adult orca first appeared to be using the mola as a prey-capture teaching tool for an accompanying juvenile orca before the mola was eventually eaten*."	
Pre-2008	(South Pacific) Australia, New South Wales, Eden	Not stated	Predation	[Not stated] *Mola ramsayi* Not Stated	Expired	Page 80. "*.... since 2002 Killer Whales have twice been observed feeding on Southern Ocean Sunfish* Mola ramsayi *off Eden NSW*"	Mustoe (2008)
Pre-2008	(South Pacific) Australia, New South Wales, Eden	Not stated	Predation	[Not stated] *Mola ramsayi* Not Stated	Expired	Page 80. "*.... since 2002 Killer Whales have twice been observed feeding on Southern Ocean Sunfish* Mola ramsayi *off Eden NSW*"	Mustoe (2008)
20090927	(North Pacific) USA, California, Monterey Bay	[6-7] (6) Not Stated	Predation	[1], *Mola mola* Est. 1 - 1.5m	Dying	Page 23, Table 1, Entry 96. Number of killer whales = 6-7, ecotype = mammal-eater, behaviour = attack, prey killed = unknown, comments = "*Transient KWs attacking a sunfish are "mobbed" by 3 HBs*" [humpbacks]. Appendix S2, Page 26, Entry 96. "*27 September 2009; Monterey Bay, CA, D. Shearwater, unpublished notes and A. Borker. ".. they appeared to be trying to kill an ocean sunfish, (Mola mola)!" "we spotted about 6–7 orcas and when we approached found them to be biting and presumably killing a sunfish. They dragged it through the water, but then lost interest. The orcas pod was rolling and breaching around the boat." "killer whales identified as Bigg's from photos by J. Durban"* *D. Shearwater, unpublished notes: "... this interaction of killer whales apparently killing an ocean sunfish, ... their*	Pitman et al. (2017)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
						behavior reminded me of every time I've ever seen them on a kill, or having just recently killed an animal. In this case, it was the mola." [DS estimated 5–6 killer whales]. [Length of the sunfish was estimated to be 1–1.5 m—]	
20101004	(North Atlantic) Ireland, Doohoma	[Not stated] (1) Adult, Female, Teleost eater	Predation	[Not stated] *Mola mola* Not Stated	Expired	Page 1. Description of stomach contents: "*Siphonostomatoid copepods were found in the stomachs and identified as Cecrops latreilli (Leach, 1816), an ectoparasite on the gills and skin of sunfish, (Mola mola (Linnaeus, 1758) and M. lanceolata (*Grabda, 1973)) [presumably referring to *Masturus lanceolatus* (Liénard, 1840)]. *Cecrops latreilli has a cosmopolitan distribution, following that of its host and has previously been recorded on the gill filaments of sunfish in Irish waters (Cooper et al., 1982). Partially digested bony structures consistent in shape and size with the modified toothless premaxilla and dentary of sunfish were also found in the stomachs. It was not possible to calculate the body size of the prey by allometric regression as the spongiform nature of sunfish bones means they are prone to shrinkage (Gregory & Raven, 1934).*"	Ryan & Holmes (2012)
Pre-2016	(South Indian) Australia, Western Australia, Bremer Canyon	[Not stated] (Not stated) Mammal eater	Unknown	[1], *Mola ramsayi* Not stated	Expired	Page 2. *"..... killer whales in southern Western Australia also potentially feed on the Southern Ocean sunfish (Mola ramsayi) (DR personal observation, unpublished)* " Page 11. "*There are other accounts of Bremer Sub-Basin killer whales potentially feeding on sunfish … (MB and DR personal observations, unpublished).*"	Wellard et al. (2016)
20130401	(Equatorial Atlantic) Ecuador, Galápagos Islands, Cerro	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are … occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo* Mola mola" (JD & DAR pers. comm.).	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)

S-1. Published sources.

Date of Interaction (yyyymmdd)	(Ocean Basin) Country, Location	[# of Orca present] (# involved) age class/size, sex, & Ecotype	Interaction Orca POV	[# sunfish present], species & size	Interaction Sunfish POV	Notes	Source
	Brujo, San Cristobal					NOTE: the quote in the publication states there were six predation events, one of those is separated out (above, dated 20050823) and of the remaining five interactions, dates and location details were supplied for three by Judith Denkinger & Daniela Alcarcón Ruales. These five are listed from here forward.	
20140226	(Equatorial Atlantic), Ecuador, Galápagos Islands, Isabela, Tagus	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo sunfish*" (JD & DAR pers. comm.). Note, this record is also listed in S-2 (Video).	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)
Pre-2016	(Equatorial Atlantic), Ecuador, Galápagos Islands	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." Note that no further details were available]	Thys et al. (2017)
Pre-2016	(Equatorial Atlantic), Ecuador, Galápagos Islands	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." Note that no further details were available]	Thys et al. (2017)
20160501	(Equatorial Atlantic) Ecuador, Galápagos Islands, "mar abierto", Banco Russo	Not stated	Predation	[presumably 1] *Mola Ramsayi* Not stated	Expired	Page 8. "*M. ramsayi here are ... occasionally eaten by orcas. Six orca predation events were reported between 2005 and 2016 (Judith Denkinger, pers comm)*." "*feeding on mola / comiendo sunfish*" (JD & DAR pers. comm.)	Thys et al. (2017), (Judith Denkinger, & Daniela Alcarcón Ruales pers. comm.)

Table S-1.2 Examples of excluded records.

Notes	Source (chronological by publication date)
Page 79. "*In Indonesia they feed on ocean sunfish (Mola mola), according to Kahn.*"	Perrin et al. (2002)
"*An attack of killer whales on an unknown prey species was observed by JO aboard the R/V BAE Orion in the Bolivar Canal on 6 October 2008. Four killer whales appeared to work cooperatively (often moving in pairs or in groups of 1 and 3) to surround another animal. The killer whales appeared to surround the animal and were observed forcing the forward section of the animal underwater, leaving the fluke of the animal to rest over the head of one of the killer whales. We speculate that the unknown prey was possibly a large shark or a sunfish (Masturus sp. or Mola mola) …*".	Alava et al. (2013)
Table 3. Listed as prey "*Sunfish (Mola mola)", "Southern sunfish (M. alexandrini)"* but no further data or sources given	Foster (2019)

References cited in Tables S-1.1 & S-1.2

Alava J.J., Smith K.J., O'Hern J., Alarcón D., Merlen G. & Denkinger J. 2013. Observations of killer whale (*Orcinus orca*) attacks on Bryde's whales (*Balaenoptera edeni*) in the Galápagos Islands. Aquatic Mammals. 39(2):196-201. doi:https://doi.org/10.1578/AM.39.2.2013.196.

Caldwell D.K. & Brown D.H. 1964. Tooth wear as a correlate of described feeding behavior by the killer whale; with notes on a captive specimen. Bulletin of the Southern California Academy of Sciences. 63(3):129-140.

Foster R.N. 2019. Fussy feeders or fallacy? Investigating the prevalence of prey preference in killer whales, globally and in the Southern Ocean. University of Canterbury, Christchurch, New Zealand. 35 pp. https://ir.canterbury.ac.nz/handle/10092/18588.

Gladstone W. 1988. Killer whale feeding observed underwater. Journal of Mammalogy. 69(3):629-630. doi:https://doi.org/10.2307/1381360.

Halstead B.W. 1967. Poisonous and venomous marine animals of the world. Vol. II. Vertebrates. United States Government Printing Office, Washington DC.

Merlen G. 1999. The orca in the Galápagos: 135 sightings. Noticias de Gálàpagos. 60(December):1-9. https://www.darwinfoundation.org/en/publications/galapagos-research/noticias-de-galapagos-60.

Morrice M.G. 2004. Killer whales (*Orcinus orca*) in Australian territorial waters. Deakin University, Warrnambool, Victoria, Australia. 50 pp.

Mustoe S. 2008. Killer Whale *Orcinus orca* sightings in coastal Victoria. Victorian Naturalist. 125(3):78-81.

Perrin W.F., Reeves R.R., Dolar M.L.L., Jefferson T.A., Marsh H., Wang J.Y. & Estacion J. 2002. Second workshop on the biology and conservation of small cetaceans and dugongs of SE Asia. Silliman University, Dumaguete City, Philippines, 24-26 July, 2002, Bonn, Germany. 161 pp.

S-1. Published sources.

Pitman R.L., Deecke V.B., Gabriele C.M., Srinivasan M., Black N., Denkinger J., Durban J.W., Mathews E.A., Matkin D.R., Neilson J.L., Schulman-Janiger A., Shearwater D., Stap P. & Ternullo R. 2017. Humpback whales interfering when mammal-eating killer whales attack other species: Mobbing behavior and interspecific altruism? Marine Mammal Science. 33(1):7-58. doi:https://doi.org/10.1111/mms.12343.

Ryan C. & Holmes J.M.C. 2012. Killer whale *Orcinus orca* predation on sunfish *Mola mola*. Marine Biodiversity Records. 5(e10):1-2. doi:http://doi.org/10.1017/S1755267211001187.

Smith K.J. 2012. Temporal and spatial analysis of killer whale sightings in the Galápagos Marine Reserve, Ecuador MSc Thesis. Texas A&M University, 88 pp.

Thys T.M., Hearn A.R., Weng K.C., Ryan J.P. & Peñaherrera-Palma C. 2017. Satellite tracking and site fidelity of short ocean sunfish, *Mola ramsayi*, in the Galapagos Islands. Journal of Marine Biology. Article ID 7097965:1-10. doi:https://doi.org/10.1155/2017/7097965.

Visser I.N. 2000. Orca (*Orcinus orca*) in New Zealand waters PhD Thesis. Auckland: University of Auckland. Available from www.orcaresearch.org, 194 pp.

Weir C.R., Collins T., Carvalho I. & Rosenbaum H.C. 2010. Killer whales (*Orcinus orca*) in Angolan and Gulf of Guinea waters, tropical West Africa. Journal of the Marine Biological Association of the United Kingdom. 90(8):1601-1611. doi:https://doi.org/10.1017/S002531541000072X.

Wellard R., Lightbody K., Fouda L., Blewitt M., Riggs D. & Erbe C. 2016. Killer whale (*Orcinus orca*) predation on beaked whales (*Mesoplodon* spp.) in the Bremer sub-basin, Western Australia. PLoS ONE.1-15. doi:https://doi.org/10.1371/journal.pone.0166670.

Whale and Dolphin Conservation Society, Dalla Rosa L., Hoyt E., Iñíguez M., Moreno M.M., Morrice M., Taylor M., Tossenberger V. & Visser I.N. 2002. *Orcinus orca* a species complex. Whale and Dolphin Conservation Society. 30 pp.

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2009 0211_Mexico	Video	Youtube, iNaturalist	Michael Van den berg, Cabowhale	20090211	20090211 (pre)
2013 0402_NZ	Video	Youtube	mzdkTV, Mazdak Radjainia	20130929	20130402
2013 0718_Mexico	Video	Youtube	FunBaja, Mrs Haruka	20130722	20130718
2014 0317_Galapagos	Video	Youtube	Janet Wilson [this is also one of the interactions listed in Thys et al. 2017, pers. comm. Judith Denkinger & Daniela Alarcón Ruales, but listed in this publication as a video due to video posting prior to Thys et al. 2017 publication]	20140317	20140226
2015 0126_Tasmania	Video	Facebook, Pers. comm. (email)	Damian Connor and Susie Buetow, Wild Ocean Tasmania, Killer Whales Australia, Ocean Sunfish Research	20150128	20150126
2017 0131_Galapagos	Video	Youtube	Galápagos Eco Fishing, Francis Zavala	20170131	20170131
2017 0420_Monterey	Video	Facebook	Monterey Bay Whale Watch	20170421	20170420

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2009 0211_Mexico	Mexico	Cabo San Lucas	N Pacific	3	3	Dyad(s)
2013 0402_NZ	New Zealand	Northland	S Pacific	3	1	Calf/juv(s)
2013 0718_Mexico	Mexico	Isla Espirito Santo, Baja California	N Pacific	1	1	Single male
2014 0317_Galapagos	Ecuador	Galápagos Islands, Isla Isabela, Tagus Cove	Equatorial Pacific	4	4	Other
2015 0126_Tasmania	Australia	East Coast, Tasman National Park in Tasmania	S Pacific	1	1	Single male
2017 0131_Galapagos	Ecuador	Galápagos Islands, San Cristobal	Equatorial Pacific	7	5	Dyad(s)
2017 0420_Monterey	USA	Monterey Bay, California	N Pacific	7	4	Unknown

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2009 0211_Mexico	Unknown	Not stated	Not stated	Not possible to ascertain [video very low resolution]
2013 0402_NZ	Fish	Not stated	Not stated	Not possible to ascertain [video very low resolution]
2013 0718_Mexico	Unknown	Not stated	Yes	trailing edge of his dorsal fin (20+) and on trail flukes (20+)
2014 0317_Galapagos	Unknown	Not stated	Yes	Adult male, on trailing edge of his left pectoral fin (20+) and on trail flukes (10+) Presumed adult female, on the trailing edge of her dorsal fin (10+)
2015 0126_Tasmania	Unknown	Not stated	Not stated	Not possible to ascertain [video very low resolution]
2017 0131_Galapagos	Unknown	Not stated	Yes	Yes 1 juv, top of dorsal fin (5+) 1 juv, L fluke (5+), R fluke (0) 1 juv, L fluke (0), R fluke (5+) 1 adult female, tip of dorsal fin (5+), L fluke (5+), R fluke (9+)
2017 0420_Monterey	Mammal	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2009 0211_Mexico	Yes	Predation	Kill (unknown)	Confirmed	1	Confirmed (source, imagery)	Mola mola
2013 0402_NZ	No	Non-predation	Play/Harass	Suspected	1	Confirmed (source, imagery)	Mola alexandrini
2013 0718_Mexico	No (only 1 orca present)	Non-predation	Interest	Suspected	1	Confirmed (source, imagery)	Mola sp.
2014 0317_Galapagos	Yes	Predation	Kill & feed	Confirmed	1	Confirmed (source, imagery)	Mola sp.
2015 0126_Tasmania	No	Predation	Kill & feed	Confirmed	1	Confirmed (source, imagery)	Mola sp. (Mola alexandrini?)
2017 0131_Galapagos	Not possible	Predation	Kill & feed	Suspected	1	Confirmed (source, imagery)	Mola alexandrini
2017 0420_Monterey	Potentially as coordinated surfacing	Non-predation	Persecute	Suspected	1	Confirmed (source, imagery)	Mola sp.

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat
2009 0211_Mexico	Est. 2	Alive	Evade	Dead	Confirmed
2013 0402_NZ	Est. 1 - 1.2	Alive	Evade	Survived	Suspected
2013 0718_Mexico	Est. 2	Alive	No response	Survived	Suspected
2014 0317_Galapagos	Est. 2	Not established	Not established	Dead	Confirmed
2015 0126_Tasmania	Est. 1.5	Fatally wounded	Dying	Dead	Confirmed
2017 0131_Galapagos	Est. 2 - 2.5	Alive	Flee	Not established	n/a
2017 0420_Monterey	Est. 0.3 - 0.5	Not established	Not established	Dead	Suspected

Interaction name	Link
2009 0211_Mexico	https://www.youtube.com/watch?v=Yf5MYigV4A0
2013 0402_NZ	https://www.youtube.com/watch?v=ocvF9gv5M0s
2013 0718_Mexico	https://www.youtube.com/watch?v=PMcBCwR-bqg
2014 0317_Galapagos	https://www.youtube.com/watch?v=yLj8N8OnVB8
2015 0126_Tasmania	https://www.youtube.com/watch?v=rFnnTdjGpRk; https://www.facebook.com/killerwhalesaustralia/photos/a.702951536431345/829602253766272
2017 0131_Galapagos	https://www.youtube.com/watch?v=IaCDfEoqoIQ
2017 0420_Monterey	https://www.facebook.com/watch/?v=1227076457390087

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2018 0105_PNG	Video	Video, Pers. comm. (email)	Rachel Barry, Matthew Barry, Cecelie Benjamin, Walindi Resort	20180106	20180105
2018 0316_Indonesia	Video	Youtube	Shu Mei	20180319	20180316
2019 0306 2019 0306_FalseBay	Video	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company), Alex Vogel	n/a	20190306
2019 1013_Malaysia	Video	Facebook, online magazine, Pers. comm. (email)	Vito Maffei, Scuba Junkie, Scuba Diver magazine		20191013
2020 0204_FalseBay	Video	Personal	Ryan Miller, Apex Shark Expeditions	20200204	20200204
2020 0305_Bremer	Video	Youtube, Facebook, blog;Pers. comm. (email)	Gemma Sharp, Whale Watch Western Australia	20200306	20200305
2020 0429_Simon's Town	Video (+ photos)	Pers. comm. (email)	David Hurwitz, Simon's Town Boat Company, Alex Vogel	n/a	20200429

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2018 0105_PNG	PNG	Kimbe Bay	Equatorial Pacific	7	2	Dyad(s)
2018 0316_Indonesia	Indonesia	Bunaken, Manado	Equatorial Pacific	3	1	Single male
2019 0306 2019 0306_FalseBay	South Africa	False Bay	S Atlantic	2	1	Single male
2019 1013_Malaysia	Malaysia	South Kapalai	Equatorial Pacific	2	1	Calf/juv(s)
2020 0204_FalseBay	South Africa	False Bay	S Atlantic	2	1	Single male
2020 0305_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	7	3	Unknown
2020 0429_Simon's Town	South Africa	Simon's Town	S Atlantic	2	2	Other

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2018 0105_PNG	Unknown	Not stated	No	No
2018 0316_Indonesia	Unknown	Not stated	No	No
2019 0306 2019 0306_FalseBay	Both	Not stated	No	No
2019 1013_Malaysia	Unknown	Not stated	No	Not possible to ascertain [video very low resolution]
2020 0204_FalseBay	Both	Not stated	No	No
2020 0305_Bremer	Both	No	No	No
2020 0429_Simon's Town	Both	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2018 0105_PNG	Not observed	Predation	Kill (unknown)	Suspected	1	Confirmed (source, imagery)	Mola mola
2018 0316_Indonesia	No	Predation	Kill (unknown)	Suspected	1	Confirmed (source, imagery)	Mola sp. (Mola alexandrini?)
2019 0306 2019 0306_FalseBay	No	Non-predation	Play/Harass	Confirmed	1	Confirmed (source, imagery)	Mola sp.
2019 1013_Malaysia	No	Predation	Kill & feed	Suspected	1	Confirmed (source, imagery)	Mola alexandrini
2020 0204_FalseBay	No	Predation	Kill (unknown)	Suspected	1	Likely (source, imagery)	Mola or Masturus
2020 0305_Bremer	No	Non-predation	Play/Harass	Confirmed	1	Confirmed (source, imagery)	Mola alexandrini
2020 0429_Simon's Town	Yes	Predation	Kill & feed	Suspected	1	Confirmed (source, imagery)	Mola sp. (Mola mola?)

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat
2018 0105_PNG	Est. 2 - 2.5	Fatally wounded	Dying (Evade)	Dead	Suspected
2018 0316_Indonesia	Est. 2	Alive	Evade	Dead	Confirmed
2019 0306 2019 0306_FalseBay	Est. 1.5	Alive	Evade	Survived	Confirmed
2019 1013_Malaysia	Est. 1.5 - 2	Fatally wounded	Expired	Dead	Confirmed
2020 0204_FalseBay	Est. 1 - 2	Alive	Flee	Dead	Suspected
2020 0305_Bremer	Est. 1	Alive	Evade	Survived	Confirmed
2020 0429_Simon's Town	Est. 2	Alive	Evade	Dead	Suspected

Interaction name	Link
2018 0105_PNG	https://www.youtube.com/watch?v=NB4afrLHqi0
2018 0316_Indonesia	https://www.youtube.com/watch?v=_n3mL7_qYjw
2019 0306	no link (Pers. comm.)
2019 0306_FalseBay	
2019 1013_Malaysia	https://www.facebook.com/watch/?v=630474280816238; https://www.instagram.com/p/B3lLYCNBmQS/?hl=en; https://www.facebook.com/watch/?v=2137160263260581 and https://www.facebook.com/scubajunkiesipadan/videos/630474280816238; https://www.scubadivermag.com/amazing-orca-encounter-at-sipadan/
2020 0204_FalseBay	no link (Pers. comm.)
2020 0305_Bremer	https://whalewatchwesternaustralia.com/single-post/2020/03/05/orca-play-with-sunfish/; https://www.youtube.com/watch?v=wxio3TMNmWI
2020 0429_Simon's Town	no link (Pers. comm.)

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2020 0716_Mexico	Video	Online news media, Pers. comm. (email)	Cristobal Alvarez		20200716
2021 0215_Costa Rica	Video (+ photos)	Instagram + personal com	Dario Nessi, @sevengillshark	20210321	20210215
2021 1116_Galapagos	Video	Instagram	Daniel Parrazo, MasterLiveAboards	20211116	Not stated
2022 0611_LaVen	Video (+ photos)	Facebook, blo	Breeanna Plater, & Ryan Sault, @roamin	202206	20220611
2022 0626_GoldCoast	Video	Instagram, Pers. comm. (email)	billybain	20220719	20220626

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2020 0716_Mexico	Mexico	Michoacán; 11 miles offsore at 210 degrees from the border of Michoacan and Colima [boat launching only looks viable from Boca de Apiza river]	N Pacific	4	4	Other
2021 0215_Costa Rica	Costa Rica	Pacific Coast	Equatorial Pacific	14	5	Dyad(s)
2021 1116_Galapagos	Ecuador	Punta Vicente Roca, Isla Isabela, Galápagos Islands	Equatorial Pacific	1	1	Single male
2022 0611_LaVer	Mexico	La Ventana, Sea of Cortez (als	N Pacific		5	5 Dyad(s)
2022 0626_GoldCoast	Australia	East Coast, Gold Coast 27.24.198 S, 153'43.832 E [decimal -27.455, 153.947]	S Pacific	8	4	Dyad(s)

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2020 0716_Mexico	Unknown	Not stated	Yes	Yes x1, dorsal fin tip (+3) x1, dorsal fin tip (+3) x1, dorsal fin tip (+1) & edge of notch (+1)
2021 0215_Costa Rica	Mammal	No	Yes	Yes [details to be confirmed from photos and video]
2021 1116_Galapagos	Other	Not stated	No	No [details to be confirmed from photos and video]
2022 0611_LaVer	Mammal	No	Yes	Yes [details to be confirmed from photos a
2022 0626_GoldCoast	Mammal	No	Yes	Yes x1 AF, right pec (+15), left pec (+20) x1 AF, dorsal fin (+8) x1j, left pec (+10) x1 SAM, right pec (+7), tail flukes L (=20), R (=20)

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2020 0716_Mexico	Yes	Non-predation	Play/Harass	Not clear if escalated further	1	Confirmed (source, imagery)	Mola alexandrini
2021 0215_Costa Rica	Yes	Predation	Kill & feed	Confirmed	1	Likely (source)	Masturus lanceolatus
2021 1116_Galapagos	Not possible [only 1 orca present]	Non-predation	No reaction	Confirmed	2	Confirmed (imagery)	Mola alexandrini
2022 0611_LaVer	Yes	Predation	Kill & feed	Confirmed	1	Confirmed (so	Masturus lance
2022 0626_GoldCoast	No, but do 'pass' the sunfish from orca to orca	Predation	Kill & abandon	Suspected	1	Confirmed (source, imagery)	Mola sp. (Mola alexandrini?)

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat
2020 0716_Mexico	Est. 1.5 - 2	Alive	Evade	Survived	Suspected
2021 0215_Costa Rica	Est. 1.5	Fatally wounded	Expired	Dead	Confirmed
2021 1116_Galapagos	Est. 1.5	Alive	No response	Survived	Confirmed
2022 0611_LaVer	Est. 1.5 - 2	Fatally wounde	Dying (Evade)	Dead	Confirmed
2022 0626_GoldCoast	Est. 0.5	Alive	Flee	Dead	Confirmed

Interaction name	Link
2020 0716_Mexico	https://roaring.earth/killer-whales-filmed-playing-with-sunfish/?utm_source=ofb&utm_medium=pa&utm_campaign=8293&fbclid=IwAR1Jsx8cSJzBM3Q2KbkjZQ07Px_zWAGJPInQnzHPns_ci29EkIltBpu9qKg
2021 0215_Costa Rica	https://www.instagram.com/p/CMo-jD_gD_n/?hl=en
2021 1116_Galapagos	https://www.instagram.com/p/CWRlfebMGGu/?hl=en
2022 0611_LaVer	https://www.instagram.com/p/Cjd-mzwvRDn/?hl=en; https://www.creativecoin.xyz/hive-119888/@inavan/orcas-in-baja-california-sur-mexico; https://www.instagram.com/p/Cfi_yBJj74l/?hl=en; https://www.instagram.com/p/Cf9-HpzjmJ9/?hl=en; https://www.instagram.com/p/CgAwjyzDQy0/?hl=en; https://www.instagram.com/p/Ceyo3j8u3uP/?hl=en;
2022 0626_GoldCoast	https://www.instagram.com/tv/CgL8O5HJ03u/

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
20220803_CaboSanLucas	Video	Instagram, Pers. comm. (email)	evansbaudin	20220805	20220803
220221006_Monterey	Video	Pers. comm. (email)	Evan Brodsky (Drone pilot, for Calfiornia Killer Whale Project), Colleen Talty (Monterey Bay Whale Watch) Nancy Black (owner Monterey Bay Whale Watch)	n/a	20221006

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
20220803_CaboSanLucas	Mexico	Cabo San Lucas, Baja California 22°50'4.10"N 109°52'32.66"W "3 miles off Cabo San Lucas"	N Pacific	4	3	Dyad(s)
220221006_Monterey	USA	California, Monterey Bay	N Pacific	5	2	Dyad(s)

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
20220803_CaboSanLucas	Unknown	Not stated	Yes	Yes x1 , right pectoral fin (+5)
220221006_Monterey	Mammal	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
20220803_CaboSanLucas	Not observed	Predation	Kill & feed	Confirmed	1	Confirmed (source, imagery)	*Masturus lanceolatus*
220221006_Monterey	Yes	Non-predation	Persecute	Confirmed	1	Confirmed (source)	Mola sp.

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat
20220803_CaboSanLucas	Est. 1.5 - 2	Fatally wounded	Expired	Dead	Confirmed
220221006_Monterey	Est. 0.5	Not established	Not established	Not established	Not established

Interaction name	Link
20220803_CaboSanLucas	https://www.instagram.com/reel/Cg2D18HrXes/?igshid=YmMyMTA2M2Y=
220221006_Monterey	no link (Pers. comm.)

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2004 0917_Monterey	Narration (no photo)	Pers. comm. (email)	Nancy Black, Colleen Talty, Monterey Bay Whale Watch	n/a	20040917
2005_NSW	Photo	Facebook	Killer Whales Australia	20160315	2005
2009 0103_Monterey	Narration (no photo)	Pers. comm. (email)	Nancy Black, Colleen Talty, Monterey Bay Whale Watch/ Island Packers	n/a	20090103
2011 1211_Monterey	Narration (no photo)	Pers. comm. (email)	Nancy Black, Colleen Talty, Monterey Bay Whale Watch	n/a	20111112
2012 (pre)_NZ	Narration (no photo)	Pers. comm. (email)	Rob Torelli	n/a	Pre-2012 (Easter, March)
2012 0824_Canada	Narration (no photo)	Pers. comm. (email)	Jared Towers	n/a	20120824
2014 0512_NZ	Narration (no photo)	Pers obs	Ingrid Visser, Orca Research Trust	n/a	20140512
2014 0803_StraitOfGibraltar	Video (but not showing interaction)	Instagram	cetaceanfreedom, Sandrine le Comte	20140803	20140802

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2004 0917_Monterey	USA	California, Monterey Bay ("36 45 80 121 55 30")	N Pacific	5	Not stated	Not stated
2005_NSW	Australia	East Coast, Southern NSW	S Pacific	Not stated	Not stated	Not stated
2009 0103_Monterey	USA	"north shore near Santa Cruz island", California, USA	N Pacific	4	Not stated	Not stated
2011 1211_Monterey	USA	Newport Beach, Monterey Bay, California, USA	N Pacific	4	1	Calf/juv(s)
2012 (pre)_NZ	New Zealand	Northland, Garden Patch, ~ 60km North of Manganui, East Coast (34°28'57.91"S 173°31'34.54"E)	S Pacific	5	Not stated	Not stated
2012 0824_Canada	Canada	British Columbia, Hecate Strait	N Pacific	4	1	Calf/juv(s)
2014 0512_NZ	New Zealand	Northland, E coast, Parengarenga Canyons	S Pacific	6	1	Single female
2014 0803_StraitOfGibraltar	Spain	Likely Strait of Gibraltar	Mediterranean Sea	12	1	Calf/juv(s)

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2004 0917_Monterey	Mammal	Not stated	Not stated	No
2005_NSW	Mammal	Not stated	Not stated	Not possible to ascertain [low resolution]
2009 0103_Monterey	Unknown	Not stated	Not stated	Not possible to ascertain [Video not supplied]
2011 1211_Monterey	Mammal	Not stated	Not stated	Not possible to ascertain [Video not supplied]
2012 (pre)_NZ	Fish	Not stated	Not stated	Not possible to ascertain [Video not supplied]
2012 0824_Canada	Mammal	Not stated		No
2014 0512_NZ	Fish	Not stated	No	No
2014 0803_StraitOfGibraltar	Fish	Not stated	Not stated	Not possible to ascertain [Video is not of interaction]

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2004 0917_Monterey	Not stated	Not established	Not established	Not established	1	Likely (source)	Mola or Masturus
2005_NSW	Not clear from text	Predation	Kill & feed	Confirmed	1	Confirmed (source)	Mola or Masturus
2009 0103_Monterey	Not stated	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola or Masturus
2011 1211_Monterey	No	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola or Masturus
2012 (pre)_NZ	Not clear from text	Predation	Kill (unknown)	Confirmed	1	Confirmed (source)	Mola or Masturus
2012 0824_Canada	No	Non-predation	Interest	Confirmed	1	Confirmed (source)	Mola or Masturus
2014 0512_NZ	No	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.
2014 0803_StraitOfGibraltar	Not stated	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola or Masturus

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat	Information sufficient to assess Evade behaviour?
2004 0917_Monterey	no size estimate	Not established	Not established	Not established	Not stated	No
2005_NSW	Est. 1 - 2	Not established	Not established	Dead	Confirmed	No
2009 0103_Monterey	no size estimate	Alive	Not established	Survived	Suspected	No
2011 1211_Monterey	no size estimate	Not established	Not established	Not established	Not established	No
2012 (pre)_NZ	no size estimate	Fatally wounded	Dying	Dead	Confirmed	No
2012 0824_Canada	Est. 1 - 1.5	Alive	No response	Survived	Confirmed	No
2014 0512_NZ	no size estimate	Alive	Not established	Survived	Confirmed	No
2014 0803_StraitOfGibraltar	no size estimate	Not established	Not established	Survived	Suspected	No

Interaction name	Link
2004 0917_Monterey	no link (Pers. comm.)
2005_NSW	https://www.facebook.com/killerwhalesaustralia/photos/a.113623852030786/1031491150244047
2009 0103_Monterey	no link (Pers. comm.)
2011 1211_Monterey	no link (Pers. comm.)
2012 (pre)_NZ	no link (Pers. comm.)
2012 0824_Canada	no link (Pers. comm.)
2014 0512_NZ	no link (Pers. observation.)
2014 0803_StraitOfGibraltar	https://www.instagram.com/p/rNGCI5GRL-/?hl=en; https://www.instagram.com/p/rNIy7RmRBZ/?utm_source=ig_web_button_share_sheet

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2014 1116_Galapagos	Photos	Facebook & Pbase	Marco Valentini, mvphoto	20210319	20141116
2015 (pre)_NZ	Narration (no photo)	Pers. comm. (email)	Rob Torelli	n/a	Pre-2015
2016 0203_Bremer	Photo	Facebook, Pers. comm. (email)	Keith Lighbody, Ocean Sunfish Research	20160203	20160203
2016 0522_Monterey	Narration (no photo)	Pers. comm. (email)	Nancy Black, Colleen Talty, Monterey Bay Whale Watch	n/a	20160522
2016 0804_StraitOfGibraltar	Photo	Flickr	Karen Debler		20160804
2017 1001_Galapagos	Narrated	Pers. comm. (email)	Judith Denkinger & Daniela Alarcón Ruales	n/a	20171001
2017 1106_Galapagos	Narrated	Pers. comm. (email)	Judith Denkinger & Daniela Alarcón Ruales	n/a	20171106
2019 0103_NZ Kaikoura	Photo	Pers. comm. (email)	Tracy Cooper, Dolphin Encounter	n/a	20190103

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2014 1116_Galapagos	Ecuador	to the east of Puerto Villamil, Isla Isabela, Galápagos Islands approximately 0°57'38.14"S 90°53'38.86"W	Equatorial Pacific	6	4	Dyad(s)
2015 (pre)_NZ	New Zealand	NW of Northland, Middlesex Bank	S Pacific	3	3	Unknown
2016 0203_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	4	1	Unknown
2016 0522_Monterey	USA	Monterey Bay, California, USA 3643.8 12206.7 [as supplied by source]	N Pacific	20	3	Calf/juv(s)
2016 0804_StraitOfGibraltar	Spain	Strait of Gibraltar, Tarifa	Mediterranean Sea	Not stated	1	Single female
2017 1001_Galapagos	Ecuador	Galápagos Islands	Equatorial Pacific	Not stated	Not stated	Not stated
2017 1106_Galapagos	Ecuador	Galápagos Islands	Equatorial Pacific	Not stated	Not stated	Not stated
2019 0103_NZ Kaikoura	New Zealand	South Island, 0.5 km S of 'Sharks Tooth', Kaikoura	S Pacific	5	1	Single male

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2014 1116_Galapagos	Unknown	Not stated	Yes	Yes x1 AF, right pec (+10), left tail fluke (+20), right tail fluke +10 clustered on innner edge of fluke) x1 AF, dorsal fin tip (+2) x1 j, dorsal fin tip (+3)
2015 (pre)_NZ	Fish	Not stated	Not stated	Not possible to ascertain [Video not supplied]
2016 0203_Bremer	Mammal	Not stated	No	No
2016 0522_Monterey	Mammal	Not stated	Not stated	Not possible to ascertain [photos not supplied]
2016 0804_StraitOfGibraltar	Fish	Not stated	No	No
2017 1001_Galapagos	Unknown	Not stated	Not stated	Not stated
2017 1106_Galapagos	Unknown	Not stated	Not stated	Not stated
2019 0103_NZ Kaikoura	Unknown	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2014 1116_Galapagos	No	Predation	Kill & feed	Confirmed	1	Confirmed (source)	Mola alex
2015 (pre)_NZ	Not stated	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola or Masturus
2016 0203_Bremer	No	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.
2016 0522_Monterey	Yes	Non-predation	Persecute	Confirmed	1	Confirmed (source)	Mola or Masturus
2016 0804_StraitOfGibraltar	No	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.
2017 1001_Galapagos	Not stated	Predation	Kill & feed	Confirmed	1	Likely (source)	Mola or Masturus
2017 1106_Galapagos	Not stated	Predation	Kill & feed	Confirmed	1	Likely (source)	Mola or Masturus
2019 0103_NZ Kaikoura	No	Non-predation	Persecute	Not clear if escalated further	1	Confirmed (source)	Mola sp.

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat	Information sufficient to assess Evade behaviour?
2014 1116_Galapagos	Est. 2	Alive	Evade	Dead	Confirmed	Yes
2015 (pre)_NZ	no size estimate	Alive	Not established	Survived	Suspected	No
2016 0203_Bremer	Est. 1.5	Alive	Not established	Survived	Confirmed	No
2016 0522_Monterey	no size estimate	Alive	Not established	Survived	Confirmed	No
2016 0804_StraitOfGibraltar	no size est	Alive	Not established	Survived	Confirmed	No
2017 1001_Galapagos	no size estimate	Fatally wounded	Expired	Dead	Confirmed	No
2017 1106_Galapagos	no size estimate	Fatally wounded	Expired	Dead	Confirmed	No
2019 0103_NZ Kaikoura	Est. 1	Alive	Evade	Not established	Not established	Indication

Interaction name	Link
2014 1116_Galapagos	https://www.facebook.com/marco.valentini.5030/posts/2147403798726508
2015 (pre)_NZ	no link (Pers. comm.)
2016 0203_Bremer	https://www.facebook.com/OceanSunfishResearch/photos/a.363800700418307/750729751725398
2016 0522_Monterey	no link (Pers. comm.)
2016 0804_StraitOfGibraltar	https://www.flickr.com/photos/karendebler/29905055071/in/photostream/ AND https://www.flickr.com/photos/karendebler/29694528710/in/photostream/
2017 1001_Galapagos	no link (Pers. comm.)
2017 1106_Galapagos	no link (Pers. comm.)
2019 0103_NZ Kaikoura	no link (Pers. comm.)

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2019 0915_Galapagos	Narration (no photo)	Pers. comm. (email)	Daniel Herrera, Judith De	n/a	20190915
2019 1030_Galapagos	Narration (no photo)	Pers. comm. (email)	David Oswaldo Paez Co	n/a	20191030
2020 0118_Bremer	Photo	Instagram	Machi Yoshida, @machi_orca	20200118	pre 20200118
2020 0125_Bremer	Photo	Instagram	Machi Yoshida, @machi_orca	20200125	20200124
2020 0204_FalseBay	Video + pers. comm.	Personal	Ryan Miller, Apex Shark Expeditions	20200204	20200204
2021 0121_Bremer	Photo	Online news media, Pers. comm. (email)	Machi Yoshida, @machi_orca,Pia Markovich, Naturaliste Charters, Kalgoorlie Miner	20210205	20210121
2021 0208_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz, Simon's Town Boat Company, Dani Abras	20210208	20210208
2021 0221_Bremer	Photo	Facebook, blog, Pers. comm. (email)	Leanne Sharp, Gemma Sharp, Jade Sharp, Whale Watch Western Australia	20210223	20210221

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2019 0915_Galapagos	Ecuador	Galápagos Islands, Isabella Punta Vicente Roca	Equatorial Pacific	5	5	Unknown
2019 1030_Galapagos	Ecuador	Galápagos Islands, Isabella Punta Vicente Roca	Equatorial Pacific	6	6	Unknown
2020 0118_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	Not stated	Not stated	Not stated
2020 0125_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	Not stated	Not stated	Not stated
2020 0204_FalseBay	South Africa	False Bay	S Atlantic	2	1	Single male
2021 0121_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	Not stated	Not stated	Not stated
2021 0208_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2021 0221_Bremer	Australia	West Coast, WA, Bremer Canyon	S Indian Ocean	Not stated	Not stated	Not stated

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2019 0915_Galapagos	Unknown	Not stated	Not stated	Not stated
2019 1030_Galapagos	Unknown	Not stated	Not stated	Not stated
2020 0118_Bremer	Mammal	Not stated	Not stated	Not possible to ascertain [orca not clearly visible]
2020 0125_Bremer	Mammal	Not stated	No	No
2020 0204_FalseBay	Both	Not stated	No	No
2021 0121_Bremer	Mammal	Not stated	No	No
2021 0208_Simon's Town	Unknown	Not stated	No	No
2021 0221_Bremer	Mammal	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2019 0915_Galapagos	Not stated	Non-predation	Persecute	Suspected	1	Confirmed (source)	Mola or Masturus
2019 1030_Galapagos	Not stated	Predation	Kill & feed	Confirmed	1	Likely (source)	Mola or Masturus
2020 0118_Bremer	Not stated	Non-predation	Play/Harass	Not clear if escalated further	1	Likely (source, imagery)	Mola alexandrini
2020 0125_Bremer	Not stated	Predation	Kill & feed	Confirmed	1	Confirmed (source)	Mola sp. (Mola alexandrini?)
2020 0204_FalseBay	No	Predation	Kill (unknown)	Suspected	1	Likely (source, imagery)	Mola or Masturus
2021 0121_Bremer	Not stated	Predation	Kill & feed	Suspected	1	Confirmed (source)	Mola sp.
2021 0208_Simon's Town	No	Predation	Kill & feed	Suspected	1	Confirmed (source)	Mola mola
2021 0221_Bremer	Yes	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat	Information sufficient to assess Evade behaviour?
2019 0915_Galapagos	no size estimate	Fatally wounded	Not established	Survivied	Suspected	No
2019 1030_Galapagos	no size estimate	Fatally wounded	Not established	Dead	Confirmed	No
2020 0118_Bremer	Est. 1	Alive	Evade	Not established	Not established	Indication
2020 0125_Bremer	Est. 0.3 - 0.5	Fatally wounded	Not established	Dead	Confirmed	No
2020 0204_FalseBay	Est. 1 - 2	Alive	Flee	Dead	Suspected	Yes
2021 0121_Bremer	Est. 0.3	Not established	Not established	Dead	Suspected	No
2021 0208_Simon's Town	Est. 1.5 - 2	Alive	Evade	Dead	Confirmed	Indication
2021 0221_Bremer	Est. 0.3	Alive	Not established	Survived	Confirmed	No

Interaction name	Link
2019 0915_Galapagos	no link (Pers. comm.)
2019 1030_Galapagos	no link (Pers. comm.)
2020 0118_Bremer	https://www.instagram.com/p/B7a76gBl7Or/?hl=en
2020 0125_Bremer	https://www.instagram.com/p/B7tHkHuFNum/?hl=en
2020 0204_FalseBay	no link (Pers. comm.)
2021 0121_Bremer	https://www.instagram.com/p/CRVGQcsj0wq/?hl=en; https://www.instagram.com/p/CKT5E6qhwcD/?hl=en; https://www.kalminer.com.au/news/albany-advertiser/absolutely-epic-orcas-play-footy-with-sunfish-at-bremer-canyon-in-rare-display-of-feeding-behaviour-ng-b881783838z
2021 0208_Simon's Town	https://www.instagram.com/p/CLC250wAjRv/?hl=en
2021 0221_Bremer	https://www.facebook.com/WhaleWatchWesternAustralia/photos/pcb.1888096594699376/1888094874699548

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2021 0823_Mexico	Photo	Pers. comm. (email).	Frida Lara		20210823 approx
2022 0728_0955hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728
2022 0728_1012hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728
2022 0728_1114hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728
2022 0728_1119hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2021 0823_Mexico	Mexico	Bahia de los Muertos	N Pacific	6	2	Dyad(s)
2022 0728_0955hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2022 0728_1012hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2022 0728_1114hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2022 0728_1119hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2021 0823_Mexico	Unknown	Not stated	Yes	Yes x1 AF, left pec (+10), left tail fluke (+20), right tail fluke (+10)
2022 0728_0955hrs_Simon's Town	Both	Not stated	No	No
2022 0728_1012hrs_Simon's Town	Both	Not stated	No	No
2022 0728_1114hrs_Simon's Town	Both	Not stated	No	No
2022 0728_1119hrs_Simon's Town	Both	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2021 0823_Mexico	Not stated	Predation	Kill & feed	Confirmed	1	Confirmed (source)	Masturus lanceolatus
2022 0728_0955hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola sp.
2022 0728_1012hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola or Masturus
2022 0728_1114hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.
2022 0728_1119hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola or Masturus

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat	Information sufficient to assess Evade behaviour?
2021 0823_Mexico	Est. 1 - 1.5	Fatally wounded	Expired	Dead	Confirmed	No
2022 0728_0955hrs_Simon's Town	no size estimate	Alive	Not established	Survived	Suspected	No
2022 0728_1012hrs_Simon's Town	no size estimate	Alive	Evade	Survived	Confirmed	Indication
2022 0728_1114hrs_Simon's Town	Est. 0.5 - 1	Alive	Not established	Survived	Confirmed	No
2022 0728_1119hrs_Simon's Town	no size estimate	Alive	Evade	Survived	Suspected	Indication

Interaction name	Link
2021 0823_Mexico	https://www.instagram.com/p/CTPaQ1CgDNM/?hl=en
2022 0728_0955hrs_Simon's Town	no link (Pers. comm.)
2022 0728_1012hrs_Simon's Town	no link (Pers. comm.)
2022 0728_1114hrs_Simon's Town	no link (Pers. comm.)
2022 0728_1119hrs_Simon's Town	no link (Pers. comm.)

Interaction name	Source type	Platform	Channel/Profile name/Contact	Date published	Date of observation (yyyymmdd)
2022 0728_1120hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728
2022 0728_1157hrs_Simon's Town	Photo	Pers. comm. (email)	David Hurwitz (Simon's Town Boat Company)	n/a	20220728
2022 0826_Galapagos	Narration (no photo)	Pers. comm. (email)	Judith Denkinger (observ	n/a	20220826
2022 1028_Monterey	Photo	Instagram, Pers. comm. (email)	"Daniel Bianchetta (photographer, for Calfiornia Killer Whale Project), Colleen Talty (Monterey Bay Whale Watch) Nancy Black (owner Monterey Bay Whale Watch)"		20221028

Interaction name	Country	Location	Ocean basin	Total Orca (present)	Total Orca (involved)	CATEGORY GLOBAL
2022 0728_1120hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2022 0728_1157hrs_Simon's Town	South Africa	Simon's Town	S Atlantic	1	1	Single male
2022 0826_Galapagos	Ecuador	Galápagos Islands, Cabo Douglas	Equatorial Pacific	3	3	Unknown
2022 1028_Monterey	USA	California, Monterey Bay	N Pacific	5	1	Calf/juv(s)

Interaction name	PREY TYPE GLOBAL [Fish, Mammal, Fish+Mammal, Other, Unkown]	Tooth wear [yes, no, not stated]	Xenobalanus globiciptis present [yes/no]	If present, who, where & ~ number
2022 0728_1120hrs_Simon's Town	Both	Not stated	No	No
2022 0728_1157hrs_Simon's Town	Both	Not stated	No	No
2022 0826_Galapagos	Unknown	Not stated	Not stated	Not stated
2022 1028_Monterey	Mammal	Not stated	No	No

Interaction name	Orca cooperative hunting	Orca Interaction cat GLOBAL (see Table 2)	Orca interaction sub-cat GLOBAL	This is highest rank (confirmed/ suspected)	# sunfish	# sunfish caveat	Species GLOBAL
2022 0728_1120hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola mola
2022 0728_1157hrs_Simon's Town	No [not possible, only 1 orca involved in the interaction]	Non-predation	Play/Harass	Suspected	1	Confirmed (source)	Mola mola
2022 0826_Galapagos	Not stated	Predation	Kill & feed	Confirmed	1	Likely (source)	Mola or Masturus
2022 1028_Monterey	Not stated	Non-predation	Play/Harass	Confirmed	1	Confirmed (source)	Mola sp.

Interaction name	Sunfish size GLOBAL	Sunfish interaction cat [Table2]	Sunfish interaction sub-cat [Table2]	Sunfish final status	Sunfish final status caveat	Information sufficient to assess Evade behaviour?
2022 0728_1120hrs_Simon's Town	Est. 1.5 - 2	Alive	Evade	Survived	Suspected	Indication
2022 0728_1157hrs_Simon's Town	Est. 1.5 - 2	Alive	Not established	Survived	Suspected	No
2022 0826_Galapagos	no size estimate	Fatally wounded	Not established	Dead	Confirmed	No
2022 1028_Monterey	Est. 0.5	Alive	Not established	Survivied	Suspected	No

Interaction name	Link
2022 0728_1120hrs_Simon's Town	no link (Pers. comm.)
2022 0728_1157hrs_Simon's Town	no link (Pers. comm.)
2022 0826_Galapagos	no link (Pers. comm.)
2022 1028_Monterey	https://www.instagram.com/p/CkTQr00rJnJ/

Supplemental Material S-4. Examples of consumption during orca-molid interactions

2020-01-25. Bremer Canyon, Western Australia, Australia.
Likely *Mola alexandrini*.

An unknown number of orca were involved in an interaction where a molid (likely *Mola alexandrini*, ~0.3-0.5 TL in size) was bitten and the intestines removed (Fig. S-4.1).

Figure S-4.1 An orca made a close pass to a molid (likely *Mola alexandrini*), which had a significant portion of its ventral body removed. Note the remains of the intestine laying across its body (arrow). Photo by Machi Yoshida for Naturaliste Charters.

2021-03-21. Pacific Coast, Costa Rica.
Likely *Masturus lanceolatus*.

Fourteen orca were present, including two females who were pregnant, 2 calves and 1 adult male. Five orca (2 adult females, 1 adult male, 2 juveniles) were involved in a 'Predation' interaction with a *Mola sp*. of unknown size (however, see details below). When the observers arrived, the molid was presumed to be still alive (Dario Nessi, pers. comm.). Shortly thereafter, two orca "*were ripping out pieces of [the molid] and within like 2 minutes there were only shreds left*" (Dario Nessi, pers. comm.). The orca were documented feeding on larger and smaller pieces of the molid, including one of the adult females who carried, in its mouth, a piece of the molid which was estimated to be >1m x 1m (Fig. S-4.2).

Very small pieces of molid tissue were consumed by the adult male (not shown). This same group of orca was documented the day prior to this encounter, feeding on an unidentified hard-shelled turtle, where all soft tissues – except the intestine – were eaten by the orca (see Case Study in main text) These two interactions (with a molid and a turtle, respectively) differ in that the orca appeared to target the intestines of the molid, but left behind the intestines of the turtle (see main text and Fig. S-4.3).

Figure S-4.2 An adult female carried a piece of the molid (likely *Ma. lanceolatus*) which was estimated to be >1m x 1m in size in comparison to the size of the orca. Photo by Dario Nessi.

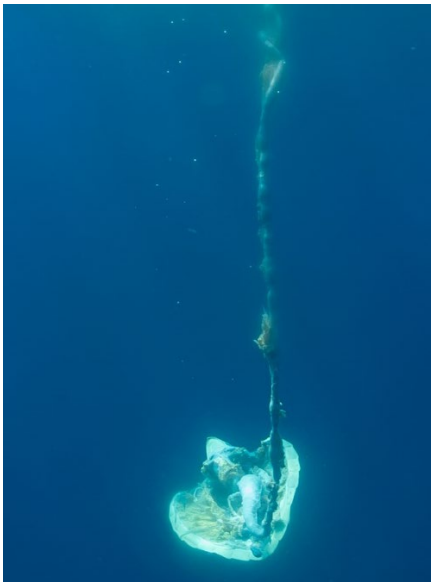

Figure S-4.3 The remains of an unidentified hard-shelled turtle ~~predated~~ on by orca. Note that nearly all of the tissue was eaten by the orca, but that intestines are left behind. Photo by Dario Nessi.

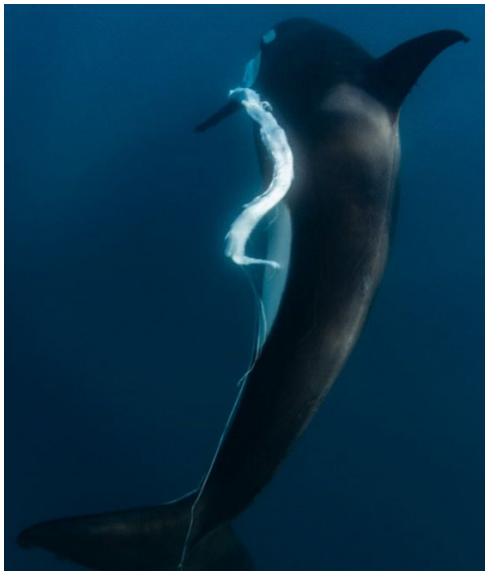

Figure S-4.4 Long parts of the molid intestine were carried (and later consumed) by at least two orca. In this image, the perspective illustrates length of the intestine. Photo by Ryan Sault.

2022-07-14. Isla Cerralvo (La Ventana), Sea of Cortez, Mexico.
Masturus lanceolatus.

Five orca were documented by a number of observers during this interaction and an extensive range of video and photographs were available, making this perhaps one of the best documented instances of orca predation on molids, to date. We present a number of images in the Case Study in the main text, with additional images herein and see Visser & Fletcher (2023) for additional images and details.

The molid, still alive, was observed exhibiting 'Evade' behaviours – see main text and Nyegaard et al. (2023) for details.

ACKNOWLEDGEMENTS

Please see the main body of text for the full acknowledgements. We express again here our thanks to the photographers/ videographers whose work and data features in this supplemental material; Dario Nessi, Ryan Sault and Machi Yoshida.

REFERENCES

Nyegaard M., Visser I.N. & Fletcher L.A. 2023. Ocean sunfish, genus *Mola* Kölreuter, 1766 (Pisces Molidae), exhibit surprising levels of agility during interactions with orca, *Orcinus orca* (Linnaeus, 1758) (Mammalia Delphinidae). Biodiversity Journal. 14(1):3-17. doi:https://doi.org/10.31396/Biodiv.Jour.2023.14.1.3.17.

Visser I.N. & Fletcher L.A. 2023. First records of orca, *Orcinus orca* (Linnaeus, 1758) (Mammalia Cetacea), predation on sharptail ocean sunfish, *Masturus lanceolatus* (É. Liénard, 1840) (Pisces Molidae), with novel components of foraging behaviour discovered through social media. Biodiversity Journal. 14(1):18-40. doi:https://doi.org/10.31396/Biodiv.Jour.2023.14.1.19.41.

Supplemental Material S-5. Tooth wear on orca involved in sunfish interactions

We provide additional information from the Published & Narrated records referred to in the main text. As per our methods, tooth wear in this current study is categorized following Jett et al. (2017), i.e., coronal wear was negligible (<10%); minor (11–25%); moderate (26–50%); major (51–75%) or extreme (76–100%).

Caldwell & Brown (1964) described an orca taken into captivity and noted "*excessive wear of the crown of the tooth*" and their Fig. 3 is reproduced here as Fig. S-5.1.

Ryan & Holmes (2012) described a stranded orca and noted "*Significant apical* [sic; coronal] *tooth-wear*" and did not include a figure. However, the senior author has subsequently provided one for this current publication and we include that here as Figs. S-5.2 & S-5.3.

Figure S-5.1. Newport, California USA (Pacific Ocean). An adult female orca was captured and placed in captivity. She was a presumed Offshore ecotype (i.e., Elasmobranch+Teleost eater, see main body of text for details). The original figure caption reads: "*Lateral view of dissected jaws of the Newport killer whale, showing extreme tooth wear. Tape measure calibrated in inches. Photograph by Cliff Brown, Marineland of the Pacific*." The worn crowns of the maxillae teeth are clearly visible because the upper left lip has been cut away (shown as white tissue in this image), whilst the tops of left mandibular teeth can only just be seen as they do not protrude above the gumline (i.e., they are located above the tape measure and below the maxillae teeth). Extracted from Caldwell & Brown (1964).

Figure S-5.2. Doohoma, Ireland (Atlantic Ocean). An adult female orca stranded and died. Before being discovered by scientists, unauthorized attempts were made by an unknown person(s) to remove some of her teeth, hence the mutilation of both the maxillae and mandibles (pers. comm. C. Ryan, Sept 2022). This orca was genetically confirmed as a 'type 1' ecotype, known to feed on teleosts. See Fig. S-5.3 for a detailed view of the "*Significant apical* [sic] *tooth-wear*". Photo by Conor Ryan.

Figure S-5.3. Doohoma, Ireland (Atlantic Ocean). The same adult female orca as Fig. S-5.2, here showing a close-up of the teeth. Coronal wear can be seen in the anterior (extreme, 76-100%) and posterior (major, 51-75% to extreme) teeth of the maxillae. However at least one tooth on the left mandible shows only negligible (<10%) or minor (11–25%) wear, whilst the tooth immediately posterior to it appears to be fractured or broken off (which may be a result of the unauthorized attempts to extract the teeth). Photo by Conor Ryan.

From Video and Narration records, there were (*n*=4) interactions where the teeth were visible and could be assessed. All involved orca who had negligible (<10%) or at most minor (11-25%), coronal wear to their teeth. For the latter category, when teeth were not damaged significantly, but images were of poor resolution for fine assessment, we used the 'minor' category so as to not under-assess tooth wear).

These four interactions involved orca who were either confirmed (*n*=3) or suspected (*n*=1) mammal eating ecotypes (see Figs. S-5.3 - S-5.11 captions, main text, and Sup Mat S-1 - Sup Mat S-3, for further details).

Figure S-5.4. Bremer Canyon, Western Australia (Indian Ocean). An adult female shows no, or minor, coronal wear. This population has been documented feeding on a range of marine mammals. Frame from video by Whale Watch Western Australia.

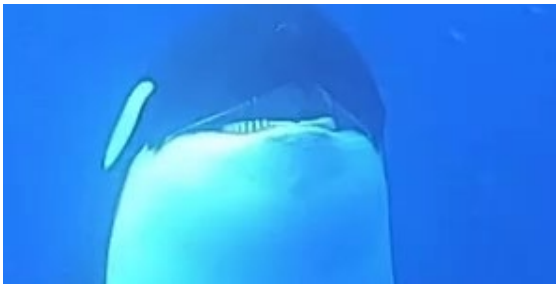

Figure S-5.5. Bremer Canyon, Western Australia (Indian Ocean). An adult female from the same interaction as Figure S-5.4, shows no, or minor, coronal wear. Frame from video by Whale Watch Western Australia.

Figure S-5.6. Gold Coast, Queensland, Australia (Pacific Ocean). An adult female shows no, or minor, coronal wear. She is about to 'mouth' (but did not eat) a dead fish which was tossed into the water, however she was documented earlier in the encounter eating blubber from an unidentified whale. Frame from video by Bill Bain.

Figure S-5.7. Gold Coast, Queensland, Australia (Pacific Ocean). An adult female from the same interaction as Fig. S-5.6, shows no, or minor, coronal wear. This orca appears to have tooth/mandible deformation, however this is purely due to the distortion of the water surface as the video does not show any malformation or missing teeth. Frame from video by Bill Bain.

Figure S-5.8. Costa Rica (Pacific Ocean). An adult male orca with no, or minor, coronal wear to his teeth. This group of orca had been documented the day prior, feeding on an unidentified turtle (see S-4, other marine fauna) and an unidentified dolphin (pers. comm. D. Nessi), i.e., they are listed as Reptile+Mammal eaters in this study. Photo by Dario Nessi.

Figure S-5.9. Costa Rica (Pacific Ocean). A juvenile orca (sex undetermined) from the same interaction as Fig. S-5.8, with no, or minor, coronal wear to its teeth. Note the remains of a *Masturus lanceolatus* molid are held in the orca's mouth and teeth marks are visible as a series of evenly-spaced white punctures at the bottom right of the remains. Photo by Dario Nessi.

Figure S-5.10. Mexico (Pacific Ocean). An adult female with no coronal wear to its teeth. Both the maxillae and mandibula teeth are visible as it consumes the remains of *Ma. lanceolatus* molid. Photo by Giacomo Rossi.

Figure S-5.11. Mexico (Pacific Ocean). An adult female from the same interaction as Fig. S-5.10, with no coronal wear to its teeth. The remains of a *Ma. lanceolatus* molid are being consumed. Photo by Giacomo Rossi.

REFERENCES

Caldwell D.K. & Brown D.H. 1964. Tooth wear as a correlate of described feeding behavior by the killer whale; with notes on a captive specimen. Bulletin of the Southern California Academy of Sciences. 63(3):129-140.

Jett J., Visser I.N., Ventre J., Waltz J. & Loch C. 2017. Tooth damage in captive orcas (*Orcinus orca*). Archives of Oral Biology. 84:151-160. doi:https://doi.org/10.1016/j.archoralbio.2017.09.031.

Ryan C. & Holmes J.M.C. 2012. Killer whale *Orcinus orca* predation on sunfish *Mola mola*. Marine Biodiversity Records. 5(e10):1-2. doi:http://doi.org/10.1017/S1755267211001187.

Comments on tassel barnacles (*Xenobalanus globicipitis* Steenstrup, 1852) and diet of orca from four different interactions with molids (*Mola* spp. and *Masturus lanceolatus*) in the Pacific Ocean. Further details of each interaction are provided in Sup Mat S-2 and Sup Mat S-3. See Visser et al. (2020) for details regarding the significance of the presence of tassel barnacles.

Figure S-6.1 Australia (Pacific Ocean). An adult female has ≥18 tassel barnacles on her right pectoral fin and ≥12 on her left. In addition to interacting with a molid, this group was documented feeding on an unidentified whale i.e., they are listed as 'Mammal-eaters' in this study. Frame from video by Bill Bain.

Figure S-6.2 Australia (Pacific Ocean). The same adult female as Fig. S-6.1 has ≥12 tassel barnacles on her left pectoral fin. Frame from video by Bill Bain.

Figure S-6.3 Costa Rica (Pacific Ocean). A presumed adult female had so many tassel barnacles on her tail flukes that they could not be individually counted, however they were present in excess of 50 per fluke (based on comparative counts, e.g., see Fig. S-6.1). In addition to predating on a *Mola mola*, this group was documented feeding on an unidentified dolphin and an unidentified turtle, i.e., they are listed as 'Mammal-eaters' in this study. Photo by Dario Nessi.

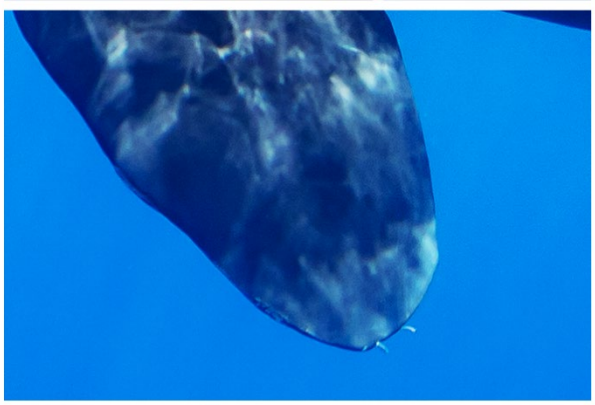

Figure S-6.4 Costa Rica (Pacific Ocean). Another orca in the same group as the female in Fig. S-6.3, had only two tassel barnacles on her left pectoral fin. Photo by Dario Nessi.

Figure S-6.5 Galápagos Islands. An adult female with ≥18 tassel barnacles on her right tail fluke (i.e., left of frame) and ≥3 on the trailing edge of her left tail fluke. Additionally, she has a cluster of tassel barnacles on the ventral side of the tip of her left fluke (insert). This group ~~predated~~ on a *M. mola*, but no other details regarding their diet are known. Photo by Marco Valentini.

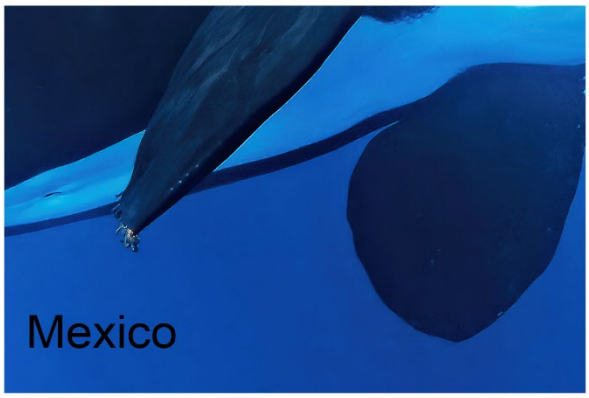

Figure S-6.7. Mexico. An adult female had no tassel barnacles on her left pectoral fin and a cluster of ≥10 on her right. In addition to predating on a *Masturus lanceolatus*, this group was documented feeding on an unidentified dolphin and fishes i.e., they are listed as 'Mammal-eaters' in this study. Photo by Giacomo Rossi.

Figure S-6.6 Galápagos Islands. Another orca in the same group as the female in Fig. S-6.5, had a cluster of >8 tassel barnacles on the tip of its dorsal fin. Photo by Marco Valentini.

Figure S-6.8. Mexico. Another orca (a juvenile) in the same group as the female in Fig. S-6.7, had ≥6 tassel barnacles on its left tail fluke and ≥24 on the trail edge of its right fluke. Additionally, it had ≥25 tassel barnacles on the dorsal surface of this fluke. Photo by Giacomo Rossi.

REFERENCES

Visser I.N., Cooper T.E. & Grimm H. 2020. Duration of pseudo-stalked barnacles (*Xenobalanus globicipitis*) on a New Zealand Pelagic ecotype orca (*Orcinus orca*), with comments on cookie cutter shark bite marks (*Isistius* sp.); can they be used as biological tags? Biodiversity Journal. 11(4):1067-1086. doi:https://doi.org/10.31396/Biodiv.Jour.2020.11.4.1067.1086.