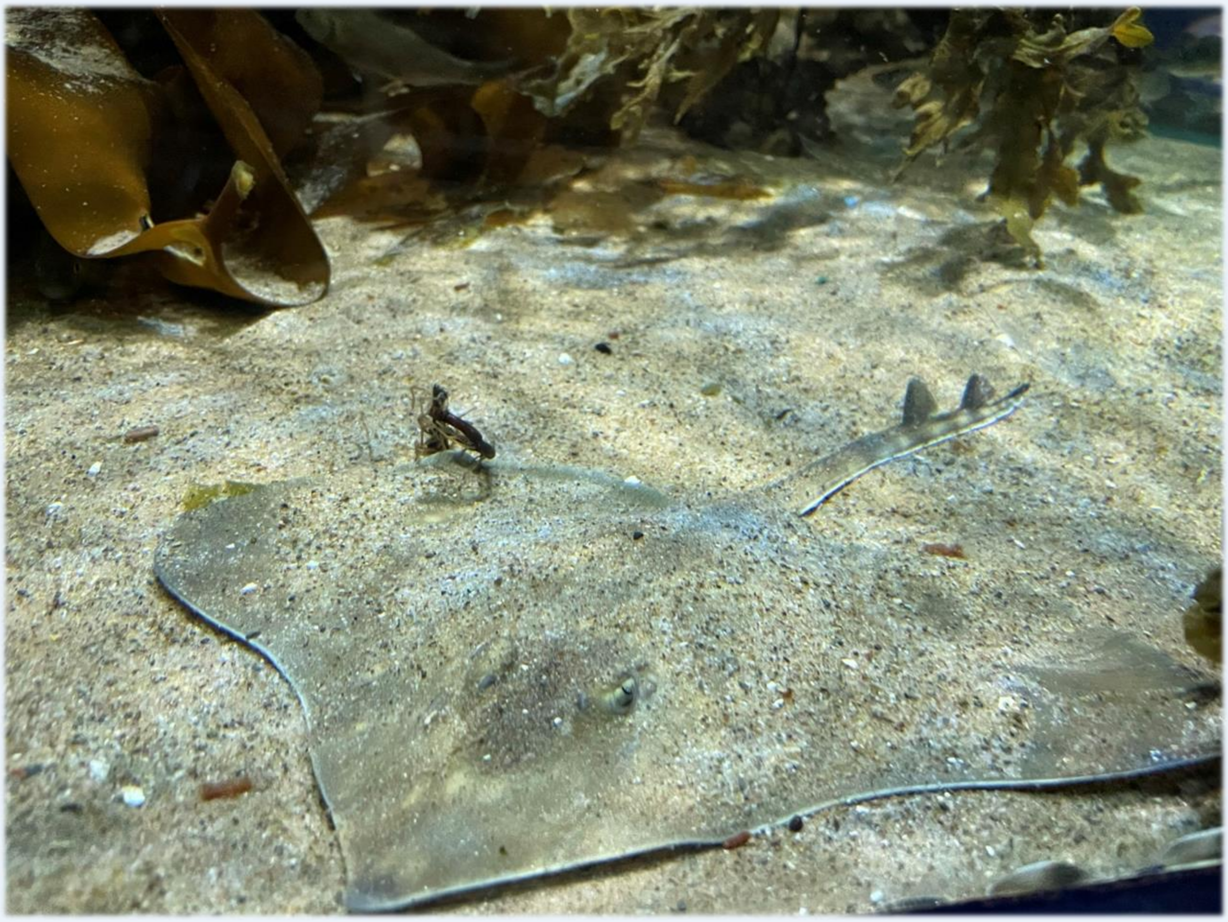
lasmobranchs Taxon Advisory Group

EAZA Best Practice Guidelines for the common skate complex

Flapper skate (*Dipturus intermedius*) & Common blue skate (*Dipturus batis*)



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EAZA Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the "Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria". These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

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Cover image: Flapper skate Cedric held at Macduff Marine Aquarium (Rowe & Rickard, 2021)

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Content

Introduction

Zoos and aquaria all over the world strive to make a difference in education, animal welfare and conservation. Especially in conservation, it is imperative for zoological institutions to demonstrate the possibilities in aiding the recovery of endangered species in the wild. The World Association of Zoos and Aquariums (WAZA) has also described the importance of the role of public aquaria in its global aquarium strategy for conservation and sustainability, and expresses the importance of cooperation with international organisations such as WWF to support in situ conservation strategies and plans. These include applying knowledge and connections to assist with programs for species survival in transport, re-introduction and assisted reproduction (Penning et al., 2009).

The two species of the common skate species complex are one of those endangered species in the wild. The flapper skate (*Dipturus intermedius*) and common blue skate (*Dipturus batis*) are both critically endangered according to current research into the decline to existing populations (Dulvy et al., 2006). Both species are bottom-dwelling in the benthic zone of the Northeast Atlantic Ocean and are considered flagship species for the conservation and protection of the ecosystems in the North Sea. (Frost et al., 2020; Griffiths et al., 2010)

The flapper skate and common blue skate are mostly threatened by fisheries, as is the case with a lot of elasmobranch species in the global seas. Both species end up as bycatch in fishing nets, where they do not always survive the ordeal. This has a major impact on the populations as a whole. Estimates of replacement mortality (i.e. total mortality which should not be exceeded to prevent population decline) for the flapper skate (*Dipturus intermedius*), which results in less young to replace one adult is estimated of female maturity at an average age of 21 years (Régnier et al., 2021).

These Best Practice Guidelines were set up to explore the possibilities in accommodating the flapper skate and the common blue skate in aquaria. This would make it possible to create a population that is both there for educational purposes as well as to provide eligible individuals for a possible re-introduction in the North Sea.

These Best Practice guidelines have been written for the Common skate species complex as a whole. The flapper skate and common blue skate are discussed separately where differences in biology or husbandry are significantly distinct. The names flapper skate (*Dipturus intermedius*) and common blue skate (*Dipturus batis*) may still be subject to discussion but are used consistently to prevent confusion throughout this document. The name common blue skate (*Dipturus batis*), instead of blue skate, is also used to prevent confusion with the blue skate *Notoraja azurea*, occurring in the Indian Ocean and Southern Australia.

Section 1: Biology and field data

1.1 Taxonomy

Order: Rajiformes.
Family: Rajidae
Genus: *Dipturus*
Species: *Dipturus batis*
Common names: Common blue skate (English), Glattrochen (German), Pocheteau gris (French), Vleet (Dutch), Dværgskade (Danish)
Species: *Dipturus intermedius*
Common names: Flapper skate (English),Grosser Glattrochen (German), Pocheteau gris (French), Flappervleet (Dutch), Storskade (Danish)

The genus of *Dipturus* consists of forty different species of skates (IUCN, 2020a), of which the two species of the common skate complex are discussed.

The ICES Working Group Elasmobranch Fishes (ICES, 2020) describes the complex as follows: *Dipturus batis*, frequently referred to as common skate, has recently been confirmed to comprise of two species being erroneously synonymised in the 1920s (Iglésias et al., 2010; Griffiths et al., 2010). The smaller species (previously described as *Dipturus flossada* by Iglésias et al., 2010) is the common blue skate (*Dipturus batis* (FAO code RJB)) and the larger species may revert to the flapper skate (*Dipturus intermedius* (FAO code DRJ)). The member of the common skate complex present in the northern North Sea is *Dipturus intermedius*, which is generally considered the more vulnerable to fishing pressure. Both species were accepted by Last et al. (2016) and are now also accepted on the Catalog of Fishes (Fricke et al., 2019) and World Register of Marine Species (WoRMS). The distribution and stock boundaries of the two species are uncertain. The larger-bodied flapper skate *Dipturus intermedius* occurs in the north-western North Sea, and this stock is likely the same as occurs of North-West Scotland. The presence and geographical extent of blue skate *Dipturus batis* in this region is uncertain, but this species may have occurred in the southern North Sea historically (ICES, 2020)

1.2 Morphology

1.2.1 Measurements

Within the common skate complex is one of the largest species of skates in the world, *Dipturus intermedius* with a maximum disk width and maximum total length of 285 centimetres. It grows according to stages in maturation from a hatchling to an adult. There are some differences in size and weight between the species of common blue skate (*D. batis*) and flapper skate (*D. intermedius*).

	Hatchling		*Adult*	
	D. batis	*D. intermedius*	*D. batis*	*D. intermedius*
Body length	21-29 cm	21-29 cm	145 cm	230 cm (up to 285 cm)

Table 1: Maximum body length for common blue skate (*D. batis*) and flapper skate (*D. intermedius*) (Ebert & Stehmann, 2013)

1.2.2 General description

The common skate complex consists of two large bottom-dwelling elasmobranch species, *Dipturus intermedius* and *Dipturus batis*. Both have a triangular shape with a long-pointed snout with protruding eyes and spiracles on the upper side (Neal & Pizzolla, 2006) (figure 1). The base of the endoskeleton is made up of cartilaginous material instead of bone, making especially the pectoral fins flexible for movement (Canadian Shark Research Lab, 2016a). The difference between the sexes is easily recognizable with outer claspers as deeply grooved cartilaginous extension of the pelvic fins on the males (figure 2), which are absent with female skates. Adults have two rows of thorns on the sides of the tail and one row on the tail (figure 3), while juveniles have only one row of thorns on the tail (figure 4) (Neal & Pizzolla, 2006; Stehmann & Bürkel, 1984). Mature males also have a large patch of thorns on the dorsal side of each wing.

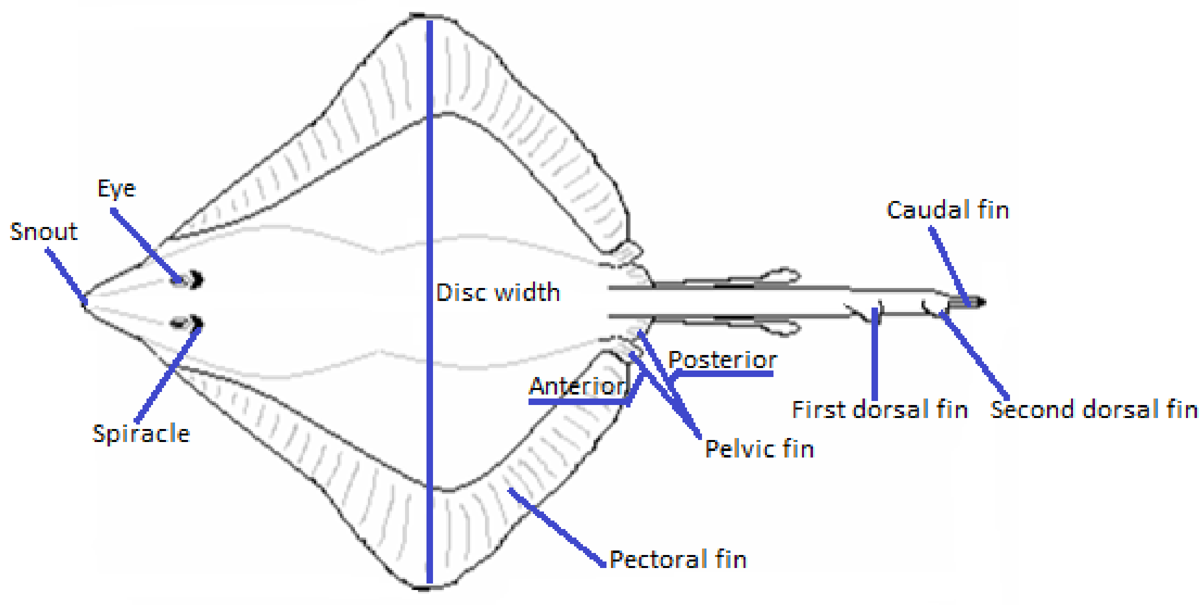

Figure 1: Illustration of the external anatomy of the common skate. Modified image from Thorburn (2008)

Figure 2: Outer claspers of an Orkney common blue skate male. © D.Wise.

Figure 3: Young female Flapper Skate (*Dipturus intermedius*) tail spines – thorns located on sides and top of tail. © D.Wise

Figure 4: 10 weeks old Flapper skate "Cedric" (see also paragraph 2.4.4.). 16 clear, small sharp spines along tail – note no sign of other thorns on sides of tail. © D.Wise

Coloration:

Its upper side is mostly a brownish green with a distinctive spotted pattern, its underside is dark grey to white with some lighter spots and sometimes black stripes, spots or marbling. Smaller individuals can have a distinct patterning on the tail. The distinctive dorsal spot patterning makes it possible to identify individuals in the wild and possibly in aquaria with photo-identification. Juveniles start off with a very dark black colour that fade to grey and ultimately changes to the colour of an adult as it matures (Benjamins et al., 2018). The coloration and patterning are different between common blue skate (*D. batis*) and flapper skate (*D. intermedius*): the differences are most notable in the brown and grey and the difference in blotted and spotted patterning (figure 5).

Figure 5: Left: an illustration of the coloration on the dorsal side of a female common blue skate (*Dipturus batis*). Right: an illustration of the coloration on the dorsal side of a male flapper skate (*Dipturus intermedius*) (Last, et al., 2016)

The species of the *Dipturus batis* complex, *D. batis* and *D. intermedius*, present slight differences in appearance in a couple of external bodily features (Iglésias et al., 2010):

- **A.** Eye with pale yellow iris (*D. batis*) versus dark green-olive iris (*D. intermedius*).
- **B.** Blotch on wing with ocellus with dark centre surrounded by pale ring (*D. batis*) versus blotch of grouped pale spots (*D. intermedius*).
- **C.** Lateral thorns on the tail perpendicular to body axis (*D. batis*) versus lateral thorns directed towards the head (*D. intermedius*).
- **D.** Short interspace between dorsal fins (*D. batis*) versus long dorsal fins interspace (*D. intermedius*).
- **E.** Tooth (lower jaw, 5th row from the symphysis; adult male (left), and female (right)) with a relatively narrow shape (*D. batis*) versus tooth with a relatively broad shape (*D. intermedius*).

Scale bars = 10mm for figures A to D' and 1 mm for figures E and E'

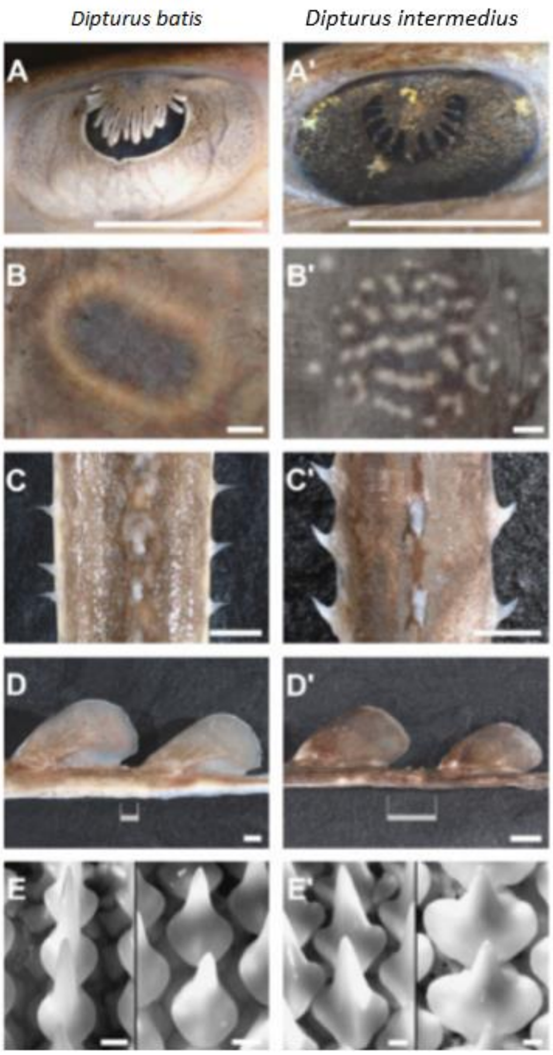

Figure 6: Morphologic differences between *D. batis and D. intermedius* (Iglésias et al., 2010)

1.3 Physiology

1.3.1 Cartilaginous skeleton

Like all elasmobranchs the skeleton of skate species consist not of bone but exclusively cartilage. The cartilage is more flexible and lighter in weight compared to bone, skates are agile and stay afloat more easily. As skates grow, the cartilage is strengthened by calcification. This is a process that causes the deposition of calcium and salts. It causes a resemblance with the characteristics of bone (figure 7).

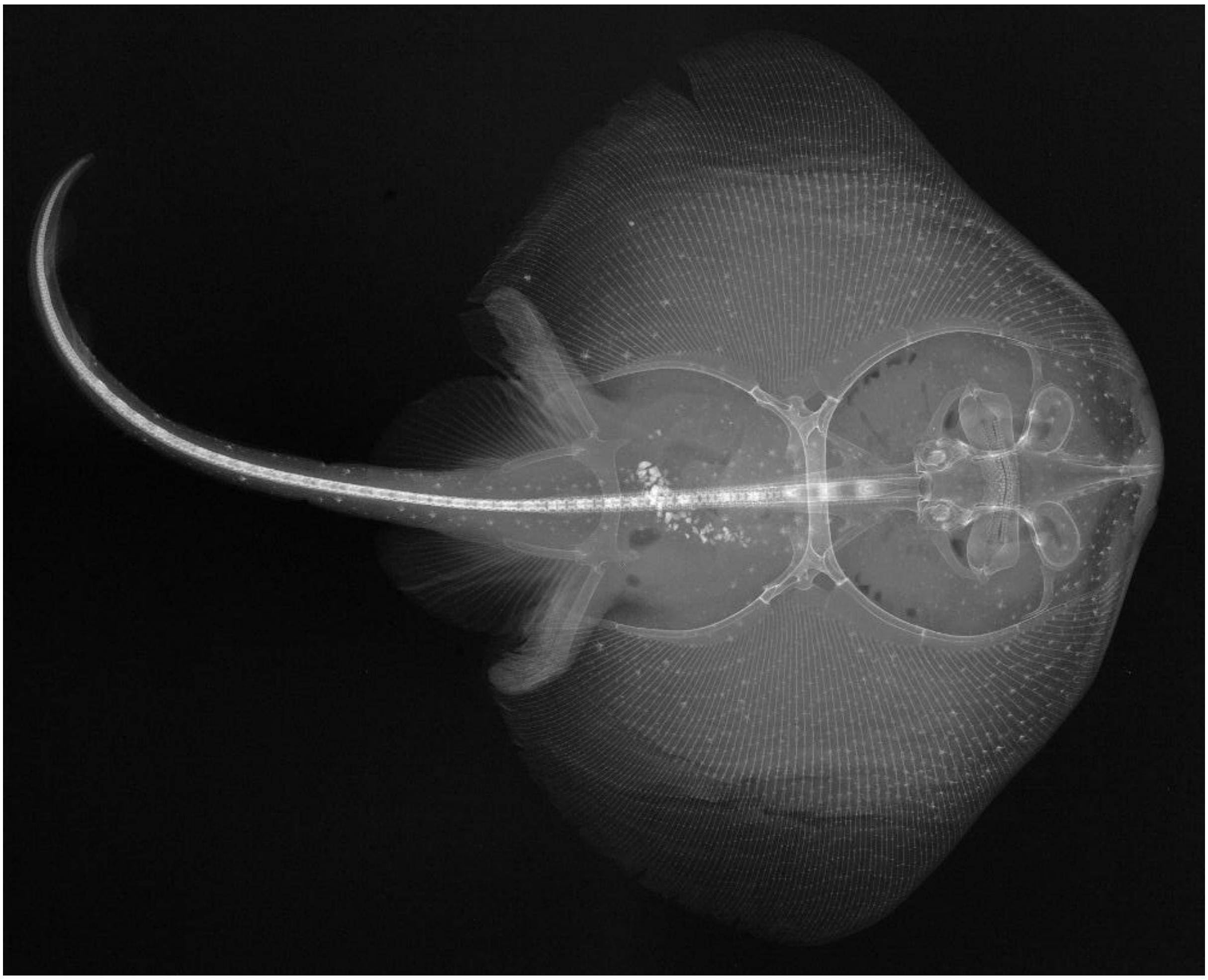

Figure 7: an X-ray image of a Monterey skate, revealing the cartilaginous structure of skates (Raredon, 2012)

1.3.2 Liver

The liver is a very large organ that consists of two pointed lobes, taking up to a quarter of the body weight. It is an important organ in all elasmobranchs because it has two crucial functions. First, it stores energy from the concentration of fatty reserves. And secondly, it increases its buoyancy because it stores very light oils to counteract the natural sinking tendency among elasmobranchs, giving the skate a so-called state of elevated buoyancy and compensating for the absence of a swim bladder (Canadian Shark Research Lab, 2016a).

1.3.3 Spiral valve intestine

The spiral valve intestine occurs in a number of elasmobranch species, and also in the common blue skate and flapper skate. This form of intestine increases the surface area to digest and absorb food. At the same time, it also takes up a minimum of space in the body cavity, giving more space for the liver and developing egg capsules (Canadian Shark Research Lab, 2016a). The eversion of this intestine does occur in some skate species, and it is suspected that this could also happen in the common blue skate and flapper skate. This has not been documented yet, but needs to be prepared for in terms of safety for the welfare for individuals (Christie, 2012; Theodosiou & Oppong, 2019; Henningsen & Whitaker, 2005) (see 2.6 Veterinary).

1.3.4 Electroreception (Ampullae of Lorenzini)

The ampullae of Lorenzini are electro receptive sensory organs in sharks, rays and skates (figure 8). The ampullae allow sharks, skates, and rays to detect moving prey by means of mechanical stimulation, temperature changes, salinity changes and electric fields (Canadian Shark research Lab, 2016b; Hofmann, 2011).

Figure 8: Image of the ampullae of Lorenzini, which are visible as small dark spots (photographed specimen in image is not a common skate) (Canadian Shark research Lab, 2016b)

1.4 Longevity

In a recently published study using citizen-science data originating from photo-identification of trophy pictures and tag–recapture data it is estimated that the flapper skate (*Dipturus intermedius*) is a long-lived species with ages estimated as over 40 years for the largest individuals captured. (Régnier, et al., 2021). There is, however, little reliable information about the age and growth of species like the flapper skate (*Dipturus intermedius*) and common blue skate (*Dipturus batis*).

1.5 Ecology, zoogeography and conservation status

1.5.1 Habitat

The common blue skate (*D. batis*) and flapper skate (*D. intermedius*) appear to have different habitats. The flapper skate is largely coastal, while the blue skate occurs mostly offshore (Thorburn et al., 2021).

The distribution of the blue skate appears to reflect its partiality to thermally less variable and warmer waters, while flapper skate were found in more variable and notably colder areas. The thermal range and current geographic distribution of these species indicate that future projected climate change could have a differential impact on distribution of flapper and blue skate in the north-east Atlantic (Frost et al., 2020).

There have also been sights of flapper skates in shallower waters: observations included an individual adult spotted in the Summer Isles (Scotland) at a water depth of 8 metres, multiple instances of individuals around the Scottish Sea lochs at a water depth between 15 and 30 metres and observations by anglers in the Sound of

Jura Marine Protected Area (Scotland) that were also in shallow water (Rickard, 2021). In Orkney, flapper skate has been seen inshore to 4 metres (Daniel Wise, pers. comm. 2021).

The shallow coastal waters are mostly located in the benthic and sublittoral zone. The bottom, or seabed, in their habitats is covered in sediment with sand, mud, sandy mud, muddy sand, rock and mixed sediment (Brand, 2018; Bates et al., 2004; Goudge & Morris, 2014; Sguottiv et al., 2016). The FAO Species Catalogue for Fishery purposes also states that *D. intermedius* prefers a "soft bottom but [is] also found on gravel and hard, rocky ground." (Ebert & Stehmann, 2013).

According to research by the Scottish Natural Heritage in 2018, the depth of water where *D. intermedius* is active differs between the seasons: flapper skates were typically located in a depth between 100 and 150 meters over summer months, while also having a larger depth range over winter months (Thorburn et al., 2018, 2021).

1.5.2 Distribution

The range of the common skate complex was once stretched from the north-east Atlantic Ocean to the entire North Sea and the Mediterranean Sea towards the far northern parts along the Norwegian coast (figure 9). It has now declined to a distribution around the coasts of the Celtic Sea, Western Baltic Sea and coastal edges of the Eastern and Western North Sea (figure 10) (Dulvy et al, 2020; Frost et al., 2020).

Figure 9: Occurrence of the *Dipturus batis* complex between 1820 and 2000, with presence in the Northeast Atlantic Ocean, Celtic Sea, English Canal, North Sea, Norwegian Sea, Mediterranean Sea, Tyrrhenian Sea and Adriatic Sea. The pictured occurrence is derived from records of human observation, preserved specimens and living specimens (GBIF Secretariat, 2019).

Figure 10: Occurrence of the *Dipturus batis* complex between 2000 and 2020, with presence diminished to the Northeast Atlantic Ocean, Celtic Sea, English Canal and edges of the North Sea. Occurrences are much more concentrated in less areas. The pictured occurrence is derived from records of human observation, preserved specimens and living specimens (GBIF Secretariat, 2019).

The species common blue skate (*D. batis*) and flapper skate (*D. intermedius*) appear to inhabit different geographic ranges, with some overlapping areas. This is assumed to be caused by different temperature ranges where these species occur, with common blue skate between 7,4^{o}C and 13^{o}C and flapper skate between 4,1^{o}C and 15,5^{o}C. This has resulted in the occurrence of the common blue skate in colder, more offshore waters and the flapper skate being in more variable and more inshore waters (Frost et al., 2020).

1.5.3 Population

Current populations reside around the coastal areas around the British islands and Ireland (figure 11a & 11b), Celtic Sea, North Sea, Norwegian coastal areas and the Western Mediterranean Sea. The existing historic populations have been declining in the areas of distribution. But recent literature suggests an increase in numbers (Rindorf et al. 2020). There is increasing anecdotal evidence that flapper skate are being found in areas of its former distribution and numbers are increasing (James Thorburn, pers. comm. 2021).

Species distribution modelling by DNA sequencing done by Bache-Jeffreys and co-authors suggests that *D. batis* was commonly distributed in the Western Approaches and Celtic Sea, extending out to Rockall and Iceland. *D. intermedius* generally appears to be less abundant, but was most frequent around northern Scotland and Ireland, including the northern North Sea, and was also present in Portugal. Two individuals were also identified from seamounts in remote areas of the Atlantic around the Azores, the furthest south and west the species has been found. This supports reports that the flapper skate historically had a much wider distribution, emphasising the large scale over which fisheries may have led to extirpations. Furthermore, these Azorean samples shared a unique control region haplotype, highlighting the importance of seamounts in preserving genetic diversity (Bache-Jeffreys et al., 2021).

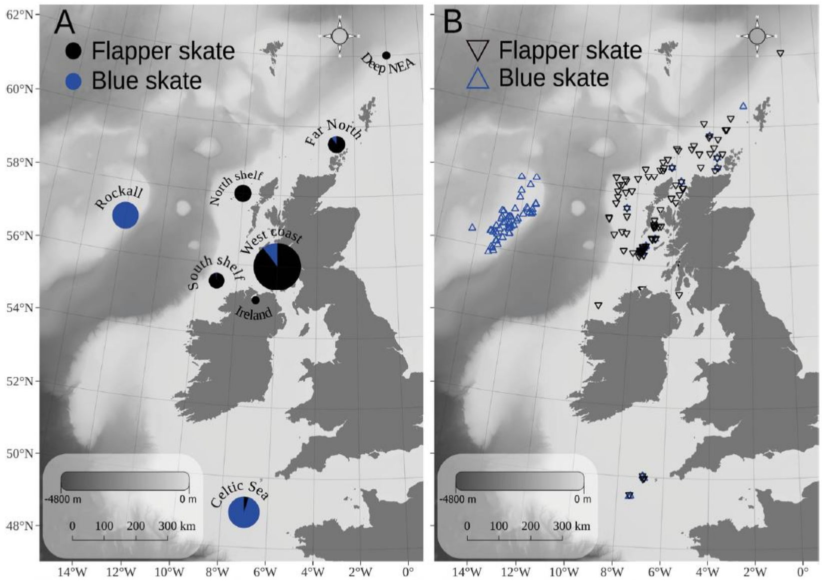

Figure 11a: Relative proportions of flapper and blue skate sampled in the study of Frost et al (2020). Sampling locations in the study included the Celtic Sea, the northern Scottish and Irish continental shelf (North Shelf), the southern Scottish and Irish continental shelf (South Shelf), the Rockall Bank, the western coast of Scotland (West Coast; includes the Loch Sunart to Sound of Jura MPA), Ireland, far north of Scotland in Orkney and Shetland (Far North) and a deep-sea area in the north-east Atlantic, to the north of Shetland (Deep NEA).
Figure 11b: Capture locations of flapper and blue skate sampled in the study of Frost et al (2020).

1.5.4 Conservation status

The species complex is considered critically endangered by IUCN (Dulvy et al., 2006), which means that it is facing an extremely high risk of extinction in the wild (figure 12). The last evaluation was undertaken in 2006 and is still under the common skate species name, so there is a possibility that both the flapper skate and the common blue skate are critically endangered (Garbett et al., 2020). The main threats to populations are fishery and the harvest of aquatic resources. It is vulnerable to trawl- and gillnet fisheries. It mostly ends up as bycatch from those fisheries. Ending up as bycatch is particularly critical as the species is large, has slow growth to adulthood and low fecundity. It is also targeted by recreational fishers, however most of them use a capture-release method. The OSPAR (Oslo and Paris Conventions) Commission has marked the species as sensitive within its managed areas (OSPAR Commission, 2010). The Helsinki Commission (HELCOM) reports the common skate as Regionally Extinct in the Baltic Sea region (The Baltic Environment Protection Commission, 2013). It is included in the EU's Biodiversity Action Plans but has not (yet) been evaluated for the CITES Appendices.

Figure 12: Depiction of the IUCN Red List category of threat for the common skate complex (Dulvy et al., 2006)

1.6 Diet and feeding behaviour

1.6.1 Food preference

Flapper skate

To explore the potential diet of flapper skates a survey describing the main species found around the Orkney islands was done in 2019. The survey recorded the presence of pollock (*Pollachius pollachius*), cod (*Gadus morhua*), ling (*Molva molva*), small spotted catshark (*Scyliorhinus canicula*), cuckoo wrasse (*Labrus mixtus*) and edible crab (*Cancer pagurus*) were spotted after being attracted to bait. Other mobile species that were found were common lobster (*Homarus gammarus*), crawfish (*Palinurus elephas*), leopard-spotted goby (*Thorogobius ephihippiatus*), butterfish (*Pholis gunnellus*), nursehound (*Scyliorhinus stellaris*), Bloody Henry (*Henricia spp*.) and seven-armed starfish (*Luidia ciliaris*). These were all present at an approximate water depth of 30 metres. (Wise, 2020)

Animals such as spiny dogfish (*Squalus acanthias*), lobster (*Nephrops norvegicus*), small spotted catshark (*Scyliorhinus canicula*), edible crab (*Cancer pagurus*), thornback ray (*Raja clavata*), cuckoo ray (*Leucoraja naevus*) and conger eel (*Conger conger*) have been observed in stomach contents of flapper skates (pers. comm. James Tornburn 2021).

Common blue skate

A survey study carried out between 2012 and 2015 surveyed for the diet of the common blue skate and found prey species including prawns and shrimp, crabs, isopods, cephalopods and teleosts. This was done by examining the gut content of 346 common blue skates. It also revealed that young skates ingested more shrimp, juvenile to mature skates ingested more crabs and this gradually transitioned to large adult skates preying more on teleost fishes (Brown-Vuillemin et al., 2020). Table 3 gives a more detailed overview of the species that were most present in gut content.

Prey category	Species		% proportion over 346 skates
Shrimp (Dendrobranchiata)	unidentified caridea	Caridean shrimp	13,44
	Crangon allmanni	Allmanni shrimp	35,63
	Crangon crangon	Annual brown shrimp	5,31
	Crangon sp.	Shrimp	26,88
	Processa canaliculata	Processa shrimp	5,94
Crabs (Anomura and Brachyura)	Unidentified Brachyura	Crab	15,31
	Liocarcinus vernalis	Grey swimming crab	5,00
	Macropipus tuberculatus	Portunid crab	6,25
Teleosts (ray-finned fish)	Unidentified Actinopterygii	Ray-finned fish	6,88
	Micromesistius poutassou	Blue whiting	4,69

Table 2: Most abundant species in the diet of the common blue skate (Brown-Vuillemin et al., 2020)

1.6.2 Feeding

The common blue skate feeds mostly on the bottom with its mouth downwards. More specific feeding behaviour is yet unknown.

1.7 Reproduction

The common blue skate species display the general reproduction in skates, which is the oviparous laying of eggs (figure 13). Fecundity is estimated at circa 40 egg capsules a year (Du Buit, 1977).

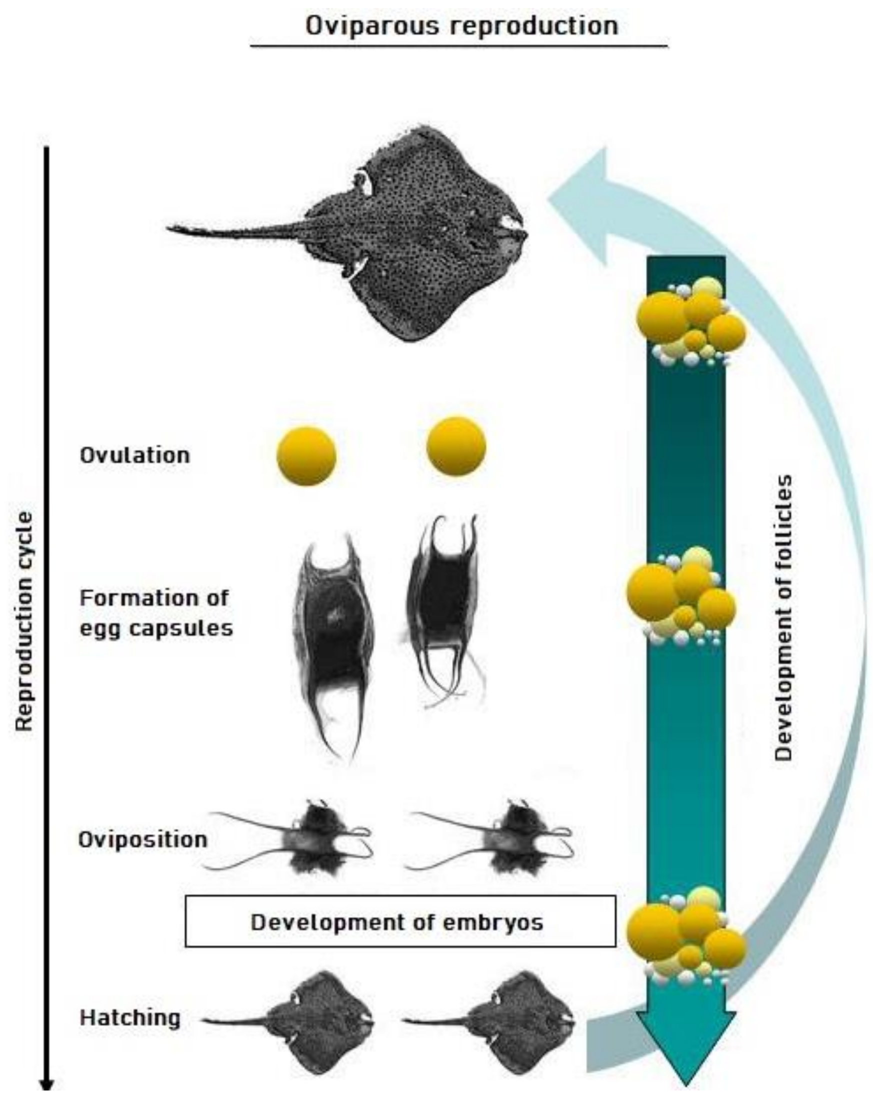

Figure 13: the reproductive cycle for oviparous skates like the flapper skate and common blue skate, edited image from the Canadian Shark Research Lab (2016a). The depicted species is unidentified species.

1.7.1 Incubation and hatching details

As has been discussed earlier, the differences in appearance between the flapper skate (*Dipturus intermedius*) and common blue skate (*Dipturus batis*) mainly exist in maximum size. This is also the case with the egg cases of the species, with a difference in shape too. Egg cases of flapper skate are usually larger in size and more rectangular in shape than egg cases of common blue skate. This can be seen in Table 3 and Figure 14 below. An interesting overview of the development in the egg of elasmobranchs in general has been described by Musa et al. (2018).

	Flapper skate	Common blue skate
Total Egg case length	235,2 ± 41,8 mm	211,9 ± 10,8 mm
Egg case length (without horns)	210,4 ± 27,4 mm	139,7 ± 5,6 mm
Egg case width	121,3 ± 10,5 mm	73,8 ± 3,6

Table 3: Sizes of egg cases in flapper skate (*Dipturus intermedius*) and common blue skate (*Dipturus batis*) Gordon et al. 2016)

Figure 14: Image of a flapper skate egg case (left) and a common blue skate egg case (right)

(Shark Trust, 2020a; Shark Trust, 2020b)

Egg laying sites are reported to be situated in boulder fields on the seafloor, around a depth of 18 to 21 metres and near adjacent tidal streams. The egg cases are laid in voids between boulders (figure 15). There they are not swept away by the tide or snatched by predators, but will get enough influx of clear, silt free, oxygenated water. Depth does not have to be a relevant factor. (Wise, 2020).

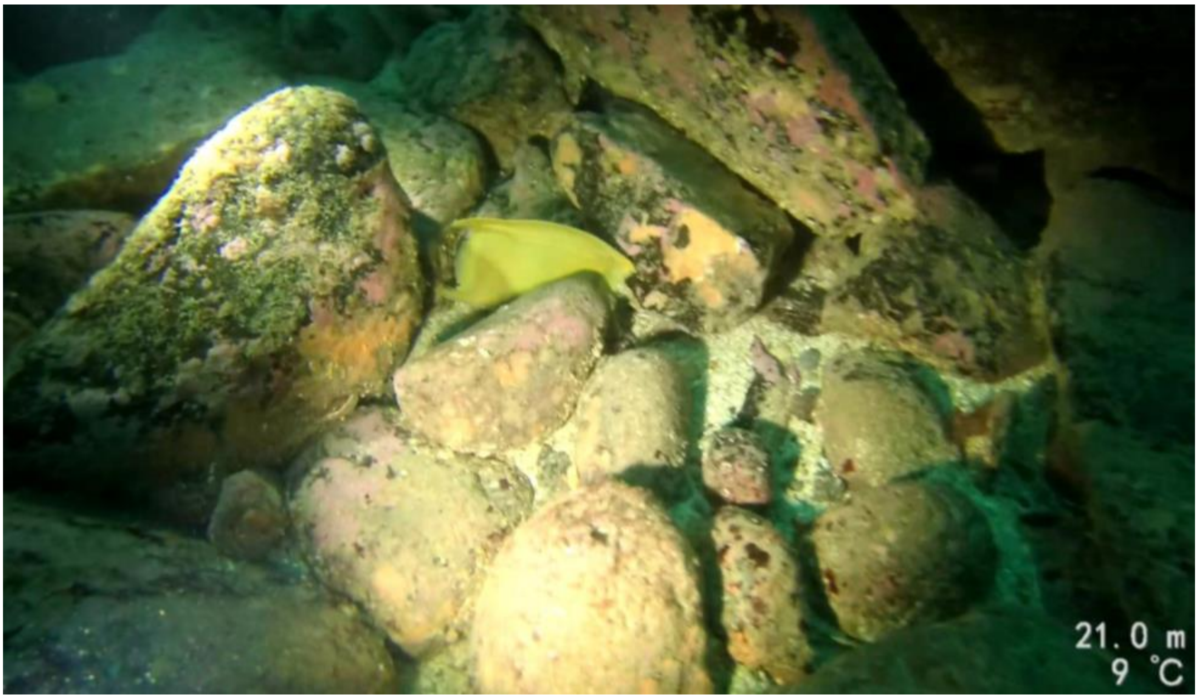

Figure 15: A diver's photo of a flapper skate egg laying site in the area in and around Sound of Shapinsay and Sound of Stronsay, Orkney islands. The egg is observed as relatively fresh and lain in a small void between boulders. This is on the sea floor in a water depth of 21 metres and water temperature of 9^{o}C © D.Wise

Benjamins et al (2021) describe in a recent article the first confirmed successful complete incubation of a flapper skate egg in an aquarium under human care. Water conditions (temperature, salinity, flow rate) were recorded, with mean water temperatures ranging from a monthly mean of 8.3 ± 1.2 to 13.2 ± 0.3^{o}C and salinity from a monthly mean of 30.5 ± 1.2 to 36.6 ± 2.3 ppt. Hatching occurred after 534 days, suggesting that flapper skate eggs take c. 5700 growing degree-days to incubate to hatching. (Benjamins et al., 2021). It is not known whether this also applies to the common blue skate.

More about the growing degree days (GDD) concept can be found in paragraph 2.4.3.

1.7.2 Developmental stages to sexual maturity

Very little information on age, growth and longevity is available for the common skate complex. Régnier and co-authors used capture-mark-recapture data to calculate the age and growth of the flapper skate (*Dipturus intermedius*). The model identified significant individual variation in parameters and growth trajectories for both sexes, with fast-growing individual females reaching the size at 50% maturity from around 10 years of age, while slow- growing females could reach this size after 25 years. Males also show important individual variation in growth but to a lesser extent, as size at 50% maturity is reached between 7 and 16 years of age for fast- and slow-growing individuals, respectively. However, caution is required when interpreting these estimated ages at the size at 50% maturity. (Iglésias et al., 2010; Régnier et al., 2021)

1.8 Behaviour

Much is still unknown about the behaviour of rajidae in general and the common blue skate and flapper skate in particular but more has become known in recent years. Research groups from Scotland and Northern Ireland are doing interesting research. A lot of citizen science data collected by recreational anglers, among others, is also yielding more and more data. An overview of recent literature can be found in the bibliography.

Mating behaviour has been proven to be difficult to document, even for elasmobranchs in general. Nevertheless, there has been done research that suggest that batoids participate in what can be described as an embrace between female and male. Chapman et al (2003) describe observations of southern stingrays (*Dasyatis americana*) in which the male grabs the female and then rotates to a 'ventral-to-ventral position', and subsequently inserts one of its claspers into the female's cloaca.

Section 2: Management in zoos and aquaria

2.1 Enclosure

2.1.1 Boundary

As is the standard with large elasmobranchs, the aquarium exhibit should be open at the top to provide a service entrance for feeding, divers and other maintenance. The open top should only be located outdoors if the local climate is suitable, as this could interfere with the maintained climate in the exhibit. It also ensures minimum disturbance by other animals like birds. Likewise, it is not recommended to facilitate a touch pool experience for visitors, as it could give a safety issue due to the thorns on the back and tails but also to prevent any welfare issues caused by stress from visitors.

The acrylic/glass boundary between exhibit and the public should be thick enough to resist the water pressure from the filled water tank. The thickness and composition of the other walls, often concrete, should also be accounted for. These are both different per size of the exhibit and can be calculated. Like a lot of elasmobranch exhibits, the water tank should not have corners that are sharper than 90 degrees.

A separation tank must be present near the exhibit to accommodate for the separation of an individual skate. This may be in the case of a welfare issue regarding behaviour or health. This tank is preferably smooth and round to prevent the individual getting stuck in a smaller enclosure and prevent injuries.

2.1.2 Substrate

As aforementioned, the species of the common skate complex are suited for the usage of a bottom with a sandy and muddy substrate. The substrate, at least 5-10 cm, can be distributed evenly among the floor of the aquarium where it is kept. From experience with guitarfish and thornback ray (*Raja clavata*), crushed oyster sand is well accepted. The rays can easily bury themselves in it. Silica and pozzolana are more aggressive for the skin, and pozzolana is heavier and more difficult for the animal to burrow (pers. comm. Renaud Herbert 2021). Greenway, Jones and Cooke (2016) discussed the use of substrate colour by thornback rays, with lighter sand substrate being beneficial to visibility for both caretakers and visitors. This can also be applied to the husbandry of flapper skates and common blue skates because of their similar habitats. The substrate layer on the floor of the exhibit should also be deep enough to facilitate burying behaviour and subsequently avoid stereotypic behaviour (Greenway et al., 2016).

2.1.3 Furnishings and maintenance

Plants that serve as furnishing and decoration of the exhibit could be bladderwrack (*Fucus vesiculosus)* and kuvie kelp (*Laminaria hyperborea*) (Rowe & Rickard, 2021). They could also serve as a refuge, but this has not been evidenced yet (Greenway et al., 2016). Small rocks and pebbles can also be distributed across the exhibit floor, as is done at Macduff Marine Aquarium (Rowe & Rickard, 2021).

Other structural items can include the use of rock shaped walls and a small cave section to mimic the natural habitat of both the skate species (Rowe & Rickard, 2021). Large rocks are used in-situ to anchor egg cases to prevent them from drifting away with the current, but this is not necessary in exhibits as the egg cases can be retrieved by divers.

2.1.4 Environment

A clean and appropriate environment provides a safe living space for the common skate species, ensuring an optimal quality for the basic needs of individuals. The environment in animals kept under human care should mirror circumstances in the natural environment of the common skate species as much as possible (Mohan & Aiken, 2004).

Filtration

The filtration within the enclosure for the common skate complex is required to use a mechanical filter (e.g. high-rate sand filter or drum filter), a protein skimmer, UV disinfection and an aerobic biological filter. This ensures the continuous flow and quality of the water in the exhibit. The filters keep the quality of the water within the minimum and maximum margins (Mohan & Aiken, 2004).

Water and water quality parameters

The water that is used for the exhibit should, as much as possible, mirror the properties of the seawater where the common skate species can be found (see 1.5.3 Population). A best practice for water quality is defined in Table 4. Here we use the water quality standards for the North Sea exhibit in Rotterdam Zoo.

Parameter	Minimal value	Optimal value	Maximal value
pH	7,8	8,1	8,3
Ammonium (mg/l NH4-N)	0,0	0,0	0,5
Nitrite (mg/l NO2-N)	0,0	0,0	0,3
Nitrate (mg/l NO2-N)	0,8	5,0	20
Salinity (‰)	30,0	34,0	36,0

Table 4: water quality standards for the North Sea exhibit in Rotterdam Zoo

The stated values of the parameters of the nitrogen cycle (NH_3-N, NO_2-N and NO_3-N) are more important for monitoring the filter system than that these values influence the health of the animal. In a well-balanced filter system with the optimal bacterial activity, the ammonia (NH_3-N / NH_4-N) and nitrite (NO_2-N) values are as good as zero. Nitrate (NO_3-N) is the end-product of the nitrogen cycle. High values are a parameter for the “aging” of the water and are lowered by renewal. At high values of NO_3-N, other parameters that have not been measured can also be significantly changed. NO_3-N is therefore seen as a signal value. Skates should only be introduced into an enclosure when the system is running optimally and the NH_3-N and NO_2-N values are close to zero and all nitrogen products are converted into NO_3-N (Mohan & Aiken, 2004).

Recent studies have demonstrated that high environmental nitrate (NO_3-N) inhibits the ability of the thyroid gland to utilize available iodide, resulting in thyroid gland overstimulation by thyroid stimulating hormone and ultimately leading to the development of goiter (Morris et al., 2011).

The water temperature for exhibits is different for the flapper skate and the common blue skate: the flapper skate can be found in a temperature between 5 and 15^{o}C and the common blue skate is found in a temperature between 8 and 13^{o}C. This is based on the natural circumstances that were mentioned earlier. The common blue skate can handle a smaller margin in water temperature that subsequently overlaps with the margin for the flapper skate.

More in-depth information about water quality and maintenance can be found in Chapter 6 of the Elasmobranch Husbandry Manual (Mohan et al. 2004).

2.1.5 Dimensions

It is advised the common skate and flapper skate have a minimum space of nine times the total length by nine times the disk width per individual, and a minimum depth of 2 meters. In general, each added individual skate requires a surface area increase of 50%. The bottom surface area is the most important measurement, as both the skate species are bottom-dwelling elasmobranchs.

It is mandatory to have an area that facilitates the isolation of a single skate or multiple skates. This could be an adjoining or a separate tank with the appropriate water quality parameters and dimensions per individual. Isolation may be necessary in case of veterinary, behavioural or any other issues regarding the welfare of the skates. It should have a depth of at least 0,5 metres and it's advised to have a diameter of the separation tank reaching at least 3 times the length of the animal.

Egg cases can also be kept in a separate environment (see 2.4 Breeding).

2.2 Feeding

2.2.1 Basic diet

Both the flapper skate and common blue skate feed on fish, squid and crustaceans. Diet primarily consists of mackerel, herring, shrimp, squid and mussels (Rowe & Rickard, 2021). Feeding ration for adult skates is estimated as 4-6 % of the body weight (BW) per week, the ration for juveniles can be multiplied with a factor of 1,5 to 3. These are guidelines and can differ between individuals and conditions, as apparent by observation and experience (Janse et al., 2004).

The mentioned prey species are easily acquirable on the market of animal feed and the fishery industry but may be less fresh when the holding institution is not in the proximity of a coastline. Most fish and other marine species can be transported frozen, but the process of thawing the food generally results in a loss of nutrients (Janse et al., 2004). Nutritional values for food items that are recognized in the diet of both species can be found in Appendix II.

2.2.2 Supplements

Supplements are commonly used to complement the basic diet of fish under human care. The supplements add missing nutrients or compensate lost nutrients in the process of thawing fish. Supplement contents vary but are generally composed of a combination of vitamins (Vitamin A, B1, B2, B3, B6, B12, C, D3, E) and minerals (iodine, cobalt, iron, manganese, potassium, selenium, sulphur, zinc). The contents differ depending on the brand or specialized type of elasmobranch supplement (Kiezebrink, 2021; International Zoo Veterinary Group, 2021; Vetafarm, 2016).

Elasmobranch tablets are used most when feeding elasmobranchs in zoological institutions. Shark tablets can be fed by inserting them in whole fish (via mouth or gill for example, see figure 16). Alternatives in liquid, powder or a gelatine-based food mixture form are also available, but are less practical in use (Janse et al., 2004).

Figure 16: Example of the addition of a shark tablet, in this case from Akwavit (Kiezebrink, 2021).

2.2.3 Special dietary requirements

The choice in feeding fish whole or in pieces depends on the width of the mouth and the size of an individual skate. The animal must be able to ingest the food, but also digest it properly. Individual skates need different sizes and amount of feed between hatchling, juvenile and adult as they grow in both size and weight.

Hatchlings can also use the nutrients in the egg yolk for a while until they are fully accumulated, so they will need only a minimum of feed in the first few weeks (Janse et al., 2004). There is one known observation of a flapper skate hatchling (see paragraph 2.4.4) where feed intake in the first weeks was examined. The animal had a large stomach with egg yolk (figure 19c) and after 54 days, it was seen for the first time that the animal had eaten and faeces were found (Daniel Wise, pers. comm.).

It is not known whether egg laying female skates need different quantities or composition in nutrition.

2.2.4 Method of feeding

There are several techniques that can be applied to feed elasmobranchs, of which feeding each individual separately has been used the most. Aquaria apply this technique to monitor the food intake of each specimen closely. For rays and skates, this is mostly done by ways of a 'vertical seafloor' using the smooth wall of a tank and using a pair of large tongs to feed each individual. This is less favourable when there is a situation with a prospect to release of individuals, as it does not mimic the conditions in the wild. Letting food sink to the bottom and in the substrate is a different way of feeding that enables natural foraging behaviour of skates. A disadvantage of this method of scatter feed is the competition between the fishes in the aquarium. Make sure that excess feed is removed afterwards as this can have a negative impact on water quality.

Food items are preferably presented as whole fish to maximize the use of the nutrients that are present in its natural prey in the wild. It may be necessary to feed fish in chopped pieces to small individuals (hatchling or juvenile) to account for the size of their mouth.

2.3 Social structure

2.3.1 Basic social structure

Research on thornback skates (*Raja clavata*) involving group size showed significant increases in stereotypies with increasing numbers of individuals (Greenway et al, 2016). It is not known whether this can also be a problem in juvenile flapper skates and common blue skates, but it is important to keep a close eye on this.

2.3.2 Changing group structure and sharing enclosure with other species

It is unknown whether welfare would be compromised when housing multiple individuals of one species in an exhibit. It is also not known how individuals could react to introductions in an aquarium setting, except for a record of the juvenile flapper skate (*Dipturus intermedius*) at Macduff Marine Aquarium in Scotland (see. Paragraph 2.4.4.) where it settled quickly and was housed with other species like juvenile seabass (*Dicentrarchus labrax*), thicklip grey mullet (*Chelon labrosus*) and juvenile thornback skates (*Raja clavata*) in one display tank (figure 17). It is not known whether this can be applied with larger, more mature individuals housed in the tank.

Figure 17: Exhibit at Macduff Marine Aquarium where a juvenile flapper skate is housed with juvenile seabass (*Dicentrarchus labrax*), thicklip grey mullet (*Chelon labrosus*) and juvenile thornback skates (*Raja clavata*) © Rowe & Rickard.

As an apex predator, housing with other bottom-dwelling animals may pose problems. Colleagues at Macduff Marine Aquarium describe a case of their 11-month-old flapper skate (disc size 27.7cm) that was most likely responsible for a juvenile (~30 cm long) nurse hound (*Scyliorhinus stellaris*) biting incident (figure 18). It is quite possible that the bite was more instinct driven than a case of being hungry, but it does highlight the apex predator nature of the flapper skate. However, this biting incident is the first since the juvenile flapper skate was added to the tank just over 6 months previously.

This incident indicates that it may be difficult, if not impossible, to add other bottom-dwelling animals to a display tank without fear of damage or death to them. This problem is likely to get more complex as the animal gets bigger (Rowe & Rickard, pers. comm. 2021).

Figure 18: a juvenile nursehound (*Scyliorhinus stellaris*) bitten by a juvenile flapper skate (*Dipturus intermedius*) © Rowe & Rickard

2.4 Breeding

2.4.1 Mating

No special precautions are known to be needed in order to facilitate mating behaviour in either species. However, seasonal cycle simulation (temperature and/or lighting) might induce mating behaviour experienced by other ray species in captivity (Rune Kristiansen, pers. comm. 2021).

2.4.2 Egg laying and incubation

Female skates deposit the egg cases on the bottom of the basin, where they can be removed from the basin by divers or with a net. It is recommended to keep the eggs capsules under water when moving. Experiences with thornback ray (*Raja clavata*) and small-spotted catshark (*Scyliorhinus canicula*) show that air inside capsules can cause problems.

If the eggs are not removed, there is a high chance of predation of the eggs by other animals. Subsequently, the egg cases can be held in a separate tank. The water should maintain enough flow for sufficient water quality without too much force on the egg cases. To minimize the chance of fungal growth, the egg cases can be held loosely strung along long, thin fishing line material. It is also important to keep each egg case in one horizontal position to prevent embryo entanglement within the egg case.

The incubation time and growth rate of ectothermic animals such as skates is partly depending on the temperature. The concept of growing degree days (GDDs) can be used to compare incubation periods. GDDs describe incubation periods of eggs based on the average temperature during the incubation multiplied by the number of days until hatching (Neuheimer & Taggart, 2007).

An egg of the flapper skate (*Dipturus intermedius*) was successfully incubated to hatching under human care in what is believed to be the first for the species, as it is described by Benjamins et al. (2021). They found an incubation period of 534 days at an average temperature of 10,7^{o}C. That gave a GDDs score of 5692. This animal was released just after hatching.

2.4.3 Birth / hatching

There are two descriptions of flapper skate births in an aquarium. One is described in detail in the above-mentioned article by Benjamins et al. (2021). The second birth is described in paragraph 2.4.4.

2.4.4 Development and care of juveniles

Cedric the young flapper skate (Dipturus intermedius) at Macduff Marine Aquarium Scotland

On January 7th 2020, a damaged flapper skate egg case had been found during an Orkney Skate Trust research survey and it was discovered to have a developing embryo inside. The egg could not be returned to the sea, as it was unlikely to survive – so was carefully nurtured in a fish tank and successfully hatched on August 12, 2020. The egg case measured 280 mm total length x 138 mm width. The minimum length was 180 mm.

The small flapper skate, named Cedric, had a total length of 280mm (nose-tail length) and a disc width of 200mm. He weighed 125 grams (figure 19a & figure 19b). On hatch, the flapper skate had a characteristic dark ventral side. Six days later the ventral side was a lot lighter and the stomach yolk sac was clear with a dark substance inside (figure 19c).

Three weeks later, the animal was moved to an 800-litre container with seawater with natural shell sand and dual air feed. Long periods of inactivity were observed in the tank. The flapper skate was then partly buried in the sand (figure 19d). Feed offered (squid, mackerel) was ignored. The first indications that the animal had eaten was around October 5, eight weeks after hatching.

On Oct 22 (day 71) after hatching the total length was 300 mm (20 mm increase from birth) and the disc width was 214 mm (14 mm increase since birth) (figure 19e & figure 19f). The animal was transported to Macduff Marine Aquarium on Dec 8 in a basic plastic box with lid. The box was filled with local clean seawater and then stored within an insulated fish box. A hole was drilled in the top to allow an air feed, powered by a 12V battery. Finally, the top was covered in cloth for darkness and a small quantity of ice around the box to maintain the temperature for the 5 hours trip to the aquarium.

At the Macduff Marine Aquarium, he was included in the native collection to highlight this fascinating and critically endangered species (figure 20) (Wise, 2021; Mcroberts, 2021; Rowe & Rickard. 2021). The aquarium staff will be able to contribute to the wider understanding of the species by monitoring Cedric's growth rate and other developmental changes. The aquarium is working closely with scientists from Orkney Skate Trust and other organisations to share information about Cedric as he grows and to ultimately coordinate his release to the wild when that time comes.

As far as we know this is the only description of a flapper skate under human care. Data from this animal will be very useful to understand how to handle eggs and juveniles in an aquarium setting.

Figure 19a: Juvenile flapper skate “Cedric” at the Orkney Skate Trust. Total length nose to tail = 280mm wing tip to wing tip = 200mm and 125 grams © D. Wise

Figure 19b: Juvenile flapper skate “Cedric” at the Orkney Skate Trust. Ventral side characteristically dark on hatch – umbilical feed obvious, stomach yolk not as obvious. Note very long tail and claspers © D. Wise.

Figure 19c: Juvenile flapper skate "Cedric" at the Orkney Skate Trust. Picture taken on 18th August 2020 (6 days old) – colouration on ventral side much lighter – stomach yolk content clear with an unknown darker substance © D. Wise.

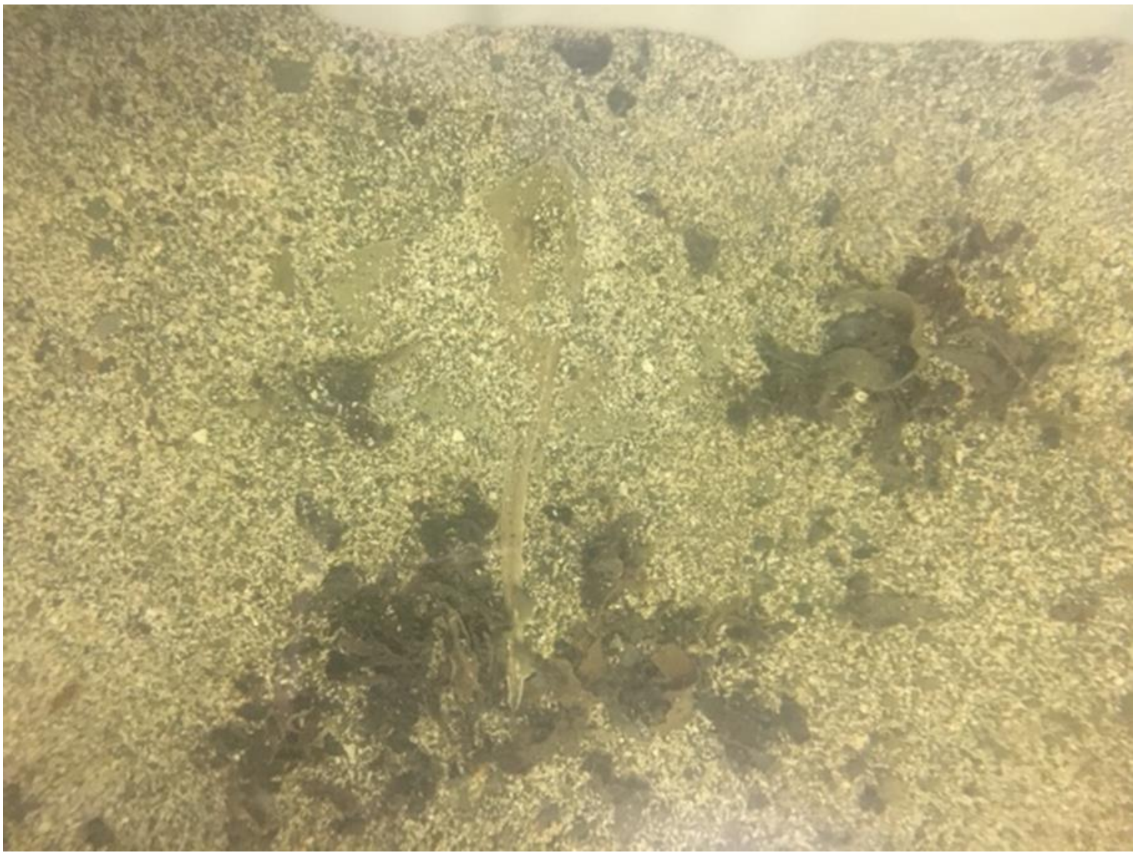

Figure 19d: Juvenile flapper skate "Cedric" at the Orkney Skate Trust on 31st August 2020. Natural behaviour exhibited – part burial in sand and long inactive periods resting – No food taken (small sections of squid, and mackerel given but ignored). © D.Wise

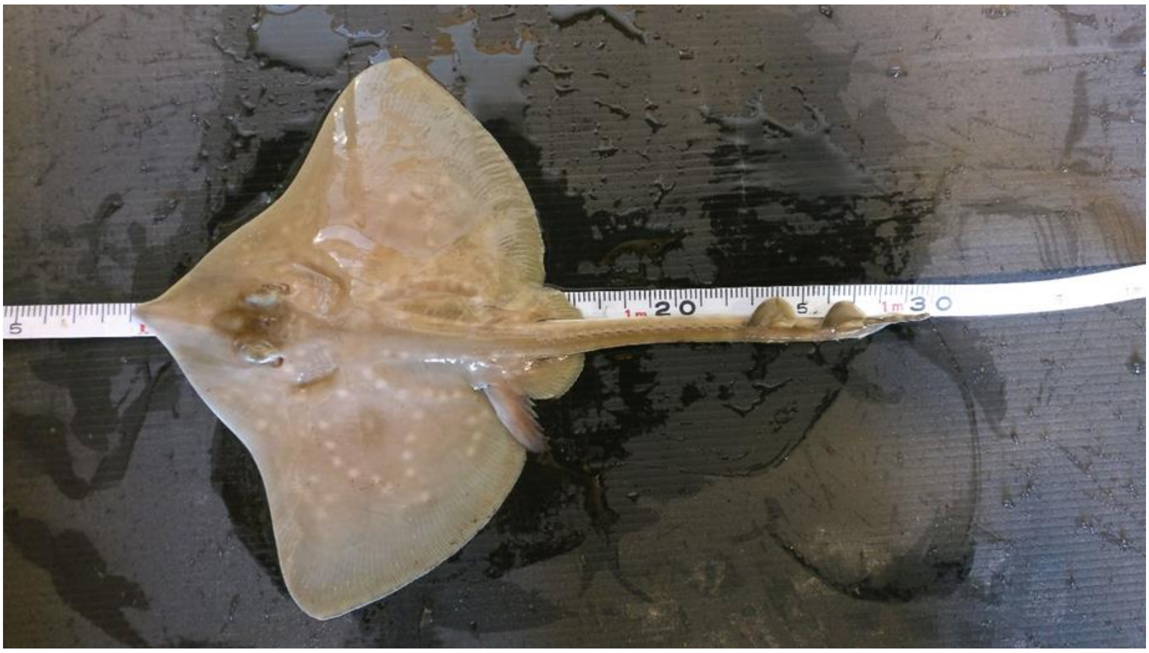

Figure 19e: Juvenile flapper skate “Cedric” at the Orkney Skate Trust. 22nd October 2020 – Total length 300mm (20mm increase from birth). © D. Wise

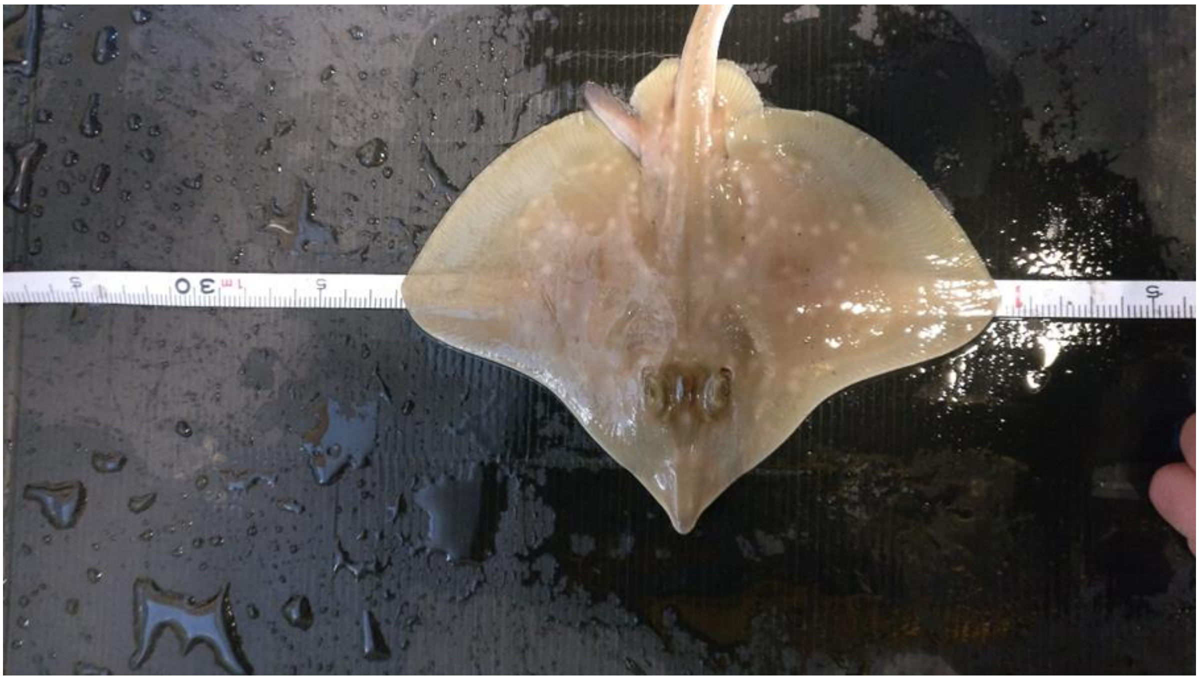

Figure 19f: Juvenile flapper skate “Cedric” at the Orkney Skate Trust. 22nd October 2020 – total width 214mm (14mm increase from birth) © D. Wise

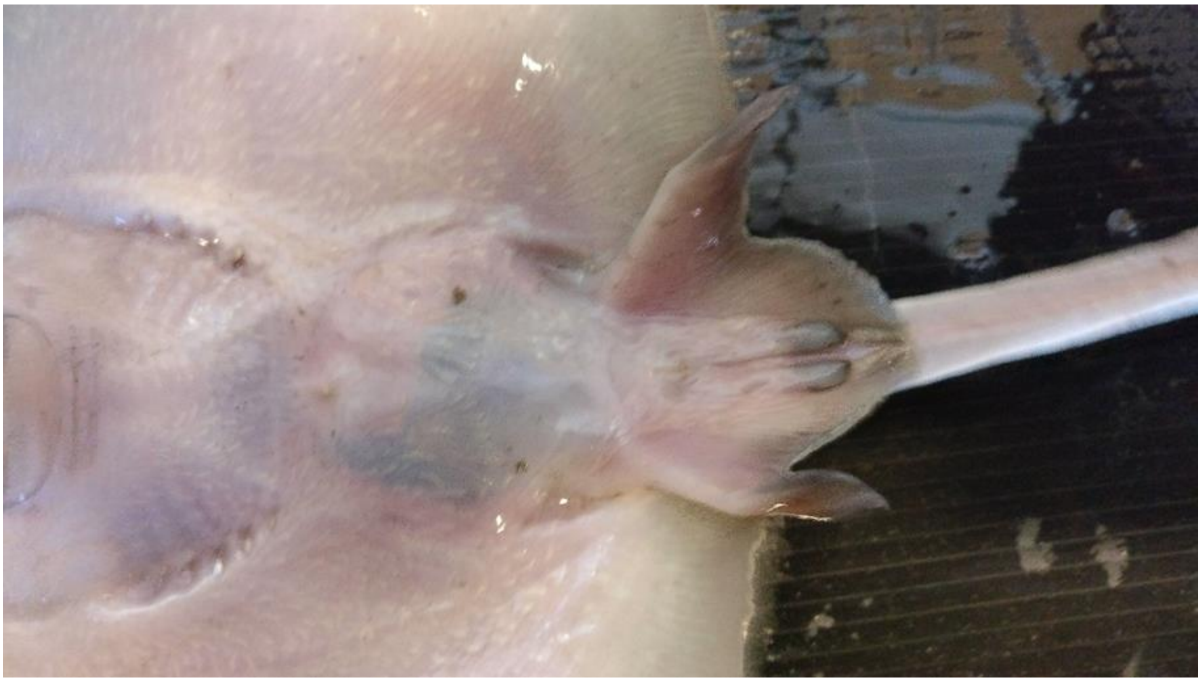

Figure 19g: Juvenile flapper skate "Cedric" at the Orkney Skate Trust. 22nd October 2020 Stomach yolk reserves depleting and male sex organs. © D. Wise

Figure 20: Flapper skate 'Cedric' at 5 months old, a juvenile individual that has been incubated, hatched and cared for by Daniel Wise in the first 2 months and thereafter by Macduff Marine Aquarium. Here it has a total length of 331 millimetres, a disk width of 231 millimetres and a weight of 158 grams © Rickard

2.4.5 Population management

At the moment there is no need for population management in aquaria. It is also unlikely that animals will be kept for a possible breeding program in the short term. As mentioned earlier, these Guidelines were written to find out whether there are opportunities for aquaria to participate in a possible future reintroduction program.

2.5 Behavioural enrichment

No specific research has been undertaken to investigate behavioural enrichment for flapper skates and common blue skates yet. Greenway and co-authors have investigated possible enrichment for captive thornback rays (*Raja clavata*), this included the use of substrate type, substrate colour, substrate depth, group size and refuge use. They concluded that preference for substrate colour mostly varied between white or yellow sand, with black sand being avoided entirely (except for one individual). Although white sand could be preferred for improved visibility of individual rays, giving a choice in substrate could lead to improved welfare and less stereotypical behaviour. This could also be applied to substrate depth, as it was recorded that preference differed greatly per individual ray (Greenway et al., 2016).

2.6 Handling

2.6.1 Individual identification and sexing

The male and female common blue skate and flapper skate are, like the majority of other elasmobranch species, easily distinguishable by the respectively the presence or absence of claspers near the pelvic fins. Individual identification may be possible by the recognition of the patterning on the back that has been concluded as unique. This can be documented with a photo (Benjamins at al., 2018).

Skates under human care should be microchipped for registration purposes, these chips can be scanned with a microchip reader. Dart tags or Floy tags are also useful in recognizing individuals when a large group is housed or when individuals are selected for reintroduction. Each tag has a unique number and if opted a different colour, making visual distinction of individuals easier. Tags on individuals that are planned to be released into the wild in the future can be incorporated with an additional chip that gives data about its whereabouts (Floy Tag & Mfg., Inc., 2021; Batsleer, 2021).

2.6.2 General handling

Both common skate species can be handled without worry for a venomous sting near the base of the tail. It does have a rough skin that could be able to cut human skin, so handling individuals in any way should be done with gloves. Young skates should be handled with more caution, as their tails are spinier than adults (Wise, 2020). Tail thorns are very sharp and can be dangerous. In mature males, the two thorn patches on the dorsal side of each wing should be avoided when handling.

2.6.3 Catching - restraining

Both common skate species can be caught by a diver using a rubber coated fishing net with meshing of 5 centimetres to avoid the thorns / spines getting caught in the netting. Like with other ray and skate species, it can be scooped up from the point of its nose and guided into the net. A net with an end that can be opened is recommended for easy release; this can promote an easy and fast release and minimize unpredictable movements or high stress levels for the individual animal (Appendix I). Another option that can be used is a round ray carrier, which can potentially be used to measure and weigh a skate directly without the need of an unhooking mat out of the water (1-2-1 Animal Handling Products Ltd., 2020a) (figure 21).

Figure 21: The use of a large ray tray for the measurement of an Australian whiptail ray at National Aquarium Baltimore (1-2-1 Animal Handling Products Ltd., 2020b)

The frame of the fishing net does have to accommodate the span width of the individual, so catching and restraining a large adult common skate may not be feasible due to the weight of the frame that the diver will have to carry in and out of the water. Due to the size and weight of both the net and the common skate, it is strongly advised against diving alone but rather by (at least) two. The first diver is then to handle the net, the other diver is to guide and assist the first diver in catching and/or restraining the individual.

It may be possible to measure or inspect individuals after capture by laying it on an unhooking mat. This mat is made of soft material and filling and is especially made to protect an individual skate from sustaining wounds. These wounds are usually a result of struggling after being caught and released from the fishing net onto the mat (Appendix I). The skate can be measured for general size by disk width and total length, but also specific aspects of its body size (figure 22).

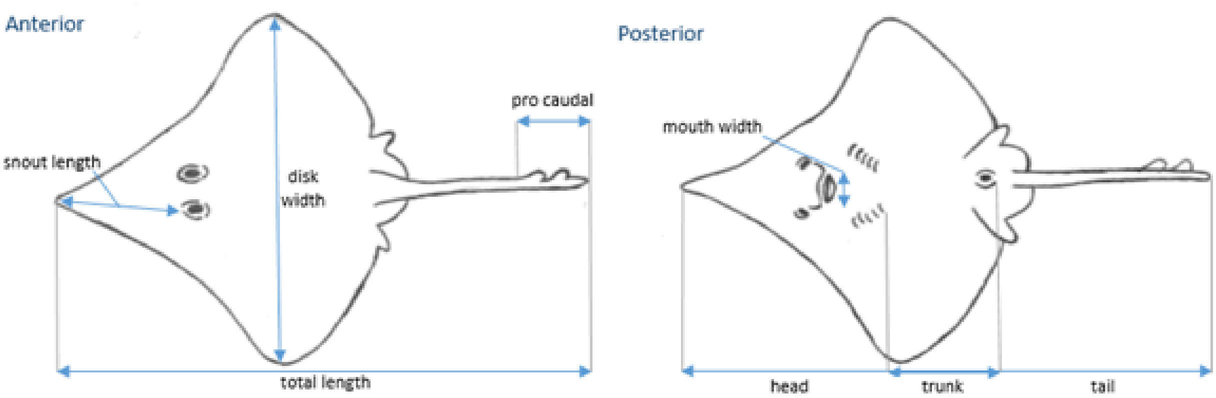

Figure 22: the anterior and posterior sides of a skate with aspects that can be measured © N. Wachters

2.6.4 Transportation

As written in the abstract of the chapter on transport in the Elasmobranch Husbandry Manual of 2004 (Smith et al., 2004), elasmobranchs are delicate animals and appropriate care should be observed during their transport or permanent damage and even death can result. Key considerations include the risk of physical injury, elevated energy expenditure, impaired gas exchange, compromised systemic circulation, hypoglycaemia, blood acidosis, hypercalcemia, accumulation of metabolic toxins, and declining water quality. Carefully planned logistics, appropriate staging facilities, minimal handling, suitable equipment, an appropriate transport regime, adequate oxygenation, comprehensive water treatment, and careful monitoring will all greatly increase the chances of a successful transport. In special cases, the use of anaesthesia and corrective therapy may be merited. Chapter 8 of the Elasmobranch Husbandry Manual Volume 1 provides a comprehensive overview of transport techniques and equipment (Smith et al., 2004). A direct link to this chapter can be found in the reference list.

The species is not currently (2021) listed in any CITES appendices. However, the CITES status of both species should be checked before each transport, as this can change over time (CITES, 2021). It still requires both an export, trans-shipment and import declaration issued by the origin, transit and destination country's agencies, as well as a veterinary health certificate (International Air Transport Association, 2014). When needed, it also requires customs documents to ensure smooth passage of national borders, including a TRACES certificate when moving animals within the European Union.

When transporting a skate or egg case by air it is bound to the IATA Container Requirements (CR), where it falls under CR51, CR52 and CR52A. These are applied to:

- small elasmobranchii under 40 cm in size (CR51);
- small elasmobranchii from 40 to 100 cm in size (CR52);
- large elasmobranchii larger than 100 cm in size (CR52A)

(International Air Transport Association, 2014)

2.6.5 Safety

The biggest risk when dealing with skates is bite marks. Always make sure to stay away from the mouth during handling. The flapper skate and common blue skate do not have a venomous spine as stingrays but do have a row of thorns along the spine and tail that may be of concern to handlers. These thorns have a blunt or sharp point and may be able to damage a net or divers' suit. They do not pose a significant threat to the safety of keepers and other personnel.

2.7 Veterinary: considerations for health and welfare

Goiter formation

Goiter is an iodine deficiency syndrome, which can be seen as a visibly enlarged thyroid gland. This is the result of a prolonged state of hyperthyroidism. The cause of this issue lies in water that contains an environmental high level of nitrate (NO_3-N) (Morris et al., 2011). This can be a problem in closed systems, but this problem will almost not occur in natural seawater systems with a lot of renewal of the natural seawater. It can be treated and prevented with a regular dose of iodine, which can be ingested via specialized shark tablets (see 2.2.2 Supplements). The level of environmental nitrate in the water of exhibits and other water tanks must be monitor to prevent any problems (see 2.1.4 Environment).

Risks in the eversion of the spiral valve intestine

Eversion of the spiral valve intestine is not abnormal but needs to be monitored closely. The eversion does not typically harm the individual itself but could draw interest of other animals that are housed in the exhibit. This could result in vulnerability to attacks with a potential threat to the individual skate (Christie, 2012). In the instance where an individual does evert the intestine, it should be monitored closely and watched for injuries. It should only be separated in a different exhibit or tank if other individuals in the exhibit display aggressive behaviour, and can be returned once the intestine has returned to normal (pers. comm. Linda Bruins - van Sonsbeek, 2021). It may be necessary to intervene if the intestine does not return to normal by itself, sometimes with the assistance by a veterinarian (pers. comm. Max Janse, 2021).

Parasites and parasitic infections

There is risk of skates contracting parasites and possibly subsequently a parasitic infection. This can occur from feed items or from newly arrived skates (from another zoological institution). Parasites in fish are mostly prevented by inspection beforehand and by freezing the fish prior to feeding it to animals. Any parasitic problems that occur within an individual from another institution are generally detected during the mandatory quarantine period (Bruins - van Sonsbeek, 2019).

Endoparasites and parasitic infections can be treated with the use of mebendazol and praziquantel, both of which are used as a standard treatment in quarantine protocols for sharks and rays (Bruins - van Sonsbeek, 2019). A ketamine bath could also help in getting rid of ectoparasites, as the parasites may also be killed due to their low tolerance to ketamine (pers. comm. Linda Bruins – van Sonsbeek, 2021). Both the skate species cannot be treated with a freshwater bath, as this is lethal to skates within minutes this is based on experiences with skates at Rotterdam Zoo (pers. comm. Linda Bruins – van Sonsbeek, 2021). Hydrogen peroxide can be used against external parasites, metronidazole against ciliates and a chitin inhibitor against crustacea (pers. comm. Renaud Herbert, 2021).

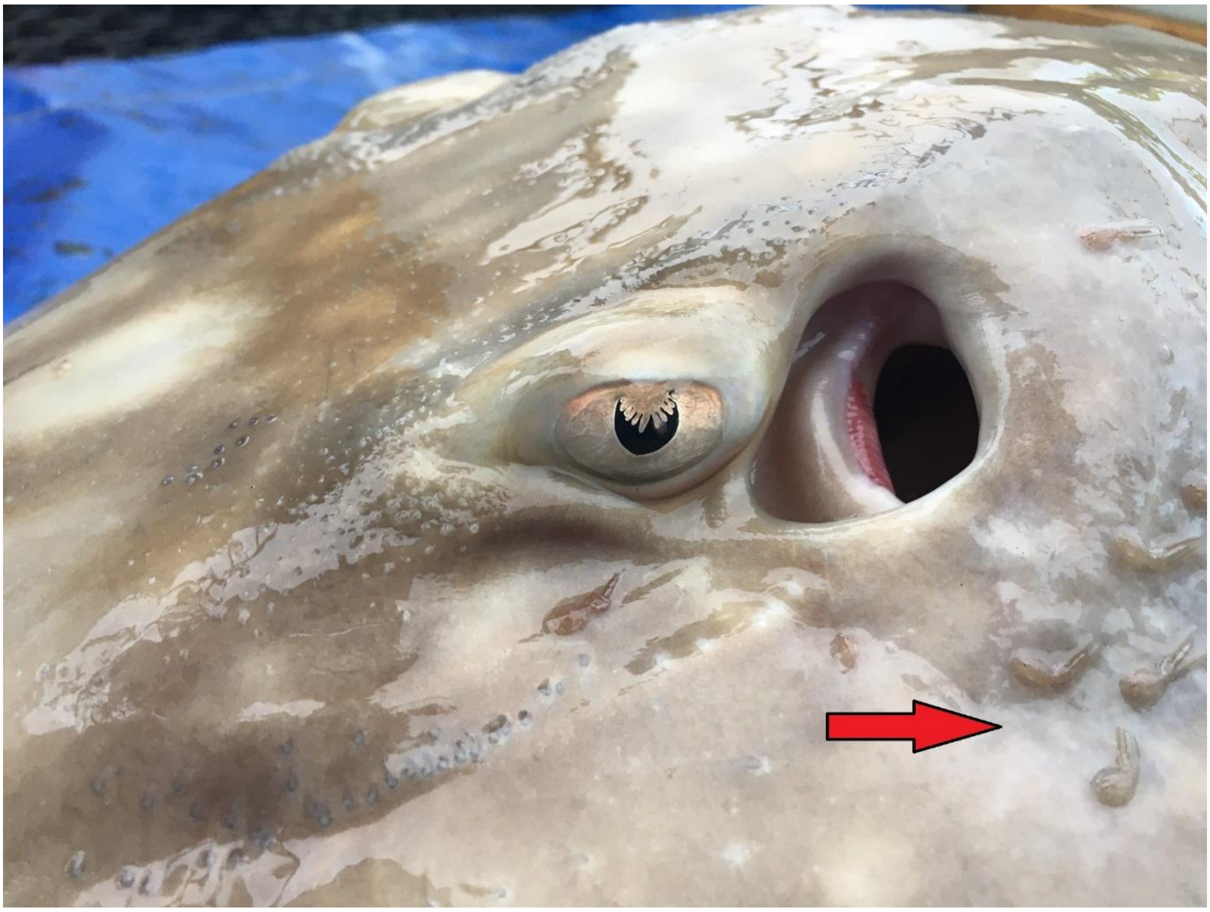

Figure 23: Lice on a flapper skate (*Dipturus intermedius*). (Daniel Wise, in. prep.)

2.8 Specific problems

The common blue skate and flapper skate can become quite large, especially the flapper skate that grows to a maximum disk diameter of 2 metres. This could present an issue later on when an individual is brought in as a juvenile. Institutions with the ambition of bringing in such an individual need to have a plan in keeping such a large skate species until death. This also counts for the maximum age of these skates: they can live up to 50 years in the wild, and possibly longer under human care in an aquarium.

Other than that, there are no known specific problems. New problems may come into view when a population under human care of common blue skates and flapper skates is being established.

2.9 Recommended research

Basic information on how to keep the common blue skate and flapper skate in aquaria is not available. Experiences gained will raise ex situ research questions in the future. At the moment it is useful to continue to collect and incorporate experiences about keeping other large ray and skate species in a newer version of these Best Practise Guidelines. New information from the field will have to be translated into the practical use for keeping common skates under human care in aquaria.

Section 3: References

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Appendix I: Nets and mat to catch common skates out of an enclosure

Using a net to catch and restrain a skate

Figure 24: A rubber landing net used to catch and restrain a ray or skate (Animal Handling Products Ltd., 2020c).

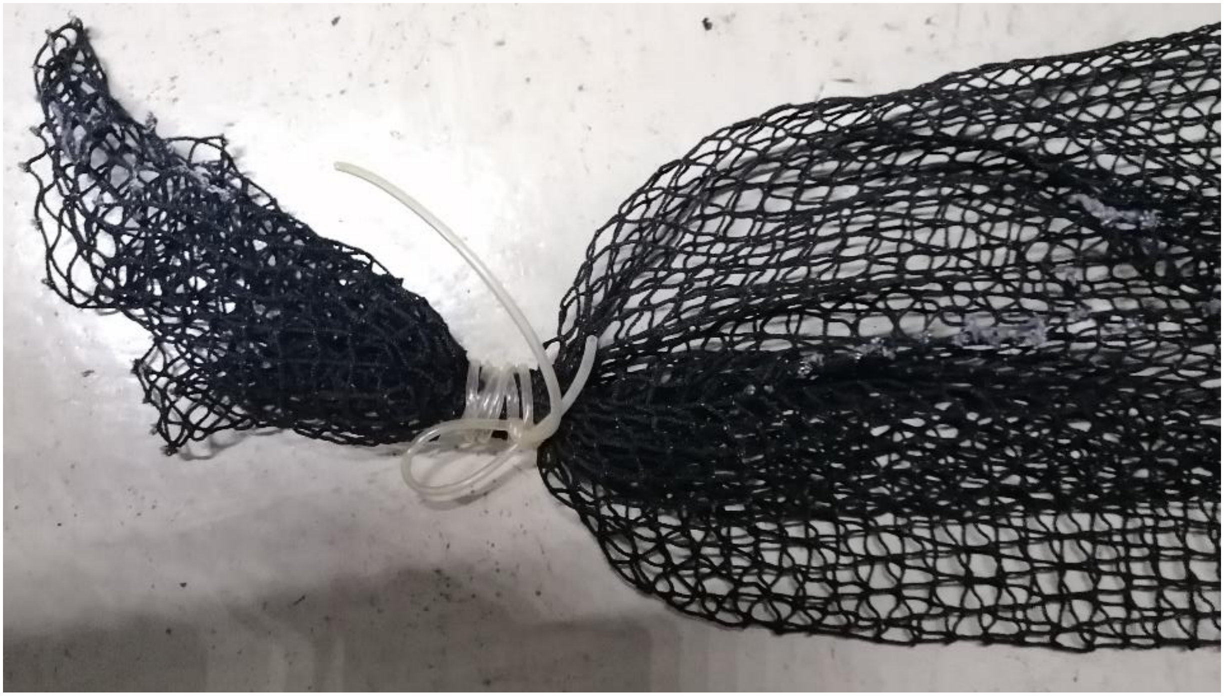

Figure 25: Technique used to open and close the end of a net with a band or tube © N. Wachters.

Using an unhooking mat for measurements

Figure 26: The measurement of a flapper skate on an unhooking mat, on a survey boat © D. Wise.

Figure 27: An unhooking mat that is owned and used by Rotterdam Zoo to lay a skate or ray on © N. Wachters.

Appendix II: Nutritional values included in the diet of the flapper skate and common blue skate

(U.S. Department of Agriculture, 2021; Brown-Vuillemin et al., 2020)

Relative importance	***70,48%***	***2,07%***			***?***
	Shrimps and prawns	**Cephalopods**			**Crayfish**
	Crangon crangon	*Sepia officinalis*	*Eledone cirrhosa*	*Loligo vulgaris*	*Palinurus elephas*
	Shrimp, 100 g	**Cuttlefish, 100 g**	**Octopus, 100 g**	**Squid, 100 g**	**Crayfish/crawfish, 100 g (spiny lobster)**
Proximates					
water	78,45 g	80,56 g	80,25 g	78,55 g	74,07 g
energy	85 kcal	79 kcal	82 kcal	92 kcal	112 kcal
nitrogen	~	~	~	~	~
protein	20,1 g	16,24 g	14,91 g	15,58 g	20,6 g
total lipid (fat)	0,51 g	0,7 g	1,04 g	1,38 g	1,51 g
total fat	~	~	~	~	~
ash	~1,23 g	1,68 g	1,6 g	~	1,39 g
Carbohydrates					
carbohydrate	0 g	0,82 g	2,2 g	3,08 g	2,43 g
Minerals					
calcium	64 mg	90 mg	53 mg	32 mg	49 mg
iron	0,52 mg	6,02 mg	5,3 mg	0,68 mg	1,22 mg
magnesium	35 mg	30 mg	30 mg	33 mg	40 mg
phosphorus	214 mg	387 mg	186 mg	221 mg	238 mg
potassium	264 mg	354 mg	350 mg	246 mg	180 mg
sodium	119 mg	372 mg	230 mg	44 mg	177 mg
zinc	1,34 mg	1,73 mg	1,68 mg	1,53 mg	5,67 mg
copper	0,391 mg	0,587 mg	0,435 mg	1,861 mg	0,381 mg
manganese	0,033 mg	0,11 mg	0,025 mg	~	0,015 mg
selenium	~	44,8 µg	44,8 µg	44,8 µg	46,2 µg

Vitamins and other components					
vitamin C, total ascorbic acid	~	5,3 mg	5 mg	4,7 mg	1,2 mg
thiamine	~	0,009 mg	0,03 mg	0,02 mg	0,007 mg
riboflavin	~	0,91 mg	0,04 mg	0,412 mg	0,046 mg
niacin	~	1,216 mg	2,1 mg	2,175 mg	4,245 mg
pantothenic acid	~	0,5 mg	0,5 mg		0,35 mg
vitamin B-6	~	0,15 mg	0,36 mg	0,056 mg	0,15 mg
folate, total	~	16 µg	16 µg	5 µg	37 µg
folic acid	~	0 µg	0 µg	0 µg	0 µg
choline, total	~	~	65 mg	65 mg	80,9 mg
vitamin B-12	~	3 µg	20 µg	1,3 µg	3,5 µg
vitamin A, RAE	~	113 µg	45 µg	10 µg	5 µg
vitamin A, IU	~	375 IU	~	~	17 IU
vitamin E (alpha-tocopherol)	~	~	1,2 mg	1,2 mg	2,85 mg
retinol	~	113 µg	45 µg	10 µg	5 µg
carotene, beta	~	~	0 µg	0 µg	0 µg
carotene, alpha	~	~	0 µg	0 µg	0 µg
tocopherol, beta	~	~	~	~	~
tocopherol, gamma	~	~	~	~	~
tocopherol, delta	~	~	~	~	~
tocotrienol, alpha	~	~	~	~	~
tocotrienol, beta	~	~	~	~	~
tocotrienol, gamma	~	~	~	~	~
tocotrienol, delta	~	~	~	~	~
vitamin D (D2 + D3), International Units	~	~	0 IU	~	0 IU

vitamin D (D2 + D3)	~	~	0 µg	0 µg	0 µg
vitamin D3 (cholecalciferol)	~	~	0 µg	~	0 µg
vitamin K (phylloquinone)	~	~	0,1 µg	0 µg	0,1 µg
Lipids					
fatty acids, total saturated	0,101 g	0,118 g	0,227 g	0,358 g	0,237 g
fatty acids, total monounsaturated	0,086 g	0,081 g	0,162 g	0,107 g	0,275 g
fatty acids, total polyunsaturated	0,152 g	0,134 g	0,239 g	0,524 g	0,59 g
fatty acids, total trans	0,004 g	~	~	~	~
fatty acids, total transmonoenoic	0,003 g	~	~	~	~
fatty acids, total transdienoic	0,001 g	~	~	~	~
cholesterol	161 mg	112 mg	48 mg	233 mg	70 mg

Relative importance	*15,35%*					
	Teleosts					
	Hippoglossoides platessoides	*Melanogrammus aeglefinus*	*Clupea harengus*	*Gadiculus argenteus*	*Scomber scombrus / Trachurus trachurus*	*Micromesistius poutassou*
	Plaice/sole, 100 g	**Haddock, 100 g**	**Herring, 100 g**	**Pout, 100 g**	**Mackerel, 100 g**	**Blue whiting, 100 g**
Proximates						
water	84,63 g	83,4 g	72,05 g	81,36 g	63,55 g	80,27 g
energy	70 kcal	69 kcal	158 kcal	79 kcal	205 kcal	90 kcal
nitrogen	~	2,61 g	~	~	~	~
protein	12,41 g	16,3 g	17,96 g	16,64 g	18,6 g	18,31 g
total lipid (fat)	1,93 g	0,45 g	9,04 g	0,91 g	13,89 g	1,31 g
total fat	~	0,32 g	~	~	~	~
ash	1,22 g	1,28 g	~	1,13 g	1,35 g	1,3 g
Carbohydrates						
carbohydrate	0 g	0 g	0 g	0 g	0 g	0 g
Minerals						
calcium	21 mg	11 mg	57 mg	10 mg	12 mg	48 mg
iron	0,18 mg	0,17 mg	1,1 mg	0,28 mg	1,63 mg	0,34 mg
magnesium	18 mg	21,1 mg	32 mg	13 mg	76 mg	21 mg
phosphorus	252 mg	227 mg	236 mg	200 mg	217 mg	222 mg
potassium	160 mg	286 mg	327 mg	400 mg	314 mg	249 mg
sodium	296 mg	213 mg	90 mg	61 mg	90 mg	72 mg
zinc	0,32 mg	0,32 mg	0,99 mg	1,03 mg	0,63 mg	0,88 mg
copper	0,019 mg	0,021 mg	0,092 mg	0,032 mg	0,073 mg	0,031 mg

manganese	0,014 mg	0,011 mg	~	0,015 mg	0,015 mg	0,104 mg
selenium	26,6 µg	25,9 µg	36,5 µg	36,5 µg	44,1 µg	31,1 µg
Vitamins and other components						
vitamin C, total ascorbic acid	0 mg	0 mg	0,7 mg	0 mg	0,4 mg	0 mg
thiamin	0,022 mg	0,02 mg	0,092 mg	0,08 mg	0,176 mg	0,056 mg
riboflavin	0,02 mg	0,057 mg	0,233 mg	0,06 mg	0,312 mg	0,046 mg
niacin	1,04 mg	3,36 mg	3,217 mg	2,1 mg	9,08 mg	1,3 mg
pantothenic acid	0,185 mg	0,403 mg	~	0,15 mg	0,856 mg	0,216 mg
vitamin B-6	0,098 mg	0,281 mg	0,302 mg	0,24 mg	0,399 mg	0,156 mg
folate, total	5 µg	12 µg	10 µg	7 µg	1 µg	13 µg
folic acid	0 µg	0 µg	0 µg	0 µg	0 µg	0 µg
choline, total	65 mg	65 mg	65 mg	~	65 mg	65 mg
vitamin B-12	1,13 µg	1,83 µg	13,67 µg	0,9 µg	8,71 µg	2,3 µg
vitamin A, RAE	10 µg	~	28 µg	12 µg	50 µg	30 µg
vitamin A, IU	33 IU	~	~	40 IU	167 IU	100 IU
vitamin E (alpha-tocopherol)	0,63 mg	0,45 mg	1,07 mg	~	1,52 mg	0,3 mg
retinol	10 µg	~	28 µg	12 µg	50 µg	30 µg
carotene, beta	0 µg	0 µg	0 µg	~	0 µg	0 µg
carotene, alpha	0 µg	0 µg	0 µg	~	0 µg	0 µg
tocopherol, beta	0,01 mg	0 mg	~	~	~	~
tocopherol, gamma	0,01 mg	0 mg	~	~	~	~
tocopherol, delta	0,26 mg	0 mg	~	~	~	~
tocotrienol, alpha	0 mg	0 mg	~	~	~	~
tocotrienol, beta	0 mg	0 mg	~	~	~	~
tocotrienol, gamma	0 mg	0 mg	~	~	~	~
tocotrienol, delta	0 mg	0 mg	~	~	~	~

vitamin D (D2 + D3), International Units	113 IU	18 IU	~	~	643 IU	57 IU
vitamin D (D2 + D3)	2,8 µg	0,5 µg	4,2 µg	~	16,1 µg	1,4 µg
vitamin D3 (cholecalciferol)	2,8 µg	0,5 µg	~	~	16,1 µg	1,4 µg
vitamin K (phylloquinone)	0,1 µg	~	0,1 µg	~	5 µg	0,1 µg
Lipids						
fatty acids, total saturated	0,441 g	0,093 g	2,04 g	0,32 g	3,257 g	0,247 g
fatty acids, total monounsaturated	0,535 g	0,057 g	3,736 g	0,329 g	5,456 g	0,279 g
fatty acids, total polyunsaturated	0,374 g	0,163 g	2,133 g	0,032 g	3,35 g	0,422 g
fatty acids, total trans	0,011 g	0,004 g	~	~	~	~
fatty acids, total transmonoenoic	0,01 g	0,003 g	~	~	~	~
fatty acids, total transdienoic	0,001 g	0,001 g	~	~	~	~
cholesterol	45 mg	54 mg	60 mg	52 mg	70 mg	67 mg