A review of size limits for the Queensland Sea Cucumber Fishery (East Coast)

Report to the Queensland Department of Agriculture and Fisheries

Paul McShane and Ian Knuckey

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fishwell CONSULTING

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Fishwell Consulting Contact Details

Name: Ian Knuckey
Address: 27 Hesse St
Queenscliff, VIC, 3224
Phone: 03 5258 4399
Email: ian@fishwell.com.au
Web: www.fishwell.com.au

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EXECUTIVE SUMMARY

A review of literature relevant to the setting of biologically-meaningful size limits for the Queensland sea cucumber fishery (east coast) (QSCF) is presented. The main species evaluated were Black Teatfish (*Holothuria whitmaei*), White Teatfish (*H. fuscogilva*), Prickly Redfish (*Thelenota ananas*), Curryfish (*Stichopus herrmanni*), Blackfish (*Actinopyga palauensis*) and Burrowing Blackfish (*A. spinea*). These species constitute most of the annual catch (~90%) from the QSCF. Information is also presented on minor species including Elephant's Trunkfish (*H. fuscopunctata*) and Sandfish (*H. scabra*).

A general lack of recent or reliable growth, mortality and fecundity information for most species prevented robust quantitative evaluation (e.g., egg-per-recruit or spawning potential ratio or spawning-per-recruit methods) of the degree of protection that may be conferred by size limits. For sea cucumber, such length-based methods are further compromised by the highly variable weight and length of individual live sea cucumbers in relatively short periods of time (minutes). Our relatively simple approach therefore, was to compare the previous Queensland size limits for these species against size limits applied in other fishery jurisdictions and published information on size at maturity and weight.

Generally, the species-specific size limits previously applied in the QSCF are considerably larger than the species' size at maturity and the size limits applied in other fisheries. Not only does this make the QSCF size limits relatively precautionary from a biological perspective, the high prices paid for large individuals relative to small individuals will also confer some economic benefits.

For Blackfish (*A. palauensis*) and Burrowing Blackfish (*A. spinea*), a species that accounts for more than half the annual catch of the QSCF, there is no reliable information on size at maturity. We therefore recommend obtaining information on size at maturity and reproductive potential as a priority need for sustainable management of these sea cucumbers.

More generally, the enforcement of size limits is problematic because sea cucumbers can change shape or shrink after harvest. The application of size limits in the QSCF, would complement other regulatory measures (catch limits, rotational harvests) that are evidently assisting in the recovery of previously-depleted populations.

Background

Sea cucumbers (Family Holothuridae) are sedentary bottom-dwelling animals readily harvested by hand in shallow water by divers (Kinch et al. 2008, Skewes et al. 2010, Anderson et al. 2011, Friedman et al. 2011, Purcell et al. 2013, Lane and Limbong 2015). Potential over-exploitation of sea cucumbers is enhanced by their accessibility and the high value of some species particularly in Hong Kong and Chinese markets (Purcell et al. 2018). Of the many species of sea cucumbers fished commercially, Teatfish (*Holothuria* spp.) are highly valued on export markets and serial depletion of these sea cucumbers is wide spread in the Indo-Pacific region (Purcell 2010, Friedman et al. 2011, Purcell et al. 2013) including in Australian waters (Eriksson and Byrne 2015, Wolfe and Byrne 2022).

The Queensland sea cucumber fishery (east coast) (QSCF) harvests ten IUCN-listed species and two species listed under the Convention on International Trade in Endangered Species of wild fauna and flora (CITES). The CITES-listed species are the Black Teatfish (*Holothuria whitmaei*) and the White Teatfish (*H. fuscogilva*). A requirement as an approved Wildlife Trade Operation (WTO) is that the Queensland government must certify that the commercial harvest of Black and White Teatfish is non-detrimental to their survival. Accordingly, the Queensland government (through its Department of Agriculture and Fisheries) applies conservative measures including limited entry (18 licence holders with ~ 30 divers) and a harvest strategy with species-specific total allowable catches (TACs) and rotational spatial harvests (Plaganyi et al. 2015, DAF 2021a).

Although a memorandum of understanding (MOU) between QSCF licence holders and the Queensland Department of Agriculture and Fisheries (DAF) specified voluntary minimum size limits for each species of sea cucumber harvested in the fishery, the current harvest strategy for the QSCF does not include size limits (DAF 2021b). Condition 7 of Part 13A of the approved Wildlife Trade Operation (WTO) declaration for the Queensland sea cucumber Fishery (DAWE 2021) states that

"*The Queensland Department of Agriculture and Fisheries must:*

a) Undertake desktop research on the main sea cucumber species harvested in the fishery to determine biologically meaningful minimum size limits. Investigations should consider key biological parameters, for example, size at maturity. Findings of this research should be published on the Queensland Department of Agriculture and Fisheries website before the commencement of the 2022-23 fishing season.

b) Work with industry to undertake fieldwork within the fishery to determine appropriate ways to implement the minimum size limits determined through 6a. This may include the development of appropriate conversion factors to account for changes in size resulting from processing. Findings of this research should be published on the Queensland Department of Agriculture and Fisheries website before the commencement of the 2023--24 fishing season.

c) *Implement minimum size limits based on work completed in 6a and 6b prior to the 2024-25 fishing season. Implementation of minimum size limits should be described in the Queensland Department of Agriculture and Fisheries application for the next Wildlife Trade Operation for this fishery.* "

The available information relevant to the setting of biologically-meaningful size limits for the QSCF is reviewed here to meet the requirements of Condition 7a (above).

The report focusses on the five main species that currently account for about 90% of the QSCF catch (DAF 2021a):

- Burrowing Blackfish (*Actinopyga spinea*);
- Blackfish (*A. palauensis*);
- White Teatfish (*H. fuscogilva*);
- Prickly Redfish (*Thelenota ananas*); and,
- Curryfish (*Stichopus herrmanni*).

We also include information on Black Teatfish (*Holothuria whitmaei*), which was a major historical component of the catch and other minor QSCF species for which there are data relevant to size limits evaluation including Elephant's Trunkfish (*H. fuscopunctata*) and Sandfish (*H. scabra*).

Size limits in Sea Cucumber fisheries

Size limits in fishery management function to provide sufficient reproductive potential in harvested populations while retaining an economically-viable yield (allowing a harvest of individuals at their optimal growth potential). Size limits have been strongly advocated as a regulatory measure for sea cucumber fisheries (FAO 2012) even though they are not widely applied (Purcell et al. 2013). In most cases, size limits apply to the length of live individuals (Kinch et al. 2008).

Where applicable in sea cucumber fisheries, size limits are nominally based on the size at sexual maturity (Kinch et al. 2008, Purcell 2010, Eriksson et al. 2013). Sexual maturity is defined as the length at which the gonads of 50% of individuals are undergoing gametogenesis during the reproductive season (Conand 1993). However, the biological basis for establishing size limits for sea cucumber fisheries is generally weak (Purcell et al. 2013, Eriksson et al. 2015, Wolfe and Byrne 2022). This reflects a lack of relevant biological information particularly on early life history, growth and mortality (Purcell et al. 2013).

Most fisheries for sea cucumbers (66%) do not apply size limits (Purcell et al. 2013). Where applicable, size limits can vary considerably among fisheries including within Australia (Table 1). For example, size limits applicable to Prickly Redfish range from 25 cm (Papua New Guinea) to 50 cm (QSCF MOU) (Table 1). Voluntary size limits had previously been applied to sea cucumbers harvested in the QSCF (DAF 2021a). Other than the main species presented above, size limits had been applied to Redfish (*Actinopyga echinites*), Surf Redfish (*A. mauritiana*), Black Lollyfish (*H. atra*), Greenfish (*S. chloronotus*), Brown Sandfish (*Bohadschia vitiensis*), Leopardfish (*B. argus*) and Amberfish (*T. anax*) (Table 1). These latter species are harvested in the QSCF but only in very small quantities (DAF 2021a).

Table 1. Size limits applied in sea cucumber fisheries. Data are live length (cm) for QSCF (DAF 2021a) and all other fisheries (Kinch et al. 2008). n/a = not applicable.

Species	Queensland (MOU)	Northern Territory	Western Australia	Torres Strait	New Caledonia	PNG
Black Teatfish	30	26	26	25	n/a	22
White Teatfish	40	32	32	32	35	35
Prickly Redfish	50	30	30	35	45	25
Blackfish	20	n/a	n/a	n/a	n/a	n/a
Burrowing Blackfish	20	n/a	n/a	22	n/a	n/a
Curryfish	35	n/a	n/a	15 (vastus) 31 (herrmranni	35	25
Sandfish	20	16	16	18	20	22
Elephant's Trunkfish	40	n/a	n/a	24	n/a	45
Redfish	20	12	12	20	n/a	25
Surf Redfish	25	n/a	n/a	22	25	20
Black Lollyfish	20	15	15	15	n/a	30
Greenfish	20	n/a	n/a	n/a	n/a	20
Brown Sandfish	25	n/a	n/a	25	n/a	20
Leopardfish	35	n/a	n/a	30	n/a	20
Amberfish	50	n/a	n/a	n/a	n/a	20

Reproductive Biology

Most of the available information on the reproductive biology of sea cucumbers relevant to the evaluation of biologically-meaningful size limits comes from the studies of Conand (1981, 1993) on populations from New Caledonia. These studies reveal interspecific differences in biology particularly in size at maturity and in fecundity.

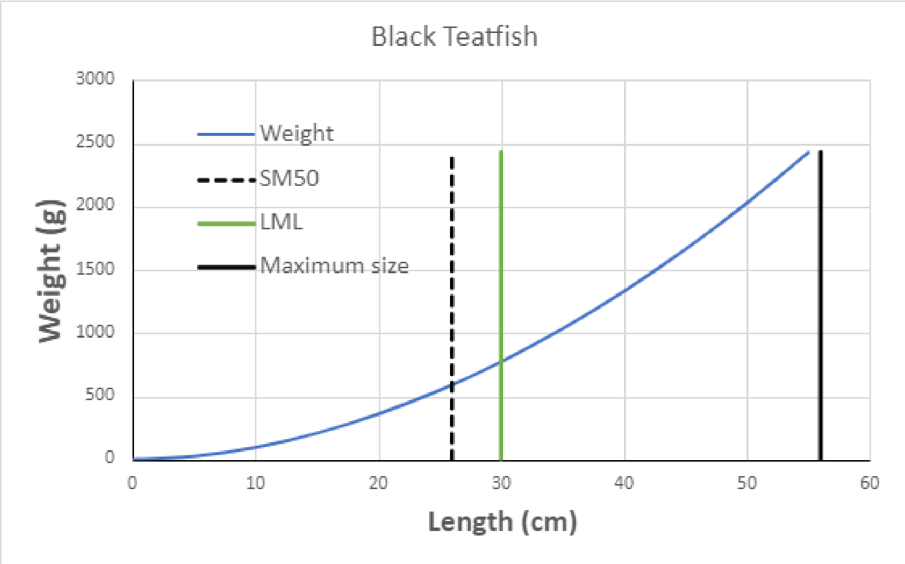
In general, sea cucumbers are dioecious broadcast spawners with males and females in equal proportions (Conand 1993). They usually spawn in summer months (Conand 1993) but some, including Black Teatfish, spawn during winter (Purcell 2010). Other sea cucumbers, including Sandfish, can spawn several times a year (Purcell 2010). Asexual reproduction can occur in sea cucumbers but not in the species currently under consideration in the QSCF (Uthicke and Benzie 2000b). The reduction of population density by fishing can threaten reproductive viability (Babcock et al. 1991, Mercier and Hamel 2009, Purcell et al. 2013, Eriksson and Byrne 2015): hence the need to conserve sufficient reproductive potential in harvested populations of sea cucumbers.

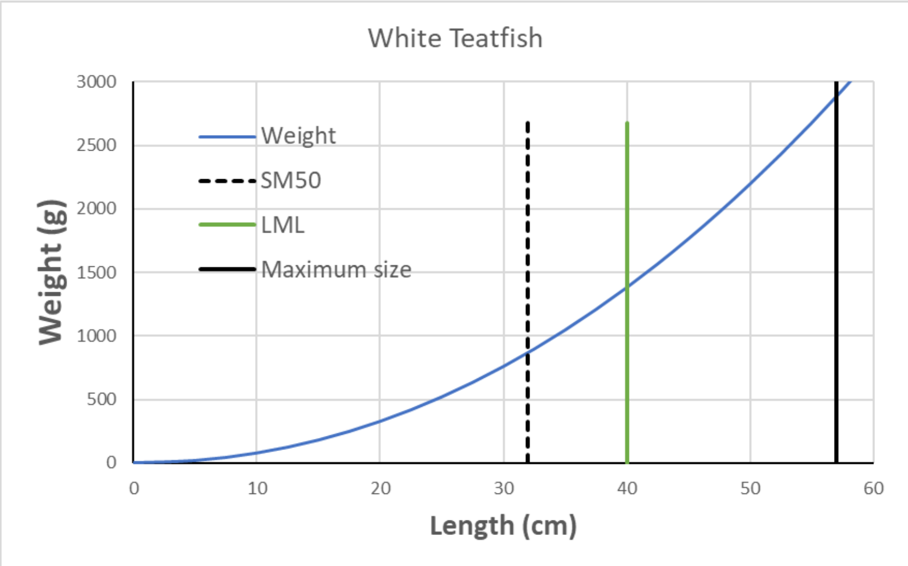
Table 2. Relevant biological information in relation to current size limits applicable to the QSCF.

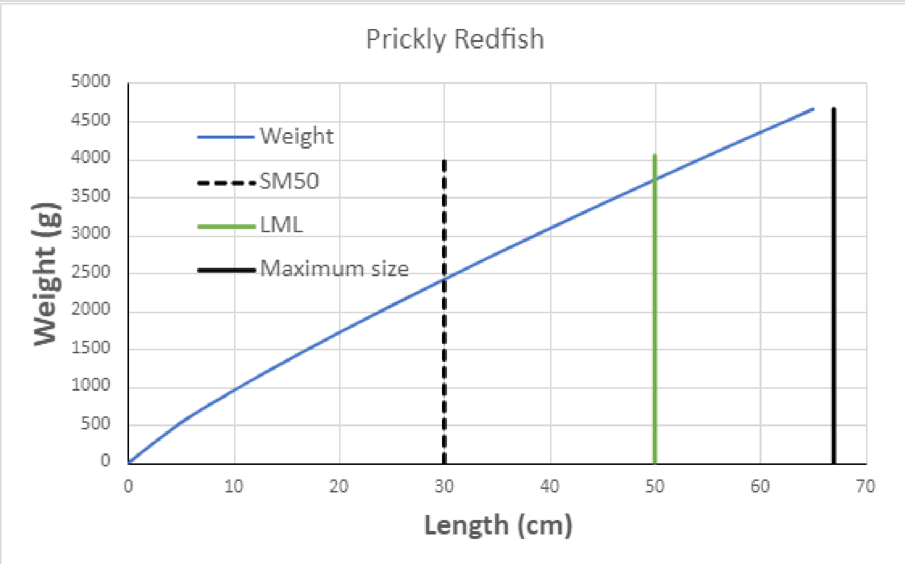
Species	MOU Size Limit (length cm)	Size at sexual maturity (length cm)	Weight at sexual maturity (drained weight/total weight g)	Fecundity (millions of eggs/spawning)	Maximum length (cm)/Age (years)
Black Teatfish	30	26.0[1]	580/800[1]	13.0 -78.5[5]	56[1]/> 10[5]
White Teatfish	40[3]	32.0[1]	900/1,175[1]	6.0 – 14.2[1]	57[1]/no data
Prickly Redfish	50[3]	30.0[2]	1,150/1,230[1]	2.2 – 7.8[1]	67[1]/no data
Blackfish	20	No data	No data	No data	40[6]no data
Burrowing Blackfish	20[3]	No data	No data	No data	38/6[4]
Curryfish	35[3]	27	450/560[1]	7.2 – 12.6[1]	57[1]/no data
Sandfish	20	16	140/185	9.2-17.3[1]	39[1]/no data
Elephant's Trunkfish	40	35	870/1,220	0.3-13.2[1]	76[1]/no data

1. Conand (1993)
2. Conand (1981)
3. DAF (2021a)
4. Wolfe and Byrne (2022)
5. Uthicke and Benzie (2002)
6. Purcell et al. (2012)

The available information, suggests that the size limits previously applied as voluntary measures in the QSCF were above the size at sexual maturity for all main species (Figure 1). In contrast, to Prickly Redfish there is relatively little difference between the size at sexual maturity and size limits applied for Black Teatfish (Table1, Figure 1). There is no such information for Blackfish or for Burrowing Blackfish (a species which accounts for more than half of the annual catch in the QSCF). However, previously applied voluntary size limits were well below the estimated maximum size for these two species (Figure 2). Where data are available, size limits applied in sea cucumber fisheries (Table 1) are well below maximum size, particularly for Elephant's Trunkfish (maximum size 76 cm) (Figure 1). Furthermore, given the lack of length at age data and growth data more generally (Uthicke et al. 2004, Purcell et al. 2013, Wolfe and Byrne 2017, 2022; Purcell et al. 2018), it is difficult to evaluate the degree of protection (i.e., years of egg production before harvest). Where information is available, fecundity of species harvested in the QSCF is generally high (millions of eggs) but varies within (particularly with size) and among species (Conand 1993) (Table 2). Of the species in the QSCF, Black Teatfish are particularly fecund with up to 78 million eggs released during spawning (Table 2). However, it is possible that growth of Black Teatfish may be relatively slow and this species may mature later than other species (Uthicke and Benzie 2002, Uthicke et al. 2004).


Black Teatfish
Weight
SM50
LML
Maximum size
Weight (g)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
Length (cm)


White Teatfish
Weight
SM50
LML
Maximum size
Weight (g)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
Length (cm)


Prickly Redfish
Weight
SM50
LML
Maximum size
Weight (g)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
Length (cm)

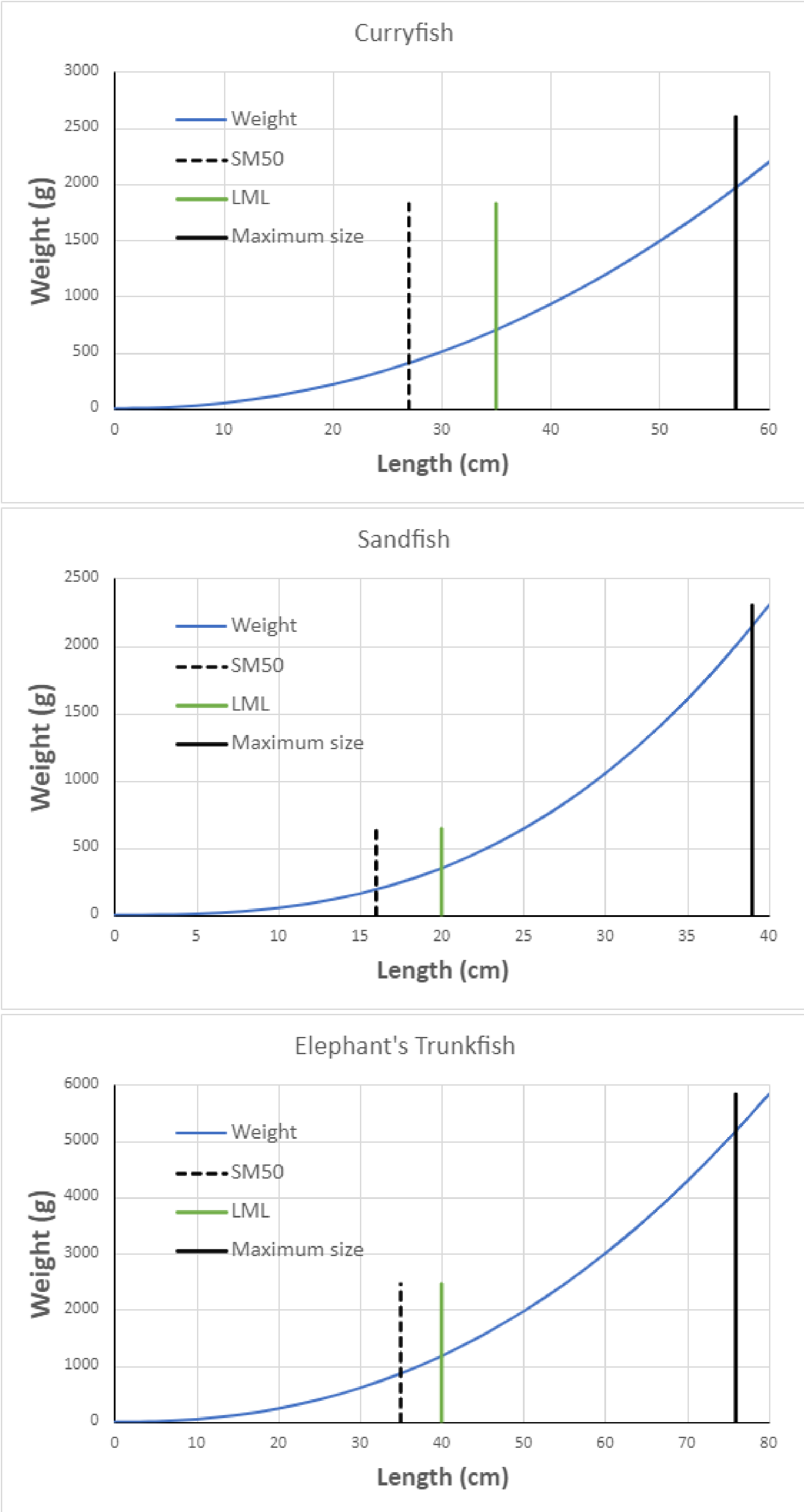


Figure 1. Length-weight relationships for sea cucumbers harvested in the QSCF overlaid by size at maturity (SM 50, vertical black dashed line), previous QSCF voluntary size limits (LML, vertical green lines) and estimated maximum size (vertical black line).

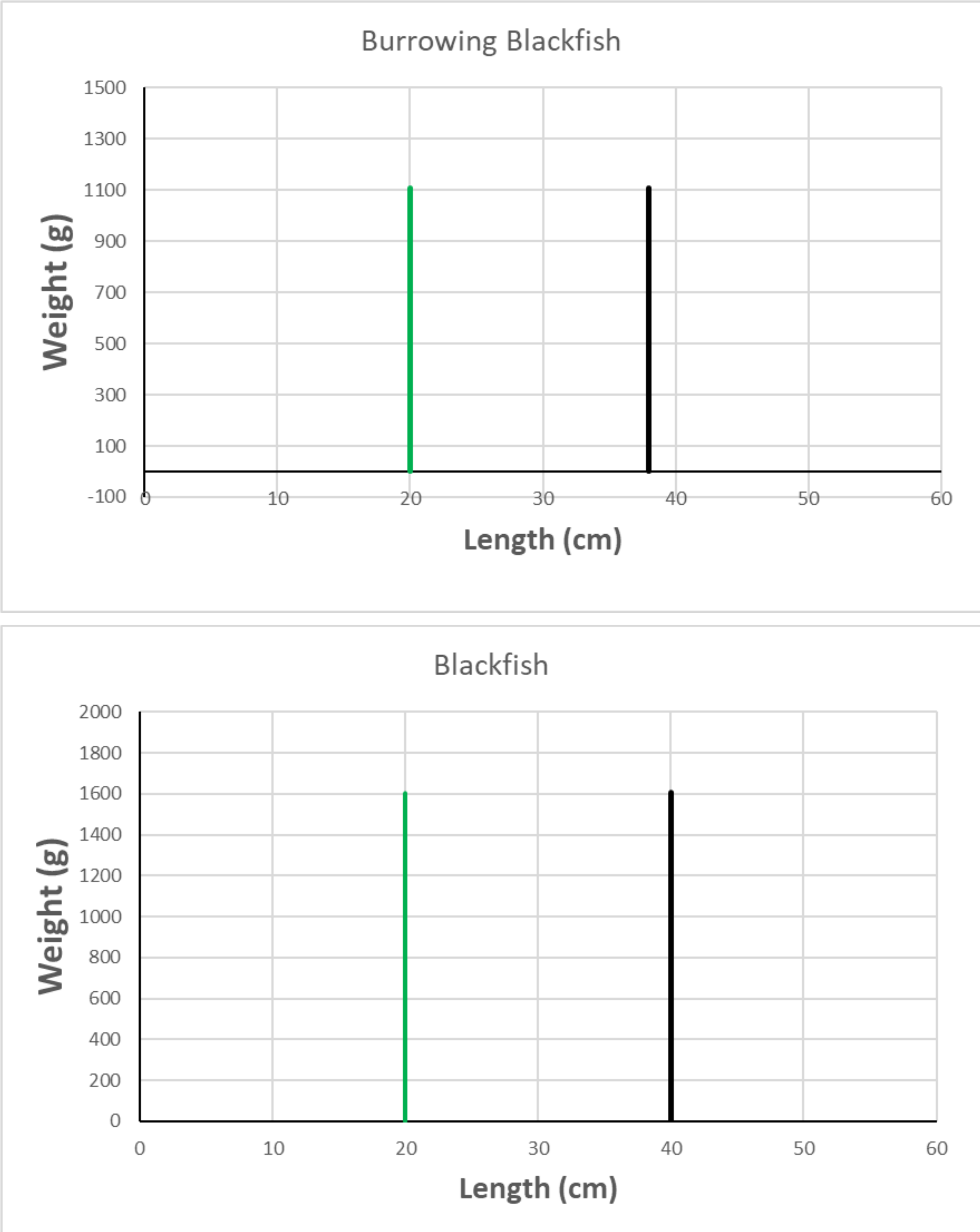


Figure 2. Previous QSCF voluntary size limits (vertical green lines) and estimated maximum length (vertical black line). Length-weight relationships and size at maturity were not available for these two species.

Fishery Management Issues

A legal minimum size (LMS) above which sea cucumbers can be harvested is a protective measure to ensure viable reproductive populations (Plaganyi et al. 2015) but there are problems in applying size limits in sea cucumber fisheries (Kinch et al. 2008, Purcell 2010). Sea cucumbers can often contract to a spherical shape when captured making accurate measurement of length difficult after harvest and potentially unenforceable (Purcell 2010). Furthermore, sea cucumbers can shrink in size depending on environmental factors (Purcell et al. 2016, Ram et al. 2016). Such a change in shape is less pronounced in Sandfish and Curryfish (Purcell 2010). Even so, because sea cucumbers in the QSCF are hand-harvested by divers, individuals of particular species may be readily gauged in their natural state by the diver. How well the natural length measured underwater by a diver corresponds to the length measure later by a compliance officer when the catch is onboard a vessel it yet to be determined and warrants further investigation. Size limits based on weight rather than length (see Table 2) overcome shape change but this may present other compliance problems (Purcell 2010), potentially due to changing levels of water retention over time.

Importantly, there is a strong price incentive to harvest large individuals (much greater than the species-specific LMS) (Purcell et al. 2018). For example, for White Teatfish, the price per individual increases exponentially with length (Purcell et al. 2018). However, fecundity also increases with length (Conand 1993) raising concerns about serial depletion of large individuals in the QSCF (Eriksson et al. 2013, Wolfe and Byrne 2017).

Biologically meaningful size limits for the QSCF

It is generally recommended that size limits should be enforced in sea cucumber fisheries (FAO 2012). At a minimum, it would be expected that a biologically appropriate size limit should be greater than the size at maturity to ensure a portion of the population can reproduce regardless of fishing intensity. This was the case for all of the previous QSCF voluntary size limits. As such, it is appropriate that these size limits could be reintroduced as part of the future harvest strategy. Concerns over the viability of some populations particularly Teatfish (*Holothuria whitmaei* and *H. fuscogilva*) suggest conservative size limits are warranted (Wolfe and Byrne 2022). The White Teatfish size limit of 40cm is well above (8cm) the stated size at sexual maturity of 32cm. The 30 cm size limit for Black teatfish on the other hand, is only 4 cm above the stated size at maturity of 26cm and, given the history of overfishing, may warrant consideration of a larger size limit in the future, even though the current TAC is extremely precautionary. Decisions on biologically meaningful size limits in the QSCF will depend on the best available information on the reproductive potential of applicable species (growth, size at maturity, fecundity), enforceability, and economic yield. Accordingly, commercial fishers, scientists and enforcement personnel should all be involved in determining species-specific size limits. However, size limits are only one of a suite of management controls applied to ensure sustainable population outcomes for the QSCF. The QSCF harvest strategy also has species-specific catch limits (TACs) and a rotational harvest strategy to ensure sustainable fishing of stocks of sea cucumbers (DAF 2021b). Existing management measures are already proving effective with evidence of recovery of previously depleted sea cucumber populations (Knuckey et al. 2022). Notably, the previously applied QSCF MOU size limits are more precautionary than those applied to the same species harvested in any other fishery.

Comparison of size limits to size at maturity is a relatively simple qualitative method of assessing whether they are biologically appropriate. To quantitatively evaluate the potential biological value of size limits with respect to relative reproductive potential, further research on growth rates, mortality, and size/age-based fecundity is required for nearly all species other than Black Teatfish, for which a fully quantitative assessment has been completed (Helidoniotis 2021). For Blackfish and, particularly, Burrowing Blackfish, there are no data on size at maturity, so precautionary size limits should apply (e.g., 25 cm). Size limits do not apply to these species in any other sea cucumber fishery.

Notwithstanding the biological value afforded by precautionary size limits, there is a considerable price premium for comparatively larger sea cucumbers. For a given TAC, industry seeks to maximise economic returns from the harvest of each species and as such, may target animals well above the size limit. The balance between TACs and size limits needs to be quantitatively evaluated to understand the impact of targeted fishing towards the larger, more fecund animals.

CONCLUSIONS

Information relevant to the setting of conservative legal minimum sizes (LMS) for the main species of sea cucumbers harvested in the QSCF is relatively scant compared with many other Australian fisheries. This is a particular issue for Burrowing Blackfish, which currently accounts for more than half the QSCF annual catch. However, where information on size at maturity was available, the previous voluntary size limits were greater than the size at maturity. Despite our concerns regarding the potential problems of sea cucumber size limits with respect to compliance, we recommend that the previous size limits would be biologically suitable for re-introduction into a future harvest strategy as a minimum, recognising that there is a suite of other management controls already in place. Such QSCF size limits would be greater than species-specific size limits currently applied in other sea cucumber fisheries. The final decisions on species-specific QSCF size limits should involve fishers, scientists, managers and enforcement personnel.

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