Supply risk of bait in Australia's Southern Rock Lobster Fishery

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Abstract

Bait is an often-overlooked component in studies addressing operational and ecological risks in commercial fishing. One of the most valued fisheries in Australia, the Southern Rock Lobster Fishery, lacks detailed information on bait use, which is relevant to both assessing ecological interactions of the fishery and also concerns around future supply. We conducted a survey to determine what species are predominantly being used as bait, assessed these species' sustainability status, and explored any risks around future supply. We found that fishers preferred a limited number of bait species and that some were being sourced from fisheries with an 'unknown' sustainability status and many fishers were concerned about future supply. Insecurity of existing supply means that other bait options need to be explored. Ongoing monitoring of species being used for bait would assist any future third party sustainability accreditation.

Keywords: *Jasus edwardsii*; fisheries; bait; risk perception; fisheries

1. Introduction

The commercial Southern Rock Lobster (*Jasus edwardsii*) fishery is economically one of the most valuable wild capture fisheries in the Australian States of Tasmania (TAS), Victoria (VIC), and South Australia (SA), with a smaller commercial fishery also occurring in Western Australia (WA; McGarvey et al. 2014; Linnane et al. 2015). Southern Rock Lobster are almost exclusively exported overseas (mostly to China) and marketed as a luxury food item (Plagányi et al., 2018). As traceability becomes an important demand in many export markets, many fisheries are seeking to increase their competitive advantage by marketing the high environmental standards that exist in Australia. For example, in WA the west coast rock lobster fishery became the first fishery to be certified as ecologically sustainable by the Marine Stewardship Council (MSC) (Caputi et al., 2018; MSC, 2014). Consequently, this has prompted other fisheries in Australia to consider pursing third party certification. However, these generally require bait to managed to the same criteria as the target species and be sourced from well-managed fisheries (e.g. MSC, 2014). Problems with meeting this criteria include that bait species are often undocumented and can be sourced from different fisheries, with different stock status. Aside from certification, fishers are also concerned that supply may reduce in the future, which would increase cost for the fishing industry.

In SA, bait (combined with ice) constitutes approximately 6.5% of the variable cost per pot lift, and in TAS bait makes up 4% of the total costs per boat per year (McGarvey et al., 2014). While not comprising an overly large proportion of total fishing costs, access to suitable bait is fundamental to the viability and success of these fisheries. Notwithstanding studies on bait efficiency or food subsidies (e.g. Saila et al. 2002; Harnish and Willison 2009; Waddington and Meeuwig 2009) it is surprising that given the seminal role that bait plays it is an often-overlooked component in studies of commercial fishing, particularly as it pertains to assessing operational and social characteristics (but see Farmery et al. 2014).

This study had three objectives: (1) to document current bait species used, (2) to assess each bait species' sustainability status, current quota allocation and landings and (3) to investigate risk to future bait supply. To achieve these objectives, we surveyed commercial Southern Rock Lobster fishers across four Australian states (WA, SA, VIC, TAS) plus interviewed major bait suppliers.

2. Materials and methods

Surveys of active commercial rock lobster fishers were conducted at industry meetings between March – May 2018 (see Supplemental Material S1 for survey questions). We also elicited the expert opinion (via informal, unstructured, interviews) with major bait processors and suppliers to the Southern Rock Lobster Fishery. The stock status of each bait species was collated from each of the relevant jurisdictions where the bait was sourced from. Differences in fishers' rating of bait use by volume vs. preference was analysed via non-parametric Mann-Whitney *U*-tests. A chi-square goodness of fit test (χ^2) was used to determine whether the frequency of responses was homogeneous for fishers' level of concern regarding bait supply – that is whether they rated their level of concern as 'not at all concerned', 'somewhat concerned', or 'very concerned'.

Results

Overall, 66 individual fishers were surveyed across TAS (n = 29), VIC (n = 27), SA (n = 5), and WA (n = 5). As there were too few respondents from SA and WA for statistical analysis, formal analyses are only presented for all states combined, and for TAS and VIC separately. Descriptive statistics are presented for each state.

Fishers reported using a total of thirteen bait taxa (Table 1) but reported preference for Blue Mackerel and Jack Mackerel (*Scomber australiasicus* and *Trachurus spp.*), Australian Salmon (*Arripis spp.*), and Barracouta (*Thyrsites atun*). Much of the bait most important to the fishery was sourced from New Zealand, other than Australian Salmon (NZ; Table 1). Bait use by volume did not differ from fisher's preference for the entire Australian fishery (Mann-Whitney U-test = 16911, p = 0.79), TAS (Mann-Whitney U-test = 2731.51, p = 0.78), or VIC (Mann-Whitney U-test = 2874, p = 0.63) showing that at present there was no supply driven effects on bait usage.

The stock status of many of the preferred bait species used in the Southern Rock Lobster Fishery is not available through formal reporting so was classified as unknown, particularly those from NZ (Table1). Australian Salmon and some stock assessment areas for Blue Mackerel, Jack Mackerel and Barracouta from NZ are classified as sustainable (Table 1). Bait species were not ubiquitous across the fishery with some species only reported from one or two states. For example, Australian Sardines were only reported from WA and VIC while frames of flathead species (i.e. waste from scalefish fisheries) were only reported from TAS and VIC. An introduced freshwater species, European Carp (*Cyprinus carpio*), was a commonly bait species in VIC and SA (Table 1). Fishers also reported using various by-catch for bait, as well as alternative bait types of terrestrial origin (Supplemental Table S1). Interestingly, some fishers from TAS and VIC reported using mutton bird (*Puffinus* *tenuirostris*) or tuna (unspecified species) as bait, while also acknowledging that the use of some of these taxa (i.e. mutton bird) are illegal. None of the bait species reported are currently assessed under MSC, but a few are in scope (Table 1).

Most (40-75%) fishers felt that the quality of bait has remained stable. When asked to rate their level of concern regarding the risk of bait supply, a significantly greater number of fishers responded that they were '*somewhat concerned'* about the future risk of bait supply (Fig. 1). This pattern was consistent for all states combined ($\chi^2_2 = 27$, $p < 0.001$) as well as for TAS ($\chi^2_2 = 11$, $p < 0.001$) and VIC ($\chi^2_2 = 24$, $p < 0.001$) (Fig. 1). Although few responses were received from SA and WA, half of the ten fishers surveys in these states combined were either *'somewhat concerned'* or *'very concerned'* about the future risk of bait supply. Despite concern over bait supply, the majority of fishers stated that they have not considered using alternative baits to this point (combined: 51.7%; n = 58, TAS: 52%; n = 25, VIC: 52.2%; n = 23, SA: 60%; n = 5, WA: 40%; n = 5).

Lobster buyers / processors also tend to be suppliers of bait and interviews confirmed that Blue Mackerel, Jack Mackerel, Australian Salmon, and Barracouta are the preferred bait types in the Southern Rock Lobster Fishery contributing roughly 90% of bait used (M. Blake, South Australian Lobster Company, *pers. comm.).* A major supplier of Australian Salmon, indicated that they could not keep up with the demand from the Australian bait market (C. Papageorge, Account Manager of United Fisheries LTD in NZ, *pers. comm.*), and MD Pty Ltd, a major seafood processor and bait supplier on King Island, TAS indicated that they are very concerned about the future supply of bait. A common theme of discussions with bait suppliers was the increasing prevalence of competition from other markets, namely the human consumption market, for fish species that have been traditionally used as bait. For example, it was noted that much of the Blue Mackerel catch is landed for human consumption markets which has driven bait prices up (M. Blake *pers. comm.*). Others expressed concern that the price of bait may increase further as human consumption demand rises, particularly from developing countries (G. Long, CEO of Frank Mason & Associates, *pers. comm*).

In New Zealand total catch for Jack Mackerel, Blue Mackerel, Barracouta, and Kahawai (Australian Salmon) in the 2018 fishing season were all near the current total allowable commercial catch (TACC) (Table 2a). However, in Australia's small pelagic fishery, in which the key target species are Australian Sardine, Blue Mackerel, Jack Mackerel and Redbait, there are large stocks that license holders are not fishing. Combined, 48,900 t of quota was allocated for the 2017/18 season, but only ~12% (5,713 t) was landed, which amounts to an additional 42,187 t of catch left in the water (Table 2b). Australian Salmon are currently classified as sustainable, and across all jurisdictions there are no set TACCs (Stewart et al., 2015). Historically, commercial landings were quite high as this species used to be directed to human consumption with canneries located across southern Australia. However, total commercial landings have markedly declined due to the closure of these canneries and there is only the residual bait market left. Due to the high cost of catching salmon it is also not anticipated that effort will be increased (S. Richey AM, Managing Director of Richey Fishing Co. and Chairman of the Australian Maritime Safety Authority, *pers. comm.)*

Discussion

Bait is an often-overlooked component in assessments of commercial fishing (Farmery et al., 2014), but is of critical importance to the viability of fishing operations. Little information was available previously on bait usage in the Southern Rock Lobster Fishery despite concerns on future risk in supply and the need for bait information for third party certification. Most commercial fishers have some level of concern regarding the future risk of bait supply and that a number of the popular bait species are being sourced from fisheries with an unknown sustainability status.

The stock status of each bait species is an important consideration for determining the risk of supply to the bait market. While none of the more preferred bait types (Blue Mackerel, Jack Mackerel, Australian Salmon, or Barracouta) are classified as overfished, Blue Mackerel, Jack Mackerel, and a large portion of the Barracouta stocks in NZ are classified as 'unknown'. Australian Salmon is classified as sustainable; however, the supply of salmon is currently limited due to the lack of dedicated harvesters (S. Richey, CEO of Richey Fishing Co., *pers. comm.*) rather than stock status (Stewart et al., 2015). Blue Mackerel and Jack Mackerel stocks in Australia are sustainable but the large stocks and total allowable catches are barely fished because of public resistance and lack of market demand. As a result, these Australian stocks contribute little to the Southern Rock Lobster bait supply compared with New Zealand. The unknown status of some of major bait sources is a potential problem for any third-party certification and may warrant change in bait source or extra research effort in the future. Many of the species appear to be underutilised, such as the Australian small pelagics where catch is only around 10% of the total allowable catch, which is already set at very low conservative levels (Ward and Grammer, 2015). So, the issue here is not one around risk to future supply, but rather risk of poor documentation of stock status of bait affecting the ability to certify and market Southern Rock Lobster as sustainable.

Risk of future bait supply is not only around availability of stock but also around the dynamics of supply which can be affected by politics and business dynamics, For example, sustainable harvesting of small pelagics in Australia was blocked by politics rather than science (Tracey et al., 2013) and catches of Australian salmon in Tasmania have declined to less than 10% of levels a decade ago despite exceptionally high stock abundance (Moore et al., 2018). For this reason, it could be useful to have alternate options for bait sources, or at least considered. A number of viable options exist to address this issue and will be further expanded on below: (1) the development of markets to utilise bait sources that would otherwise go to waste, (2) the use of waste from the control of the invasive European Carp (*Cyprinus carpio*), and (3) trials of artificial baits.

Fish waste management can have a large impact on the environment (Arvanitoyannis and Kassaveti, 2008) and is already being utilised by fishers to some extent with frames of many species and imported Barracouta heads from New Zealand. A challenge in finding further marine waste sources suitable for bait is that wild scalefish demand and landings are in steep decline in Australia due to competition from the rapid increase in production of farmed Atlantic Salmon (Ogier et al., 2018). Atlantic Salmon waste is difficult to access for bait due to biosecurity management (Crawford, 2003).

European Carp (*C. carpio*) is an introduced freshwater species that adversely affects the health of Australia’s native rivers and wetlands. Carp stocks are estimated to be around 500,000 tonnes (http://www.frdc.com.au/Media-and-Publications/FISH/FISH-Vol-25-1/Carp-clean-up-campaign-on-the-cards) and could provide therefore provide a bait source for the Southern Rock Lobster fishery, however supply is limited by the marginal profitability of the commercial fishers given current demand for bait and thus price (Carlin and Morison, 2018). There are plans to reduce carp stocks using a viral disease, *koi herpesvirus* (KHV) which may affect future availability for bait (http://www.carp.gov.au/).

The market dynamics between the low price for bait, expected increases in demand from the human consumption market, the falling demand because of stock rebuilding, and the perceived investment risk due to political and public opposition to commercial harvesting of fish indicate that the risk issues surrounding bait are much more nuanced that just the negligible risk of running out fish. As such, other alternatives to fish bait need to be considered such as artificial baits. Artificial (or synthetic) baits have been developed that mimic molecules released from fish dispersed at a controlled rate from a soluble mix (Dellinger et al., 2016). The authors reported that this synthetic bait reliably caught stone crab, blue crab, and American lobster in field trials. Another study in WA using three artificial bait types was less successful with catch rates substantially lower than natural fish (Caputi et al., 2001). Further development appears needed but the fact that some catch occurred is encouraging.

To better understand trends in bait use across the Southern Rock Lobster Fishery, a formal reporting scheme or periodic survey similar to the western rock lobster fishery in WA may be warranted. For example, the western rock lobster fishery is required to report on the amounts, and types, of bait used (Bellchambers et al., 2017). While on-board observes recording a sub-sample of bait could be one way of addressing this issue, a more thorough approach would be the implementation of formal bait usage reporting as a part of commercial fishers' daily logbook requirements. This could be helpful if the Southern Rock Lobster Fishery were to seek third-party sustainability accreditation.

Future bait demand is expected to decrease in the future as all states involved in fishing for Southern Rock Lobster are in the process of stock rebuilding. This implies higher catch rates in the future and therefore fewer potlifts. For example, in 2010 the Western Rock Lobster Fishery in WA changed their management targets from achieving maximum sustainable yield (MSY) to maximum economic yield (MEY) which then led to a process of stock rebuilding (Caputi et al., 2015). Since 2010, Western Rock Lobster catch rates have been steadily increasing while effort has simultaneously decreased (Caputi et al., 2018, 2015). This same pattern is expected to happen in TAS, VIC, and SA as stocks rebuild, and with the average reported amount of bait used as 1 kg per potlift (Gardner et al., 2015) this may reduce the number of potlifts and as such bait demand by as much as 30%.

While fishers are concerned about the risk of future bait supply, the cause of change is complex and appear unrelated to the status of stocks of bait species. This is apparent in the high abundance of stocks like Australian small pelagics and European carp that are barely harvested. Potential causes for future bait scarcity are complex and include reduce waste frames and fish heads as catch of wild scalefish declines due to falling demand through competition with farmed Atlantic salmon. Political uncertainty also affects the willingness of firms to invest in harvesting bait. Bait production is a business reliant on high volume due to the low price which means there are a small number of suppliers which creates risk and volatility in supply. The fact that stocks of suitable bait species exist in high abundance means that supply will likely continue, however there is risk of interruptions in supply, increase in price, and a possible need to shift to less preferred bait types.

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References

Arvanitoyannis, I.S., Kassaveti, A., 2008. Fish industry waste: treatments, environmental impacts, current and potential uses. Int. J. Food Sci. Technol. 43, 726–745. https://doi.org/10.1111/j.1365-2621.2006.01513.x

Bellchambers, L.M., How, J., Evans, S., Pember, M., Lestang, S, D., Caputi, N., 2017. Ecological Assessment Report: Western Rock Lobster Resource of Western Australia Fisheries Research Report No. 279, Department of Fisheries, Western Australia. 92pp.

Brown, L.D., Cai, T., DasGupta, A., 2001. Interval estimation for a binomial proportion. Stat. Sci. 16, 101–117.

Caputi, N., de Lestang, S., How, J., Trinnie, F., Fletcher, W. (Rick), 2018. Ecosystem-based fisheries management (or 'triple bottom line') assessments of the western rock lobster resource: is there an optimal target for fishing? Mar. Policy 94, 264–274. https://doi.org/10.1016/j.marpol.2018.05.015

Caputi, N., de Lestang, S., Reid, C., Hesp, A., How, J., 2015. Maximum economic yield of the western rock lobster fishery of Western Australia after moving from effort to quota control. Mar. Policy 51, 452–464. https://doi.org/10.1016/j.marpol.2014.10.006

Caputi, N., Stevens, R., Christianopoulos, D., McCoy, D., 2001. Off-season trial of artificial rock lobster baits. FRDC Project No. 99/372. 15pp.

Carlin, L., Morison, J., 2018. Economic and Social Indicators for the Lakes and Coorong Fishery 2016/17. PIRSA Fisheries and Aquaculture. EconSearch. https://www.bdo.com.au/getmedia/186c6a81-e51d-432b-9b5f-87aaad32465b/Lakes_and_Coorong_Final_180716.pdf.aspx.

Crawford, C., 2003. Environmental management of marine aquaculture in Tasmania, Australia. Aquaculture 226, 129–138. https://doi.org/10.1016/S0044-8486(03)00473-3

Dellinger, A., Plotkin, J., Duncan, B., Robertson, L., Brady, T., Kepley, C., 2016. A synthetic crustacean bait to stem forage fish depletion. Glob. Ecol. Conserv. 7, 238–244. https://doi.org/10.1016/j.gecco.2016.07.001

Farmery, A., Gardner, C., Green, B.S., Jennings, S., 2014. Managing fisheries for environmental performance: the effects of marine resource decision-making on the footprint of seafood. J. Clean. Prod. 64, 368–376. https://doi.org/10.1016/j.jclepro.2013.10.016

Gardner, C., Hartmann, K., Punt, A.E., Jennings, S., 2015. In pursuit of maximum economic yield in an ITQ managed lobster fishery. Fish. Res. 161, 285–292. https://doi.org/10.1016/j.fishres.2014.08.015

Harnish, L., Willison, J.H.M., 2009. Efficiency of bait usage in the Nova Scotia lobster fishery: a first look. J. Clean. Prod. 17, 345–347. https://doi.org/10.1016/j.jclepro.2008.08.005

Linnane, A., Gardner, C., Reilly, D., How, J., 2015. Southern rock lobster Jasus edwardsii, in: Stewardson, C., Andrews, J., Ashby, C., Haddon, M., Hartmann, K., Hone, P., Horvat, P., Mayfield, S., Roelofs, A., Sainsbury, K., Saunders, T., Stewart, J., Stobutzki, I., Wise, B. (Eds.), Status of Australian Fish Stocks Reports 2016. Fisheries Research and Development Corporation, Canberra.

Maloney, L., Liggins, G., Andrews, J., Emery, T., 2015. Tiger flathead Platycephalus richardsoni, in: Stewardson, C., Andrews, J., Ashby, C., Haddon, M., Hartmann, K., Hone, P., Horvat, P., Mayfield, S., Roelofs, A., Sainsbury, K., Saunders, T., Stewart, J., Stobutzki, I., Wise, B. (Eds.), Status of Australian Fish Stocks Reports 2016. Fisheries Research and Development Corporation, Canberra.

McGarvey, R., Punt, A.E., Gardner, C., Feenstra, J., Hartmann, K., Hoshino, E., Burch, P., Paterson, S., Matthews, J.M., Linnane, A., Rippin, L., Morison, J., 2014. Bioeconomic decision support tools for Southern Rock Lobster. Report to the Australian Seafood Cooperative Research Centre. Project No. 2009/714.20.

Moore, B., Lyle, J., Hartmann, K., 2018. Tasmanian scalefish fishery assessment 2016/17. Institute for Marine and Antarctic Studies, Hobart.

MPI, 2017. Fisheries Assessment Plenary, May 2017: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries. Wellington, New Zealand. Wellington, New Zealand.

MSC, 2014. Marine Stewardship Council MSC Fisheries Standard and Guidance. Version 2.0, 1st October, 2014 314pp.

Ogier, E., Gardner, C., Hartmann, K., Hoshino, E., Leon, R., Lyle, J., Mundy, C., 2018. Economic and Social Assessment of Tasmanian Fisheries 2016 / 17. Institute for Marine and Antarctic Studies, Hobart.

Patterson, H., Larcombe, J., Nicol, S., Curtotti, R., 2018. Fishery status reports 2018. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra. CC BY 4.0.

Plagányi, É.E., McGarvey, R., Gardner, C., Caputi, N., Dennis, D., de Lestang, S., Hartmann, K., Liggins, G., Linnane, A., Ingrid, E., Arlidge, B., Green, B., Villanueva, C., 2018. Overview, opportunities and outlook for Australian spiny lobster fisheries. Rev. Fish Biol. Fish. 28, 57–87. https://doi.org/10.1007/s11160-017-9493-y

Saila, S.B., Nixon, S.W., Oviatt, C.A., 2002. Does lobster trap bait influence the Maine inshore trap fishery? North Am. J. Fish. Manag. 22, 602–605. https://doi.org/10.1577/1548-8675(2002)022<0602

Stewart, J., Fowler, A., Andrews, J., Lyle, J., Smith, K., Emery, T., 2015. Australian salmons Arripis trutta, Arripis truttaceus, in: Stewardson, C., Andrews, J., Ashby, C., Haddon, M., Hartmann, K., Hone, P., Horvat, P., Mayfield, S., Roelofs, A., Sainsbury, K., Saunders, T., Stewart, J., Stobutzki, I., Wise, B. (Eds.), Status of Australian Fish Stocks Reports 2016. Fisheries Research and Development Corporation, Canberra.

Tracey, S., Buxton, C., Gardner, C., Green, B., Hartmann, K., Haward, M., Jabour, J., Lyle, J., McDonald, J., 2013. Super trawler scuppered in Australian fisheries management reform. Fisheries 38, 345–350. https://doi.org/10.1080/03632415.2013.813486

Waddington, K.I., Meeuwig, J.J., 2009. Contribution of bait to lobster production in an oligotrophic marine ecosystem as determined using a mass balance model. Fish. Res. 99, 1–6. https://doi.org/10.1016/j.fishres.2009.04.002

Ward, T., Moore, A., Andrews, J., Norriss, J., Stewart, J., 2015. Australian sardine Sardinops sagax, in: Stewardson, C., Andrews, J., Ashby, C., Haddon, M., Hartmann, K., Hone, P., Horvat, P., Mayfield, S., Roelofs, A., Sainsbury, K., Saunders, T., Stewart, J., Stobutzki, I., Wise, B. (Eds.), Status of Australian Fish Stocks Reports 2016. Fisheries Research and Development Corporation, Canberra.

Ward, T.M., Grammer, G.L., 2015. Commonwealth Small Pelagic Fishery: Fishery Assessment Report 2017. Report to the Australian Fisheries Management Authority. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

SARDI Publication No. F2010/000270-9. SARDI Rese.

Table 1. Reported bait taxa used in the Southern Rock Lobster Fishery from each state by origin, type, stock status.

Species	**States**	**Origin**	**Type**	**Stock status**	**Source**	**Additional notes**
Blue mackerel (*Scomber australasicus*)	WA, SA, VIC, TAS	New Zealand	Whole	Unknown	(MPI, 2017))	No estimates of current and reference biomass, or yield, are available.
Australian Salmon (*Arripis spp.*)	WA, SA, VIC, TAS	Australia	Cutlets/Heads	Sustainable	(Stewart et al., 2015)	Both eastern and western Australia stocks are classified as sustainable.
Jack Mackerel (*Trachurus spp.*)	SA, VIC, TAS	New Zealand	Heads	Unknown	(MPI, 2017)	Assessment status is complicated by the reporting and management of three species under a single code.
Barracouta (*Thyrsites atun*)	SA, VIC, TAS	New Zealand	Heads	Sustainable/ unknown	(MPI, 2017)	Estimates of current and reference biomass are not available with the exception of stock assessment area 1. In area 1, Barracouta are rated as very likely (>90%) to be at or above the target biomass level (50%)
Kahawai (*Arripis spp.*)	WA, VIC, TAS	New Zealand	Heads	Sustainable/ unknown	(MPI, 2017)	Estimates of current and reference biomass are not available with the exception of stock assessment area 1. In area 1, Kahawai or Australian Salmon are rated as very likely (>90%) to be at or above target biomass level of 52%.
Australian Sardine (*Sardinops sagax*)	WA, VIC	Australia	Whole	Sustainable	(Ward et al., 2015)	All four separate biological stocks are rated as sustianable
Tiger Flathead (*Platycephalus richardsoni*)	TAS, VIC	Australia	Frames	Sustainable	(Maloney et al., 2015)	
European Carp (*Cyprinus carpio*)	SA, VIC	Australia	Unspecified	Introduced		Freshwater species
Atlantic salmon heads (S*almo salar*)	TAS	Australia	Heads	Farmed		Aquaculture species
Bony bream (*Nematalosa erebi*)	VIC, SA	Australia	Unspecified	Not assessed		Freshwater species
Leatherjackets (F: Monacanthidae)	VIC	Australia	Unspecified	Not assessed		
Shark heads (unspecified species)	VIC, TAS	Australia	Heads	Unspecified species		

Table 2. Current total allowable commercial catches (TACC) and landings in tonnes (t) of popular and potential bait sources.

Country	Species	TACC (t)	Landings (t)	Source
(a) New Zealand	Jack Mackerel (*Trachurus declivis*)	51,327	44,518	https://fs.fish.govt.nz/Page.aspx?pk=7&tk=100&sc=JMA
	Blue Mackerel (*Scomber austraasicus*)	11,550	11,154	https://fs.fish.govt.nz/Page.aspx?pk=7&tk=100&sc=EMA
	Barracouta (*Thyrsites atun*)	33,402	26,052	https://fs.fish.govt.nz/Page.aspx?pk=7&tk=100&sc=BAR
	Kahawai (*Arripis spp.*)	2,728	1,908	https://fs.fish.govt.nz/Page.aspx?pk=7&tk=100&sc=KAH
(b) Australia	Jack Mackerel (*Trachurus declivis*) - east	18,880	2,748	(Patterson et al., 2018)
	Jack Mackerel (*Trachurus declivis*) - west	920	0	(Patterson et al., 2018)
	Blue Mackerel (*Scomber australasicus*) - east	12,090	2,858	(Patterson et al., 2018)
	Blue Mackerel (*Scomber australasicus*) - west	3,230	0	(Patterson et al., 2018)
	Australian Sardine (*Sardinops sagax*)	9,550	97	(Patterson et al., 2018)
	Redbait (*Emmelichthys nitidus*) - east	3,410	10	(Patterson et al., 2018)
	Redbait (*Emmelichthys nitidus*) - west	820	0	(Patterson et al., 2018)

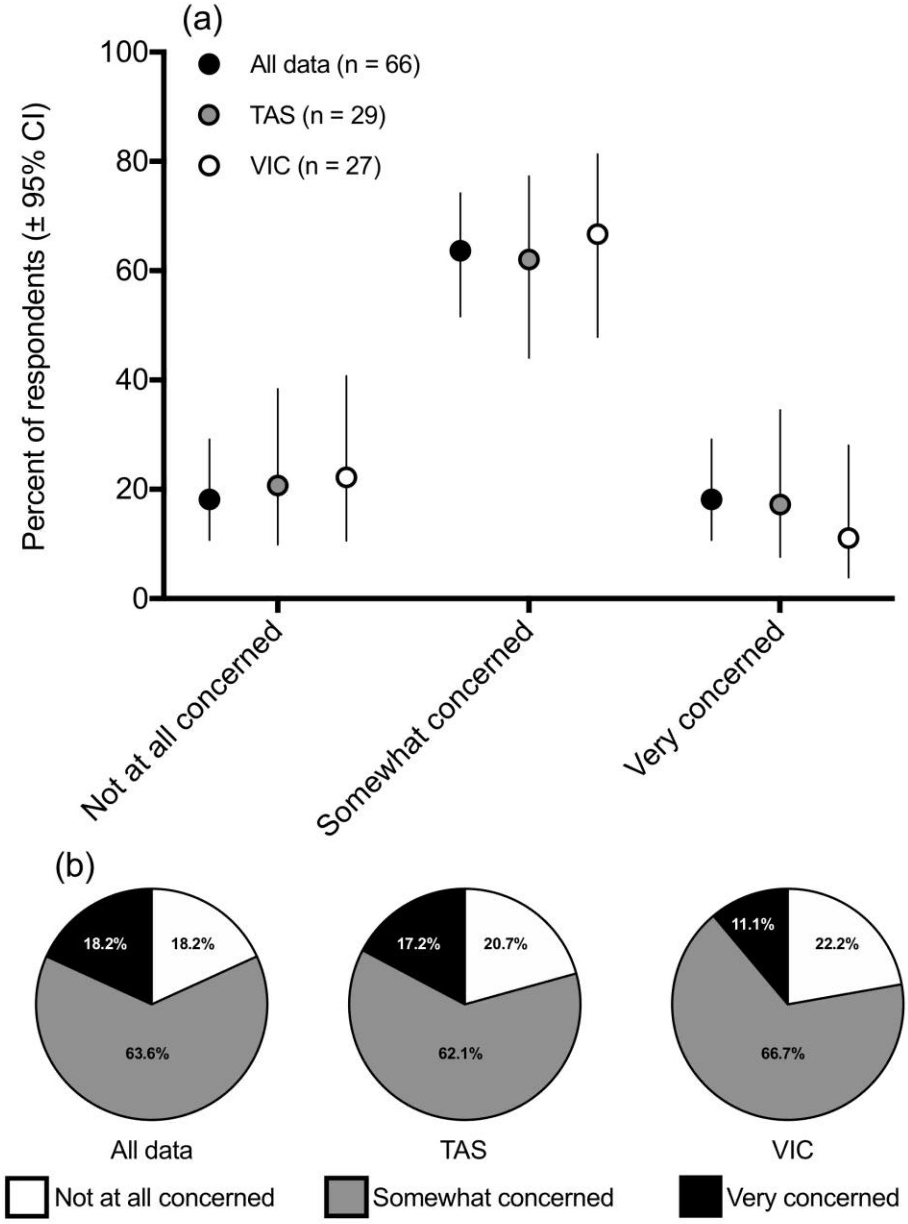

Figure 1. (a) Fishers' level of concern regarding the risk of bait supply for all data combined (*black circles*), TAS (*grey circles*) and VIC (*white circles*). Data are the mean percent of respondents and error bars reflect 95% confidence intervals computed via the hybrid Wilson/Brown method (Brown et al., 2001). (b) Raw percentage of fishers' level of concern regarding bait supply.

Supplemental material

S1. Survey questions asked to commercial Southern Rock Lobster fishers

1) What bait species do you currently use?
a) List species used by volume with the most important first.
b) List species by preference with the most important first.
2) Where do you typically source your bait from?
3) Has the overall cost of bait increased or decreased? If the cost has increased do you feel that it is a fair or unfair increase in cost?
4) Has the quality of bait increased or decreased?
5) Please rate your level of concern regarding bait supply as 'not at all concerned', 'somewhat concerned', or 'very concerned'.
6) Please list any bycatch species used as bait in order of preference, with the most important first.
7) Have you ever used, or considered using, alternate bait sources? If so what are they?
8) If you have any additional comments or concerns with regards to bait supply or cost, please provide any additional information

Table S1. Reported bycatch taxa and other alternate sources that the Southern Rock Lobster Fishery opportunistically uses for bait.

State	Species	State	Species
TAS	Barber perch (*Caesioperca rasor*)	*VIC*	Wrasse (*Notolabrus spp.*)
	Bream (*Acanthopagrus spp.*)		Rock cod (*Pseudophycis spp.*)
	Rock cod (*Pseudophycis spp.*)		Conger eel (*Conger verreauxi*)
	Conger eel (*Conger verreauxi*)		Gurnard perch (*Neosebastes scorpaenoides*)
	Gurnard perch (*Neosebastes scorpaenoides*)		Leatherjacket (*Meuschenia spp.*)
	Jackass morwong (*Nemadactylus macropterus*)		Ling (*Genypterus spp.*)
	Leatherjacket (*Meuschenia spp.*)		Octopus (unspecified species)
	Longfin pike (*Dinolestes lewini*)		Shark heads (unspecified species)
	Sharks (unspecified species)		Small local reef fish (unspecified species)
	Snapper (*Pagrus auratus*)		Snapper (*Pagrus auratus*)
	Striped trumpeter (*Latris lineata*)		Jackass morwong (*Nemadactylus macropterus*)
	Silver trevally (*Pseudocaranx dentex*)		Tuna heads (unspecified species)
	Wrasse (*Notolabrus spp.*)		Chicken parts
	Orange roughy frames (*Hoplostethus atlanticus*)	*SA*	Blue groper (*Achoerodus gouldii*)
	Cat food		Leatherjacket (*Meuschenia spp.*)
	Cow hocks		Rock cod (*Pseudophycis spp.*)
	Wallaby		Wrasse (*Notolabrus spp.*)
	Kangaroo	*WA*	Leatherjacket (*Meuschenia spp.*)
	Mutton bird		Small local reef fish (unspecified species)