Appendix P

Thorburn 2014, Supplementary information on the Occurrence of *Pristis* (Sawfish) and *Glyphis* (River Shark) Species in Doctor's Creek, Western Australia.

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SUPPLEMANTARY INFORMATION ON THE OCCURRENCE OF *PRISTIS* (SAWFISH) AND *GLYPHIS* (RIVER SHARK) SPECIES IN DOCTORS CREEK, WESTERN AUSTRALIA.

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1. INTRODUCTION

1.1 Basis of Request

In February 2014 Indo-Pacific Environmental Pty Ltd (IPE) was approached by Tidal Energy Australia (TEA) to provide expert guidance on rare elasmobranch fauna occurring in the vicinity of their proposed Tidal Power Project in Doctors Creek near Derby, Western Australia. The request was in response to addressing knowledge gaps and questions raised by the Australian Government Department of the Environment (Department) as part of the project Environmental Impact Statement (EIS) review and which related to the distribution and ecology of *Pristis* species (Sawfish) and *Glyphis garricki* (Northern River Shark) which have been reported from the proposed project area.

1.2 Relevant Subject Matter Expertise

Indo-Pacific Environmental Pty Ltd is a Western Australian based consultancy specialising in studies of fish and fisheries. Its Principal Scientist (and Director), Dean Thorburn, is one of the leading authors on research into *Pristis* and *Glyphis* species in Australia and has firsthand experience studying these species in waters of King Sound (including Doctors Creek itself) and the Fitzroy River. Studies of *Pristis* and *Glyphis* species formed a significant part of Dean's Doctor of Philosophy degree (PhD) and his involvement in research on the groups is ongoing. Relevant experience was gained through numerous projects with key outcomes including:

- Primary author on numerous reports and journal articles describing the first records of the occurrence and ecology of *Glyphis* species in Western Australia (these include the original specimens recorded from Doctors Creek) (see for example Thorburn 2006, Thorburn and Morgan 2004, 2005a, Thorburn *et al.* 2004a);
- Primary author of reports and journal articles on distribution, biology and life history aspects of *Pristis* species (see for example Thorburn 2006, Thorburn and Morgan 2005b, Thorburn *et al.* 2004b, 2007a, 2007b);
- Primary author on the most widespread survey of estuarine and riverine elasmobranchs (targeting *Pristis* and *Glyphis* spp) conducted in Australia (Thorburn *et al.* 2003);
- The establishment of a Sawfish tagging program in the Fitzroy River in 2003 in conjunction with colleagues at Murdoch University. This program continues today and remains the longest standing study of Sawfish in the world (Thorburn 2006, Whitty *et al.* 2008, Morgan *et al.* 2011); and
- The establishment of a tagging program of *Pristis pristis* in the Northern Territory which has run since 2006 and drafting and implementation of the first *Pristis pristis* specific

monitoring and management plan (see Indo-Pacific Environmental 2007, Indo-Pacific Environmental 2006-2013).

An expanded list of relevant publications and reports can be found in the Reference section of this document. The ecological information provided in these publications and reports has contributed significantly to the management of these species in Australian waters and key documents including the Draft Recovery Plan for Sawfish and River Sharks (Department of the Environment 2014). Indo-Pacific Environmental Pty Ltd has also been engaged directly by the Australian Commonwealth Government on several occasions to provide comment on their behalf on potential impacts to these species and for management guidance in relation to major projects proposed in Northern Australia.

1.3 Structure of Document

Relevant project documentation was reviewed including the Derby Tidal Power Station EIS (Aecom 2013) and the letter of response from the Department dated the 10th of February 2014 which provided comment on the EIS. Queries raised by the Department in this latter document (and additional correspondence dated 23rd May 2014) and during subsequent discussion with Aecom and TEA were also considered. Matters of concern were subsequently categorised into broader headings to be addressed within this document. These headings subsequently include:

- Historical sampling and species distribution in Doctors Creek and other areas of King Sound;
- Comparison of catch per unit effort (CPUE) from various areas of King Sound;
- Consideration of Doctors Creek as critical foraging, breeding or pupping habitat;
- Species migration, movement and potential stranding in Doctors Creek; and
- Pre- and post-development fauna surveys and potential offsets.

2. DISCUSSION

2.1 Sources of Information

Information provided herein has been attained from numerous sources including published journal articles, project reports, PhD and Master's degree theses and unpublished data held by key authors. The information has been kept relative to the currently proposed Tidal Power Project and development site at Doctors Creek itself. It aims to provide unbiased information on the presence of the species in question in waters of the proposed project area.

Sampling in Doctors Creek and other parts of King Sound has been conducted from 2002 until 2010. As no major developments or other factors that may have greatly influenced the environment present in King Sound (and thus the fauna present) have occurred in recent years the information provided herein should be considered current and relative to the species occurring in those waters at this point in time.

2.2 *Pristis* species and *Glyphis garricki* in King Sound

2.2.1 Historical sampling and species distribution in Doctors Creek and other areas of King Sound

Data collection and sampling in Doctors Creek, other areas of King Sound and the rivers entering it for *Pristis* and *Glyphis* species began in 2002 and were reported up until 2011. Dedicated sampling in King Sound for these species was initially conducted by Thorburn between 2002 and 2005 (see Thorburn 2006, Thorburn and Morgan 2004, Thorburn *et al*. 2003, 2007a, 2007b) and subsequently by Whitty between 2005 and 2009 (see Whitty 2011). Morgan *et al.* (2011) also conducted additional surveying in 2009 and 2010 however a vast majority of this was conducted within the Fitzroy River itself. In addition these latter authors also collected historical records of sawfish distributions which were obtained through the collection of rostra held in private collections for which capture location details could be ascertained.

In relation to the occurrence of *Pristis* spp. and *G. garricki* in Doctors Creek, sampling throughout King Sound and the rivers entering it between 2002 and 2010 yielded:

- A total of 17 *G. garricki* captures of which 4 were from the eastern arm of Doctors Creek. An additional two records were identified from photos taken by fishers in the Meda River in 2008 (Whitty 2011);
- A total of 173 *Pristis pristis*. Of these only three were captured in King Sound, none of which were captured in Doctors Creek itself. Furthermore, the collection of rostra

resulted in 11 records from King Sound, however, all of these were from tidal waters near the mouths of the Fitzroy and Robinson Rivers or in deeper water of King Sound;

- A total of 44 *Pristis clavata* being captured between 2002 and 2005. Of these three were captured in waters of King Sound to the south of Derby and close to the Fitzroy River mouth (Thorburn 2006). A further 55 were captured between 2005 and 2010 of which 12 were captured in King Sound, with one being from Doctors Creek itself (Whitty 2011, Morgan *et al*. 2011, Whitty pers. comm.). An additional record of a single *P. clavata* occurring in Doctors Creek was also made by Morgan *et al.* (2004); and
- No captures of *Pristis zijsron* being recorded from King Sound by these aforementioned authors. Records of the species occurrence in King Sound were only ascertained from the collection of a limited number of rostra taken from individuals captured in waters near its confluence with the Indian Ocean.

2.2.2 Comparison of catch per unit effort (CPUE) from various areas of King Sound

The figures presented in Section 2.1.1 indicate that only very low numbers of Pristids utilise waters of Doctors Creek when compared to other areas (and habitats) sampled in King Sound and the rivers entering it. Indeed, the studies outlined above indicate that riverine waters are vastly more important in providing habitat to both *P. pristis* and *P. clavata* in the area (see also Thorburn et al. 2007a and 2007b, respectively). *Pristis zijsron* has not been recorded in coastal waters of the upper King Sound. Based on these captures, Doctors Creek would be considered to represent only marginal habitat for Pristids.

Whilst three of the 10 *G. garricki* captured by Thorburn (2004, 2006) were from Doctors Creek this relatively high proportion may be explained by the fact that essentially only two areas in King Sound were sampled between 2002 and 2005 and which were sampled repeatedly (Figure 1). This was due to the environmental conditions present in King Sound and difficulties in accessing other creek systems in the area by a small boat after launching from Derby. Sample sites were either located in a small tributary in Doctors Creek (or on occasion Luggers Creek to the north) or at the mouth of another tributary approximately 20 km south of Derby. Maps identifying these locations can be found in Thorburn and Morgan 2003 (Figure 1) and Thorburn 2006 (Figure 5.1). Due to the very high flow rates and highly variable depth present in King Sound gill nets were generally set on an outgoing tide and over the low tide when water movement was reduced and nets could be fished without them being pushed over by strong flows. Sinking gill nets were either 40 or 60 m long and comprised of 150 mm and 200 mm stretched monofilament mesh of two metres depth. Gill nets were set on seven different days in Doctors Creek and four days in the area to the south of Derby with these fishing days being

distributed throughout the year. Gill nets (per 20 m) were fished for a total of 177 hours in Doctors Creek and 133 hours in the area to the south of Derby. Catch per unit effort data was subsequently calculated from gill net data for the two survey areas sampled using 100 hr^{-1} of 20 m net as the standard unit of effort. CPUE was found to be 1.13 *G. garricki* in the Doctors Creek area and 5.28 in the area to the south of Derby. It should be noted, however, that the total hours fish and CPUE calculation presented herein is based purely on the netting undertaken by Thorburn and Morgan between June 2003 and September 2004 (see Thorburn and Morgan 2003 and Thorburn 2006). This does not include the numerous hours in which Morgan set gill nets in Doctors Creek for previous studies in 2000 and 2001, such as that of *Lates calcarifer* (Morgan unpublished data, see also Morgan *et al.* 2004), and which resulted in no captures of *G. garricki* by gill net. In consideration of these additional hours in which gill nets of a similar mesh size and length were fished in Doctors Creek prior to June 2003 and that no *G. garricki* were captured, the CPUE would be significantly lower if this previous fishing effort could be accurately determined and incorporated into the calculation.

Whitty (2011) also provided CPUE data for five various areas surveyed between 2005 and 2009 and included NW King Sound, SW King Sound, SE King Sound (which incorporated both survey areas sampled by Thorburn 2006), Point Torment Area and Stokes Bay. Although a number of different gill net mesh sizes were utilised by that author in his calculations (which can lead to some size classes of *G. garricki* being excluded from capture) a vast majority of the net used was considered an appropriate size for capturing *G. garricki* in King Sound. CPUE for *G. garricki* was subsequently calculated to be 2.3, 1.1 and 0.2 per 100 hr^{-1} of 20 m net in Stokes Bay, SE King Sound and NW King Sound, respectively. Both studies therefore report lower CPUE data for the areas incorporating Doctors Creek than in other areas of King Sound.

Species catch data by Thorburn (2003a, 2006) indicated that *G. garricki* was the most abundant Carcharhinidae encountered in the turbid waters of King Sound. Whitty (2009) also found *G. garricki* to be the second most abundant Carcharhinidae after the Bull Shark (*Carcharhinus leucas*). These results lead the latter author to suggest that *G. garricki* in King Sound, 'are not as rare as currently thought'. This conclusion was also surmised by Field *et al.* (2008) during their study which investigated the distribution and abundance of *Glyphis* species (and Pristids) through collection onboard fishery observer data and targeted surveys conducted along the Northern Territory coastline.

2.2.3 Consideration of Doctors Creek as critical foraging, breeding or pupping habitat

Capture records and CPUE data outlined in the previous sections indicates that Doctors Creek does not represent what would be considered to be critical habitat for any of the species in

question. In relation to Pristids, only two *P. clavata* have been recorded from Doctors Creek itself. Studies by Thorburn (2006) and Thorburn *et al.* (2007b) resulted in the capture of *P. clavata* up to 2332 mm total length from waters to the west of Derby in King Sound. Despite this larger size, this individual and others approaching this length were found to be immature. This data, and the fact that no mature *P. clavata* have been captured in King Sound (or the rivers entering it) by the aforementioned authors or by Whitty (2011), suggests that inshore waters of King Sound are not breeding or pupping areas for *P. clavata.*

An acoustic tracking study undertaken in waters of the Pilbara and Kimberley regions of Western Australia by Stevens *et al.* (2008) indicated that *P. clavata* was found to enter the inundated canopy of mangroves at high tide and retreat from them at low tide. While this type of movement in fishes often relates to feeding habits, *P. clavata* were not observed to move much during these periods or be actively foraging within the mangrove canopies at high tide. These authors subsequently suggested that the use of mangroves at high tide may be predator avoidance behaviour. The mangrove habitat present in Doctors Creek does not appear to differ greatly from any other mangrove area in the upper reaches of King Sound. While Doctors Creek may provide some foraging area for *P. clavata,* the low numbers of individuals captured suggest it is no more important for foraging than any other. Based on the fact that *P. clavata* has been captured in much higher abundance in other areas of King Sound and in other habitats (e.g. estuarine waters of rivers), it could be suggested that Doctors Creek does not represent significant habitat for the species.

The freshwater river systems which enter King Sound (including the Fitzroy River which has been extensively sampled between 2002 and 2011) have been shown to provide vastly more important habitat for *P. pristis* than the coastal tidal creeks of King Sound such as Doctors Creek. Thorburn (2006) and Thorburn *et al.* (2007a) discuss that the rivers entering King Sound act as nurseries for *P. pristis.* Furthermore, no captures of mature *P. pristis* in the rivers or waters of King Sound were reported by these authors, or by Whitty 2011, leading them to surmise that this species leaves the rivers prior to maturity and heads offshore into deeper marine waters to breed (and subsequently pup). In consideration of this and the fact that no *P. pristis* have been captured within Doctors Creek itself between 2002 and 2010 there is no evidence to suggest breeding of *P. pristis* would occur in Doctors Creek or that it represents significant or critical habitat for the species.

CPUE data for *G. garricki* indicates that lower numbers of the species were captured in Doctors Creek than other parts of King Sound. From that end Doctors Creek cannot be considered to represent more significant habitat for this species than any other area surveyed. Studies by Thorburn (2003a, 2006), Thorburn *et al.* (2004), Whitty (2011) and Morgan *et al.* (2011) all

report and discuss that a number of the *G. garricki* captured between 2002 and 2010 were mature. In Doctors Creek, one specimen captured was found to have semi-calcified claspers (indicating the individual was maturing), another male was mature and the remainder were immature from this site. The size ranges encountered within Doctors Creek and the range in stage of maturity does not provide any evidence to suggest Doctors Creek represents a more significant breeding site for the species than any other. Considering the fact that vast areas within Doctors Creek are dry at low tide and that tidal flow and turbulence is extreme during periods of movement (i.e. it is a highly dynamic and unstable environment) it is more likely this species breeds in deeper open waters of King Sound where water turbulence would be reduced and the engagement of the male and female could be maintained.

The information provided above suggests that Doctors Creek does not represent critical or significant habitat for *P. pristis* or *P. clavata.* Furthermore, there is no evidence to suggest that Doctors Creek represents a more significant location for *G. garricki* than any other area of King Sound. Based on this information, and considering the spatial scale of the proposed project compared to King Sound, it is unlikely that a development in Doctors Creek would result in a population level effect.

2.2.4 Species migration, movement and potential stranding in Doctors Creek

Doctors Creek is a tidal coastal creek that is not fed by fresh headwaters. Water exchange is purely tidal driven (i.e. it is not a river) and therefore does not represent any pathway or corridor for fish migration. Data collected between 2002 and 2010 does not indicate that Doctors Creek represent a more significant habitat for *P. pristis*, *P. clavata* or *G. garricki* than any other area of King Sound or the rivers entering it. Indeed it could be considered marginal habitat for the two former species listed. Doctors Creek also does not appear to provide any critical habitat for any specific part of the life histories of these species. Doctors Creek likely provides some habitat for foraging, however, access to its upper reaches and inundation of the mangrove canopy is limited in duration due to the very large tide present and the fact that a large proportion of Doctors Creek is dry at low tide. Furthermore, it is unlikely that this foraging habitat differs in any significant way to that in other parts of King Sound.

The presence of *P. pristis*, *P. clavata* and *G. garricki* in King Sound indicates that they are well adapted to moving in strongly flowing turbulent water. Thorburn (2006) and Thorburn and Morgan (2004) discuss several morphological features of *G. garricki* which would assist with mobility and stability of this species in the shallow rapidly flowing waters of King Sound, including the possession of large pectoral fins and large second dorsal fin. The study by Kirby *et al.* (2009) also discussed and applied the swimming ability of *P. pristis* when designing a

fishway to overcome the barrage present near Camballin on the Fitzroy River. These authors were able to deduce that a *P. pristis* up to 1.2 metres in length would be able to navigate up a fishway with a flow rate of 1.52 m/s. It should be remembered, however, that the upstream movement of *P. pristis* in a fishway which was flowing at this speed was not relying on burst speed but rather a maintainable swimming speed which would allow *P. pristis* to navigate against a flow. Burst speeds are subsequently far greater.

The morphology of *P. pristis*, *P. clavata* and *G. garricki* and the fact that all have been recorded from confined habitats which would restrict movement (for example, within very shallow minor tidal creeks and drains or far within the mangrove canopy) indicate the ability of these species to manoeuvre in rapidly flowing waters and in and out of restricted passages. Some concern was raised by the Department in relation to these species navigating through the large sluice gates present on each of the barrages. Considering the gates on the high basin (i.e. those receiving incoming tidal water) will be open when water on either side is equal (i.e. when there is no flow) and the large size of the openings (6.5 x 10 m) it is likely that ample opportunity will exist for these species to move in and out of the basin through the sluice gates and even during periods of incoming flow.

Some comment was also made by the Department that *G. garricki* generally moves upstream on the flood tide and downstream on the ebb tide. As such potential disruption to the movement of *G. garricki* was raised in relation to the proposed regime for opening and closing the sluice gates. As outlined in the EIS the sluice gates on the high basin will be open when water on both sides is equal and left open on the incoming tide. *Glyphis garricki* which enter the basin on the incoming tide may therefore become trapped in the high basin when the sluice gates are closed on the outgoing tide. As these individuals may subsequently remain in the high basin for an extended period (i.e. throughout multiple tidal cycles) some potential for the high basin to act as a mortality sink was expressed. As discussed above, however, *G. garricki* has the ability to manoeuvre in rapidly flowing water. The extended period for which the sluice gates are open means there is therefore opportunity for them to exit the basin at some point. Furthermore, the proposed design and regime for opening and closing the sluice gates means that the high basin will permanently maintain a very large volume of water even throughout the corresponding low tide. As stated in the EIS, the post-construction low tide depth of the high basin (i.e. the minimum depth it will attain) is predicted to be mean sea level. This is in contrast to the natural low tide water level in Doctors Creek which is estimated at five metres below (-5m) mean sea level. Considering the fact that a very large of volume of water will be maintained in the high basin at all times and all parts of the tidal cycle, the potential stranding of *G. garricki* in retreating waters is unlikely as is the likelihood of the high basin becoming a mortality sink.

To facilitate movement of *G. garricki* in and out of the basins, design modifications can be made to the sluice gates to create areas of slower moving water. Such modifications are extensively used in fishways to facilitate movement against flow. Furthermore there may be an option to incorporate additional openings in the barrage walls to provide more access points for fish to move between the basins and King Sound and to maintain the alignment of fish movement with the incoming and outgoing tides.

2.2.5 Pre- and post-development fauna surveys and potential offsets

Pre-development surveying in waters of the proposed tidal power development may provide additional data on the utilisation of Doctors Creek by *Pristis* spp. and *G. garricki* and which will build on the current data set. As relatively few accounts of *G. garricki* are known to science any information gathered will aid in furthering an understanding of this species biology and ecology. Surveys should incorporate sampling by gill net and line fishing with detailed records of fishing effort maintained for the calculation of CPUE to provide some measure of relative abundance. Size and sex data should also be collected for any captured individuals in order to provide further indication of size at maturity for males which can be determined externally by inspection of the claspers. Furthermore, traditional tagging (with cattle style or straw tags) may provide some population and growth data through recaptures of tagged individuals should they occur.

While dedicated pre-construction gill net and baited line surveys may provide some limited data on *Pristis* spp. and *G. garricki* for comparison to post-construction surveys, such surveys are only likely to result in the capture of very low numbers of individuals in Doctors Creek. It is therefore unlikely that sufficient data for statistical comparison to post-construction surveys would be attained such as that required for a BACI based monitoring program. An alternative to this would be the collection of abundance data on other fish species co-occurring in Doctors Creek and measurement of relevant habitat characters. This community or habitat type based assessment takes into account a broad range of ecological conditions and assumes that if these factors remain stable over time (such as between pre- and post-construction) then it is likely that conditions remain suitable for a species of concern (in this case *Pristis* spp. and *G. garricki*).

Acoustic tagging and tracking studies may also be an appropriate way to determine movement of these species within Doctors Creek and throughout King Sound, however, the establish of an array of receivers in Doctors Creek prior to any development would be challenging. This is due to the fact that the very high flow rates and variation in water level would make it difficult to

establish stable moorings upon which to install receivers. While the attachment of receivers to mangroves or a pylon driven into a shallower area where the flow may be reduced may be an option, the receiver is likely to be out of the water for large parts of the day and therefore its effectiveness far reduced. Furthermore, the use of acoustic listening stations may be hindered by the turbidity present in Doctors Creek, which greatly affects the distance over which a transmission can be received. Nevertheless strategically placed infrastructure may provide an indication of how individuals utilise Doctors Creek over a period of time. Post-construction monitoring by this method would be more achievable as infrastructure such as the sluice gates and levee walls would provide a stable platform upon which to attach acoustic receivers. Monitoring during this period may provide information on whether tagged individuals are navigating through sluice gates and indeed exiting the basins, and may provide information on species behaviour in response to modified flow regimes. This data would subsequently be highly valued when designing infrastructure and mitigation strategies for other future developments in northern Australian waters and may guide any future design modifications for the currently proposed tidal power station.

While population studies of Australian Pristids have been recently undertaken (see Phillips *et al.* 2008, Phillips *et al.* 2011, Phillips 2012), pre and post-construction monitoring associated with a development in Doctors Creek would provide an opportunity to collect tissue samples for genetic analysis in broader population studies. This is particularly relevant to *G. garricki* upon which there have been no population studies to date (Department of the Environment 2014). It should be noted at this point, however, that it is unrealistic to expect that any pre-construction survey works undertaken by TEA could be conducted to establish population numbers on any of these species or to determine whether *G. garricki* in King Sound are part of a single Australia wide population or is isolated. This is due to the fact that these species (in particular *G. garricki*) occur naturally in very low abundance (like most elasmobranchs) and population estimates have not and are unlikely to be definitively established for any region of Australia. Furthermore, the sampling required to collect sufficient samples over such a vast remote geographical area is unfeasible from an economic, logistic and effort perspective. Nevertheless, tissue samples collected during monitoring associated with the proposed tidal power station could be forwarded to an appropriate research institution for use in population studies when sufficient samples have been collected throughout coastal waters of Australia.

Data collected during monitoring such as that outlined above could significantly contribute to our current knowledge base on *Pristis* spp. and *G. garricki* in particular. Indeed, the type of research programs outlined above and species specific education programs aimed at the wider community to disseminate information on the findings could be considered practical offsets for the proposed tidal power station in Doctors Creek. Furthermore, opportunity exists to tie in with

existing research programs such as those undertaken by Murdoch University which has seen *Pristis* and *Glyphis* species monitored in King Sound and the Fitzroy River since 2001 (see Reference section for examples). The type of data collected could also be aligned with the actions and objectives outlined in the Draft Recovery Plan for Sawfish and River Sharks (Department of the Environment 2014) and contribute to delivering some of these. Furthermore, the involvement of indigenous rangers operating in the Derby area (or establishment of additional groups) in any monitoring or education program may provide an avenue for direct community engagement and provide a potential funding and training opportunity for those groups.

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FIGURES

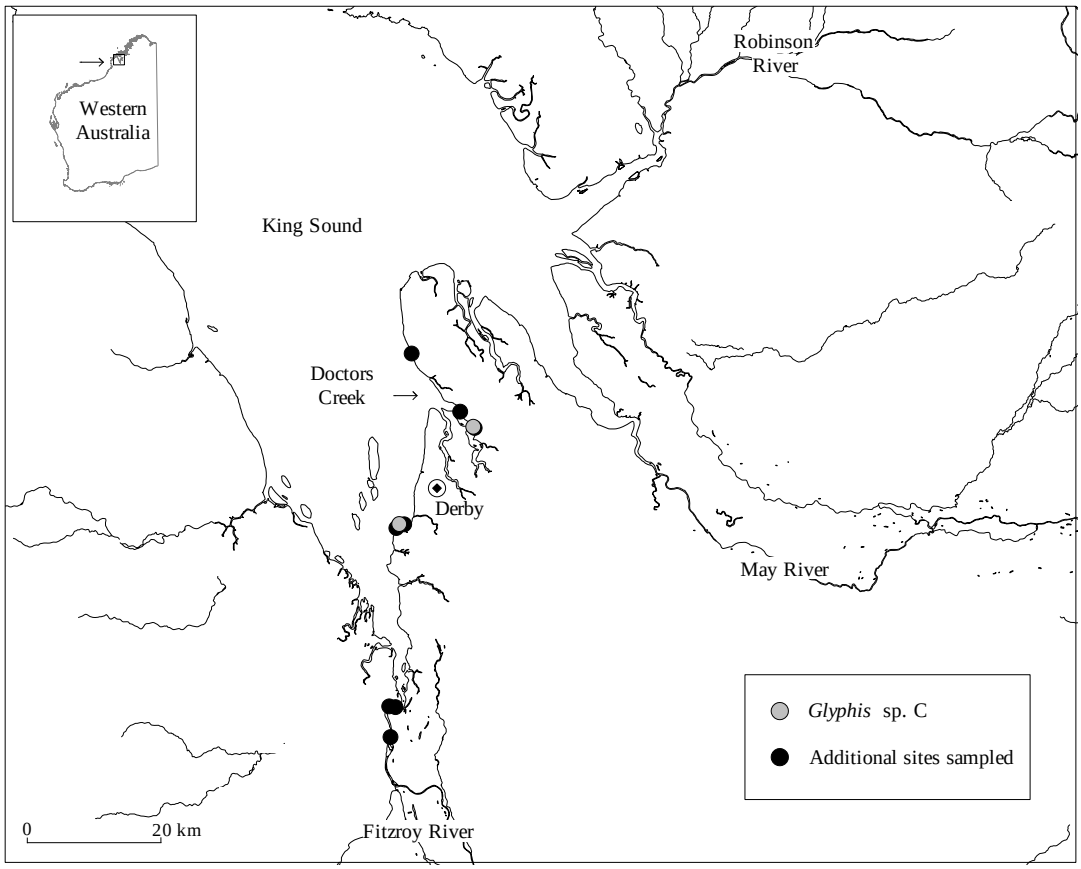

Figure 1. Capture locations of *Glyphis garricki* in King Sound by Thorburn and Morgan (2004).