Trawl bycatch of syngnathids in Queensland: catch rates, distribution and population biology of *Solegnathus* pipehorses (seadragons)

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GRIFFITH UNIVERSITY

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

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Table of Contents

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OBJECTIVES:

1. Quantify catch rates and determine distribution of the two pipehorse species taken incidentally in trawl fisheries in Queensland.
2. Determine basic biological characteristics of pipehorses, including age structure of both sexes, fecundity, longevity and recruitment timing.
3. Contribute to a management regime for syngnathid bycatch, based on new knowledge of catch rates, distribution and basic biology.

Non-technical Summary

Results from this study are being used by Queensland Fisheries Service in the revision of the management regime for syngnathid species caught incidentally as bycatch in the Queensland East Coast Trawl Fishery. Results will assist in the production of a sound management regime, based on scientific data, by directing discussions to key issues regarding syngnathid bycatch. This will contribute to the overall management and viability of the QECTF. Information from this study will assist Environment Australia in making well-informed decisions regarding export authorisation for syngnathids. Benefits also extend to the public and scientific community. Some syngnathids are seen by the public as conservation icons, and the presentation of scientific data will better inform the community about syngnathid bycatch. The scientific community will benefit from the increased knowledge about the biology of a deep water syngnathid species.

The substantial export value resulting from trade in *Solegnathus* species underlines the importance of obtaining information about their distribution, catch rates and population dynamics to ensure pipehorse harvests from bycatch in the Queensland East Coast Trawl Fishery (QECTF) are sustainable. The draft management arrangements for syngnathids proposed restrictions on the taking of pipehorses, but also pointed out that management was difficult without some basic biological knowledge of the species. The current study provides the first estimates of pipehorse catch rates resulting from bycatch in the QECTF, and reports information about the distribution, size and age structure, reproductive biology and growth rates of the two *Solegnathus* species involved.

The first objective of the project was to quantify catch rates and determine distributions of the two pipehorse species taken incidentally in trawl fisheries in Queensland: *Solegnathus hardwickii* and *Solegnathus dunckeri*. We obtained information about the distribution, catch and trade of pipehorses from three separate sources: the Queensland Fisheries Service scallop surveys, dried seafood processors and trawl logbooks. Bycatch of *S. hardwickii* was recorded from Innisfail to Mooloolaba, and *S. dunckeri* from Fraser Island to Mooloolaba. In the QFS surveys, pipehorses were caught only at depths greater than 25 m. Pipehorse bycatch appears to increase with proximity to reefs, and the species are likely to be more abundant in areas having some three-dimensional structure (e.g. sessile biota). During 2000, the CPUE calculated from processor plant purchases and the QFS survey ranged from 0.6 to 1.3 pipehorses. boat day^{-1}, and the CPUE determined from logbooks were about 0.3 syngnathids. boat day^{-1}. For fisheries that overlap with the depth distribution of pipehorses, syngnathids are caught on approximately 6% of boat days. For boat days on which syngnathids were caught, catch frequencies from the logbooks vary between 1 and 100 syngnathids. boat day^{-1}, with 25% of boats catching only one syngnathid and 84% catching between one and ten syngnathids. Approximately 15% of syngnathids caught are likely to be species other than *Solegnathus*.

The second objective was to determine basic biological characteristics of pipehorses, including age structure, fecundity, longevity and recruitment timing. Biological information (including wet and dry weight, total length, species and sex, and the presence of eggs or egg scars) and the location of catch were obtained from both the Queensland Fisheries Service scallop survey and dried seafood processors. Information was derived predominantly from *S. hardwickii*, because comparatively few *S. dunckeri* were obtained. *S. hardwickii* individuals caught from the southern processor region were larger than those from the northern processor region, and males were larger than females. *S. hardwickii* breeds throughout the year, with a peak in the proportion of pregnant males from mid-winter to spring. Males became mature at about 320 mm. Further investigation is necessary to determine the proportion of the population resulting from the peak breeding period. Growth rates of 1.2 mm. d^{-1} for juveniles and 0.3 mm. d^{-1} for adults were calculated from length frequency analysis. Otolith analysis provided an unusual result; ring formation was most visible in the asteriscus. A sub-sample of adults was shown to have 3-5 potential annuli in their otoliths, possibly indicating ages of 3-5 years, although it remains for these annuli to be validated.

The final objective was to utilise the information obtained from the first two objectives on catch rates, distribution and biological characteristics to contribute to a management regime for syngnathid bycatch in the QECTF. Examination of the distribution and biological characteristics of *S. hardwickii* indicates that this species is moderately sustainable to incidental bycatch by trawl fishing. As a result of this study, the following recommendations regarding syngnathid bycatch are suggested.

Future investigations of pipehorse bycatch in Queensland should focus on fishing sectors operating at depths greater than 25 m and therefore on the following species: red spot, blueleg and eastern king prawn, scallop and stout whiting. The current recording of syngnathid data in logbooks should continue, but should be expanded to include the stout whiting fishery, preferably with common syngnathid species identified (at least to genus). Ideally, independent validation of the logbook data is necessary to confirm the data reported. The distribution of the identification kit developed during the current project would assist with accurate completion of logbooks. Data on CPUE and pipehorse sizes should continue to be recorded for at least the next 5 to10 years and should be used to establish whether population densities or sizes are changing, and to separate any effects of fishing from changes resulting from environmental fluctuations. Even this long-term project may be inconclusive if fishing has already affected population densities or sizes. We strongly recommend that pipehorse densities and size distributions be measured in un-trawled areas and especially in any areas where trawl closures are being implemented. A more thorough investigation of the biology of *Solegnathus* species is needed to clarify the age at maturity, the proportion of the population resulting from the peak breeding period, and to confirm the age structure of *Solegnathus* bycatch. A catch limit for *Solegnathus* is not a practical solution to managing bycatch of syngnathids in the QECTF, because so few pipehorses would survive being caught and returned to the sea. Alternative strategies introduced by QFS aimed at cumulatively reducing the catch of all incidental species and therefore reducing the impact of the fishery are supported.

KEYWORDS: bycatch, pipefish, pipehorse, seadragon, Syngnathidae, trawl fishery.

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1.0 Background

Pipehorses are fish from the unusual family Syngnathidae, which includes seahorses and pipefish. Increased public awareness of syngnathids and growing demands for their use in Traditional Chinese Medicine (Vincent 1996) have resulted in concern for the conservation status of this family. Whilst Australian waters are home to half of the world's syngnathids (Vincent 1996), remarkably little is known about many of these species. Syngnathid exports from Australia are thought to have increased in the last decade, partly in response to a booming trade in China and also as a result of depletion of stocks in places such as the South China Sea. The majority of this market is generated from the trade, principally from Queensland, of two species of pipehorses (also called pipefish, and known in Asia as seadragons), *Solegnathus hardwickii* and *Solegnathus dunckeri*, which are caught incidentally as bycatch in the Queensland East Coast Trawl Fishery (QECTF). *Solegnathus* pipehorses reportedly command the highest price of any syngnathid in Asian markets, with retail values of $US 1 500 per kg dry weight (Vincent 1996), and more recent estimates of up to $AUS 1 300 (QFS 2001). High demand for these species, in conjunction with management limitations arising from the paucity of information available about their biology, potentially makes them vulnerable to overexploitation. Concern about the impact of trawl fishing on the population characteristics (Stobutzki et al. 2000) and conservation status (Haysom 1985) of syngnathids has resulted in syngnathids being removed from Schedule 4 of the Wildlife Protection Act, making it illegal to export them without an authority. Presently, Environment Australia (EA) has issued interim export authorities until the Queensland Fisheries Service (QFS) implements a management regime. QFS drafted management arrangements (QFMA 1998) prior to the current project, but had to do so without knowledge of catch rates or biology.

To date, Environment Australia has recorded information on quantities of syngnathids exported. Following the removal of syngnathids from Schedule 4, we arranged for requests for the collection of other information about the product exported to be issued in conjunction with the granted authority. Companies given authority to export were provided with our kit (Appendix 3) which included instructions for data collection and an explanation of why this information was being requested. Amounts of pipehorses purchased and basic biological measurements were thus obtained to assist in establishing the biological status of *Solegnathus* species in the QECTF. From mid 2000, information on syngnathid bycatch was also obtained from trawl logbooks, following changes in 1999 to fisheries legislation providing specifically for species caught incidentally during trawling (QFMA 1999).

Prior to the current project, the actual amount of *Solegnathus* species caught as incidental bycatch in the QECTF was unknown. Catch estimates of 5 to 20 pipehorses during more than 10 days at sea had been reported by trawl fishers (Vincent 1996). The QECTF is a multi-species fishery, based upon 19 commercially important species (QFMA 1996). The principal species are divided into seven fishery sectors based upon the catch location and/or the type of species (Table 1, QFMA 1996). These fishery sectors operate seasonally in specific areas (Table 1) and comply with various restrictions including the major closure periods for the northern and southern regions. Catch statistics are recorded daily by trawl fishers in logbooks, which are submitted to the QFS on a monthly basis. From these records, bycatch rates can be calculated using either the catch per unit effort (CPUE) or ratio method.

The CPUE method measures the bycatch per unit of fishing effort, whilst the ratio method compares the ratio of bycatch to the total target species catch (Andrew and Pepperell 1992). In March 2000, new logbooks called 'OT07' were introduced which required greater detail of bycatch to be recorded (QFS 2001). Instead of total syngnathid catch being included in the category 'other', it is now listed separately, although different syngnathid species are not distinguished. Whilst the total bycatch in the QECTF has been estimated (QFMA 1996), accurate bycatch rates of individual species, particularly those occurring in low abundance, are scarce (Jones and Derbyshire 1988, Watson et al. 1990), and few sources actually mention syngnathid bycatch (Haysom 1985, Stobutzki et al. 2000).

In the past two decades, research into syngnathid biology has resulted in a substantial increase in knowledge about the ecology and reproductive biology of some species (Gronell 1984, Howard and Koehn 1985, Vincent and Sadler 1995, Masonjones and Lewis 1996, Berglund et al. 1986, 1988, Lazzari and Able 1990, Vincent et al. 1995, Matsumoto and Yanagisawa 2001). The increase in research effort is partly due to the characteristic breeding biology of the syngnathid family, whereby males exclusively brood and care for offspring. This provides an excellent opportunity to test theories of sexual selection and mating systems (Vincent et al. 1992), especially with more recent advances enabling parentage to be determined genetically (Jones and Avise 1997a, b). The majority of research has focused on seahorse and pipefish species inhabiting shallow coastal waters, whilst species that occur at depth, such as Australian *Solegnathus* species, have remained largely unstudied (Lourie et al. 1999). Prior to this study, basic information on the biology and catch rates of *Solegnathus hardwickii* and *Solegnathus dunckeri* was scarce, making it difficult to establish the sustainability of these species to trawl bycatch (QFS 2001).

This report covers two main topics that will assist with the development of a management regime for *Solegnathus* bycatch in the QECTF. The first topic is the distribution and catch rates of *S. hardwickii* and *S. dunckeri*, and the total amount of *Solegnathus* exported. The second topic is the biology of *S. hardwickii* and to a lesser extent *S. dunckeri*, to determine their morphology, reproductive biology, growth rate and the utility of using otoliths for ageing.

Table 1: Sectors of the Queensland East Coast trawl fishery, target species, depths, locations and peak fishing periods. MB = Moreton Bay, HB = Hervey Bay, T = Townsville, PCB = Princess Charlotte Bay, GBR = Great Barrier Reef, Fraser = Fraser Is. Whiting fishery closure from 1 Jan – 31 March, scallop fishery closure from 20 September to 31 October 2000. Major closures for the southern region from 20 Sept to 1 Nov/12 December, and for the northern region from 15 December to 1 March/14 May - two dates depending on fishing strategy (QFMA 1999). Information in this table was taken from QFMA (1996) and DPI (2001a).

Sector	Target species	Depth (m)	Latitude (key areas)	Peak fishing period
Eastern King	Eastern king *(Penaeus plebejus)*	10-250	South of 21°S (MB to Fraser)	Oct, Nov (MB) Dec–Feb (ex. MB)
Red Spot King	Red spot king (*Penaeus longistylus*) Blue leg king *(Penaeus latisulcatus)*	30-50	18°S - 21°S (GBR lagoon, T)	Aug
Bay Prawn	Greasy prawn (*Metapenaeus bennettae*) Eastern king (*Penaeus plebejus*) Brown tiger (*Penaeus esculentus*)	< 25	(MB and HB)	
Tiger Prawn	Grooved tiger (*Penaeus semisulcatus*) Brown tiger (*Penaeus esculentus*) Blue endeavour (*Metapenaeus endeavouri*) False endeavour (*Metapenaeus ensis*)	< 20-25	North of 22°S (PCB, T)	Feb, Mar
Banana Prawn	Banana prawn (*Penaeus merguiensis*)	< 15	North of 25°S	Jan-Jun
Stout/Trawl Whiting	Stout/Trawl whiting (*Sillago robusta*)	46-60	24’30°S - 27°S (MB to Fraser)	Apr-Dec
Scallop	Saucer scallop (*Amusium balloti*)	30-50	21°S - 26°S (HB to Gladstone)	Nov-Jan

2.0 Need

The development of export markets in Australia and substantial export value resulting from trade in *Solegnathus* species underlines the importance of obtaining information about their distribution, catch rates and population dynamics. Such information is fundamental to the development of a management regime for syngnathid bycatch in the QECTF. The draft management arrangements for syngnathids proposed restrictions on the taking of pipehorses, but also pointed out that management was difficult without some basic biological knowledge of the species (QFMA 1998). The draft management arrangements identified the need, firstly, to determine catch rates and distribution of pipehorses as bycatch species, and secondly, to understand their basic biology. It is important to know population characteristics including age structure, fecundity, longevity and recruitment timing. Conservation groups that use syngnathids as symbols of healthy oceans are also pursuing the pipehorse bycatch issue. This further demonstrates the need for a sound management regime based on the biology of the species and its interaction with the trawl industry.

3.0 Objectives

The objectives in the original project proposal were:

1. Quantify catch rates and determine distribution of the two pipehorse species taken incidentally in trawl fisheries in Queensland.

2. Determine basic biological characteristics of pipehorses, including age structure of both sexes, fecundity, longevity and recruitment timing.

3. Contribute to a management plan for syngnathid bycatch, based on new knowledge of catch rates, distribution and basic biology.

The third objective was altered during the course of the project, with the word “plan” being replaced by “regime”, so that the objective became:

3. Contribute to a management regime for syngnathid bycatch, based on new knowledge of catch rates, distribution and basic biology.

This change was made at the suggestion of QFS staff, who informed us that no separate management plan, as a distinct document, was being considered for syngnathids alone. Rather, there will be a management regime taking into consideration all bycatch species including syngnathids, and management planning documents will include one or more sections on syngnathids.

4.0 Methods

4.1 Distribution, Catch and Trade

Data sources

Information about the distribution, catch and trade of pipehorses was gathered from three separate sources:

1) Queensland Fisheries Service scallop surveys (hereafter QFS surveys)

2) dried seafood processors holding authority to export (hereafter processors)

3) trawl logbooks (hereafter logbooks)

Pipehorses (and any other syngnathids) were collected during two surveys run by QFS, involving trawling for scallops between Hervey Bay and Shoalwater Bay (Figure 1). Trawls of 20 minutes duration were done at night, for a 10 day period in October 1999 (421 trawls) and an 11 day period in October 2000 (374 trawls), and were independent of commercial trawling activities (i.e. the pipehorse densities obtained are fishery independent). Commercial scallop trawlers use three inch mesh, but in these surveys, because QFS were also interested in obtaining population estimates for juvenile scallops, two inch mesh, typically employed by prawn trawlers, was used. Three Scallop Replenishment Areas (SRA) closed to commercial trawling were also trawled: Hervey Bay, Bustard Head and Yeppoon.

Information was obtained from four processors distributed between Brisbane and Townsville. The supply of information was a condition of the provision of authority to export syngnathids, applied for individually by each processor and issued by Environment Australia. The issuing of authorisations by EA was continually under negotiation during this study, with processors receiving authority to export for varying periods from six weeks to six months. The different periods during which processors supplied information were taken into account when analysing data. Data from the first authority period were obtained via EA, and in subsequent authority periods were requested using a kit for recording information on pipehorses (Appendix 3), developed in consultation with QFS, Queensland Seafood Industry Association (QSIA), Environment Australia and processors. The kit was distributed to all processors, and requested that the total wet and dry weight of all pipehorses brought into the processors by each fisher, fisher company or wholesaler, and the port from which the trade took place, be recorded in monthly summaries. We also obtained from processors the catch locations for all pipehorses they purchased directly at the port (i.e. not from other processors).

Records of syngnathid bycatch and fishing effort within the QECTF were obtained from trawl logbooks between July and December 2000, following the introduction of the OT07 logbooks which provided for the recording of bycatch of permitted fish as separate categories (QFS 2001). In the OT07 logbooks, syngnathids are recorded as total syngnathid catch, therefore pipefish and seahorses can potentially be included along with pipehorses.

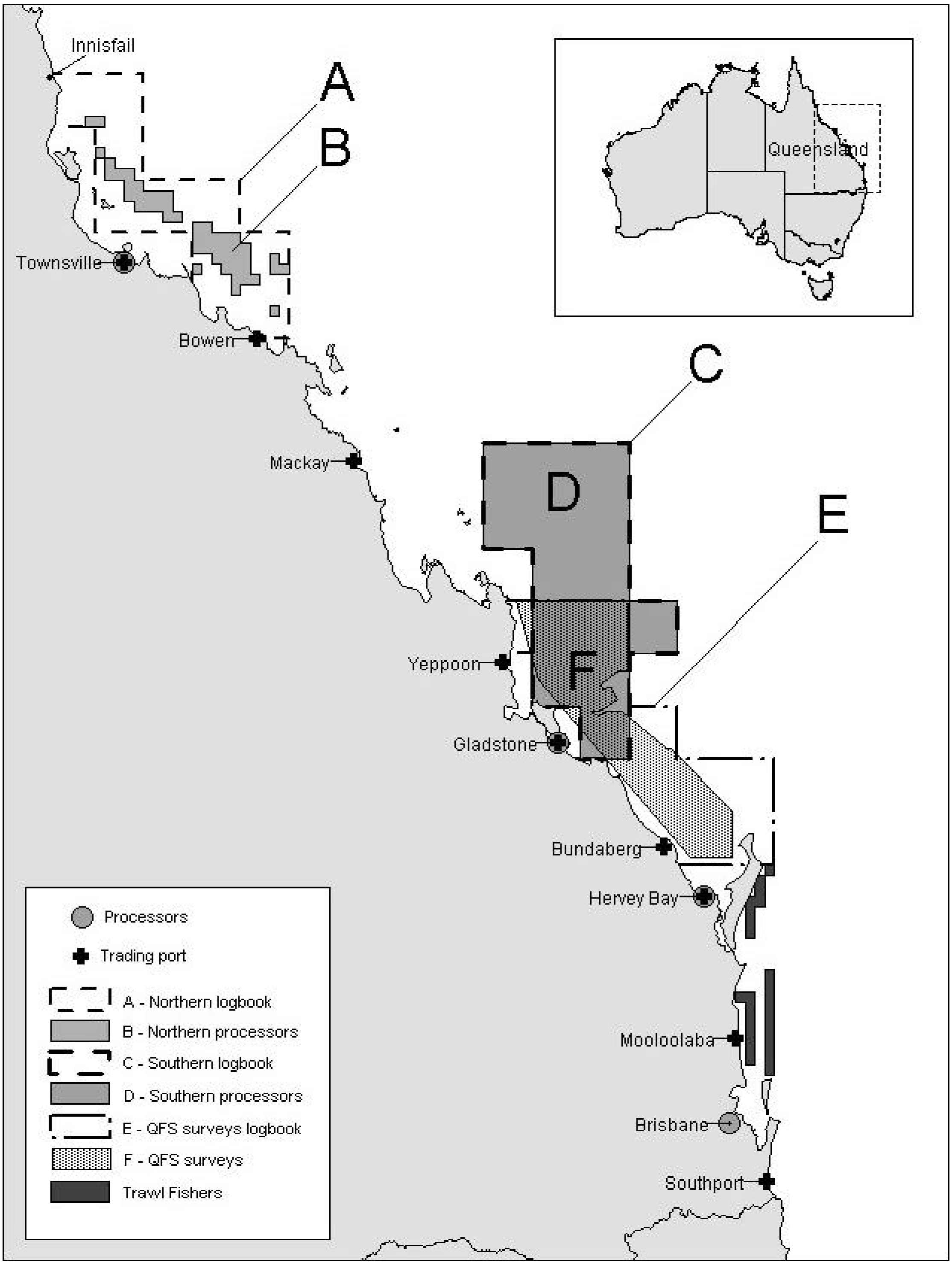

Figure 1: A section of the Queensland East Coast Trawl Fishery, showing the areas where pipehorse catch was recorded by processors (areas B and D) and trawl fishers, the area of the QFS surveys (area F) and the areas from which logbook information was requested (areas A, C and E) to match processor and QFS survey areas.

Distribution

The distributions of *Solegnathus* species bycatch were established from the QFS surveys and processors, and from additional interviews with trawl fishers.

Factors potentially influencing the distribution of pipehorses were investigated for the area covered by the QFS surveys. A more detailed analysis was possible for this area in comparison to those of other data sources, as information on trawled depth and scallop catch per trawl was available, and the sediment type (expressed as carbonate fraction, which gives an indication of coral-derived substrate as opposed to terrestrial-derived substrate) had been mapped (Stevens 1995). To determine if there was a relationship between depth and pipehorse occurrence, the frequency distribution of depths of all trawls was compared to the frequency distribution of depths of trawls that caught pipehorses using a Kolmogorov-Smirnov (K-S) test. To determine if scallop catch correlated with pipehorse occurrence, the frequency distribution of scallop catch of all trawls was compared with the frequency distribution of scallop catch for trawls catching pipehorses, using a K-S test for the combined data from 1999 and 2000. K-S tests were used instead of regression analysis because the presence or absence of pipehorses, rather than the number of pipehorses, was being investigated. To determine if pipehorse catch correlated with the sediment type, the number of trawls with and without pipehorse catch on each carbonate fraction (categorised into 0-40, 40-60, 60-100%) were compared using a chi square test.

Catch rates

Trawl logbook CPUE (syngnathids. boat day^{-1}) was calculated from monthly summaries of syngnathid catch (number of syngnathids) and total fishing effort (number of boat days) obtained from QFS for the entire QECTF by dividing the region into three sections: north of Innisfail, Innisfail to Gladstone, and south of Gladstone to the NSW border. Information was obtained from July 2001 onwards when the new OT07 logbooks providing for the recording of syngnathid bycatch were operational (QFS 2001). Logbook data were requested for these latitudinal areas to 120 nautical miles out to sea (on a ½ degree basis) to obtain monthly changes in CPUE. Total effort for these regions was requested for the fishing sectors overlapping with the depth distribution of pipehorses (eastern king prawn, red-spot king prawn, stout whiting and scallop), to avoid including fishing effort in sectors unlikely to catch pipehorses (see section 6.1, Distribution). A confidentiality issue prevented us from obtaining logbook data from QFS when less than five boats recorded information for any data request, and some syngnathid catch may therefore have been missed. Some syngnathid catch may also be unaccounted for because a small number of fishers did not use the OT07 logbooks, and in the stout whiting fishery recording of syngnathid bycatch is currently not required. The overall catch frequencies of syngnathids from OT07 logbooks (for the entire QECTF) were also obtained from QFS, and these included all syngnathids caught irrespective of the number of boats operating.

Logbook CPUE was also calculated for specific areas within the QECTF that encompassed the catch locations of the processors (northern and southern) and the QFS surveys (Figure 1). Effort from all fishing sectors except the stout whiting fishery was used, as this included any effort in these specific areas. The logbook CPUE values for these specific regions were compared with CPUE calculated either independently of the trawl fishery (from QFS surveys) or in conjunction with processor purchases from the fishery, to assess the reliability of different data sources. For the northern and southern processors, CPUE was calculated using purchase data from processors (as a record of catch), and effort data from the trawl logbook over the same period for the region encompassing this catch (Figure 1). The logbook effort used to determine CPUE includes fishing sectors that are unlikely to catch pipehorses, therefore the calculated CPUEs are lower than if CPUEs were calculated only from fishing sectors likely to catch pipehorses. The CPUE from the 2000 QFS survey was calculated directly from total catch (number of pipehorses) and fishing effort (number of boat days). In addition, pipehorse bycatch densities (pipehorses. km^{-2}) were calculated from the QFS surveys, by determining the area sampled, where: area sampled = effective distance across nets $\times$ distance trawled. Densities, catch and CPUEs reported here are indicative only of retained catch. Actual pipehorse population densities could not be established because trawling is unlikely to capture all pipehorses in the area sampled, and pipehorses that are caught may not be retained throughout the duration of the trawl.

Three comparisons of CPUE were made from comparable areas (Figure 1):

1) Northern region CPUE calculated from the processors catch and logbook effort (B) was compared with the CPUE calculated solely from logbooks (A).

2) Southern region CPUE calculated from the processors catch and logbook effort (D) was compared with the CPUE calculated solely from logbooks (C).

3) The CPUE calculated independently from the 2000 QFS survey (F) was compared to the CPUE calculated solely from logbooks (E).

Trade

Using the kit supplied (Appendix 3), processors were asked to record in monthly summaries the total amount (wet and/or dry weight) of *Solegnathus* (by species) purchased, and the total amount exported during their authority period. Purchase quantities were compared with logbook catch, and export quantities were compared with historical export estimates.

4.2 Biology

Data sources

Biological information was obtained from two sources: the Queensland Fisheries Service scallop surveys (QFS surveys) and dried seafood processors (as described in section 4.1). The majority of the specimens measured were *S. hardwickii*, with only a small number of *S. dunckeri* measured, therefore unless otherwise indicated the remainder of the biology sections refer to *S. hardwickii*.

During the QFS surveys, 51 and 42 pipehorses were collected in 1999 and 2000 respectively. Biological data were also collected from processors by supplying them with a kit for recording information on pipehorses (Appendix 3). The information requested included wet and dry weight, total length, species and sex, and the presence of eggs or egg scars (depressions on the underside of tail where eggs are positioned indicating a current or recent pregnancy), in addition to the location of catch (section 4.1). We requested that 100 pipehorses from each of two locations be measured monthly. If larger numbers were available for any one location and time, a representative sample of 100 pipehorses was selected. If insufficient numbers were available from one location, a pooled sample of 100 pipehorses from more than one location, but the same time, was selected.

Analysis of data from the first authority period established a strong relationship between wet and dry weight, therefore in subsequent authority periods only wet weights were requested. The kit was also amended to avoid occasional misidentifications uncovered during reliability checks and processing plant visits by researchers.

Morphological measurements

Processors measure pipehorses when frozen (tail is curled), therefore, to establish the actual length of a pipehorse, the approximate length of the curled tail needed to be determined. The length of frozen pipehorses (ten male and ten female selected haphazardly from the 1999 QFS survey), from the snout to the point along the curled tail furthest from the snout was measured. Pipehorses were thawed and the tail straightened to measure the length from the tip of the snout to the tip of the uncurled tail. The tail curl represented 6% of the total length for pipehorses between 360 – 465 mm, underestimating the total length by an average of 28 mm (± 3 s.d., n = 20 pipehorses). All further measurements were made from the tip of the snout to the curl in the tail, eliminating the need for thawing to measure length.

To establish the relationship between wet and dry weight of pipehorses measured during the first authority period, dry weight was plotted against wet weight and examined using regression analysis. Wet weight was plotted against length (processors recorded the length and wet weight) for both sexes, examined using regression analysis and the sexes compared using an ANCOVA. Comparisons of length and of weight were made between sexes and between species using K-S tests. Comparisons of data from different processing plants were also made, to determine if measurement protocols were resulting in any differences in biological variables for pipehorses purchased from the same area.

Length frequency distributions from the northern region (north of Bowen) and the southern region (south of Mackay to Mooloolaba), corresponding to the regions of processor catch purchased by processors (Figure 1), were compared using a K-S test to determine whether pipehorse lengths were different between regions.

Reproductive biology

The peak reproductive period was established as the time when the proportion of males with egg scars (indicating pregnancy) was greatest. Recruitment was determined by analysis of size frequency distributions to establish the time of appearance of a new cohort. The minimum size of males at maturity was established as the smallest size of a pipehorse with egg scars, and the size at which 50% of pipehorses had egg scars was also determined. The minimum size of females at maturity could not be determined, as this would require histological analysis beyond the scope of the present study. To determine if male length correlated with mating success, lengths of mature males with and without egg scars were compared using a K-S test. Regression analysis was used to test the relationship between length and brood size (no. of eggs) for both *S. hardwickii* and *S. dunckeri*.

Information about pipehorse embryos and hatchlings was difficult to obtain. Only one processor recorded details of the condition of egg scars (indicating time since pregnancy) and the presence of eggs or embryos. No further information about the numbers or sizes of the embryos was obtained from the processors, however, during the 1999 QFS survey, a single pregnant male was caught with eggs containing well-developed embryos. The dimensions of the eggs were measured, then the eggs were removed and dissected to enable measurement of the length of the embryo from the tip of the snout to the tip of the tail.

Growth rates

Data from the region south of Mackay were unsuitable for growth rate determinations, as information was received for inconsistent periods and large proportions of the pipehorses measured were not sexed. For pipehorses from the region north of Bowen (Figure 1), relative length frequency distributions were plotted at monthly intervals and the modal length identified. Modes were plotted for males and females and growth rates calculated by analysis of modal progression. Growth rates were also estimated for juveniles by determining the time between the peak reproductive period and the attainment of adult size.

Otolith ageing

Otolith preparation

Otoliths from 46 of the pipehorses from the 1999 QFS survey were removed under a dissecting microscope. At least one sagitta, one lapillus and two asterisci were extracted from each pipehorse. Otoliths were examined using different preparation techniques, described below, to establish which combination of otolith and technique provided the clearest resolution of internal structure.

1) No preparation - ten randomly selected sagittae, lapilli and asterisci were placed on a concave slide and observed when dry and under a drop of water.

2) No preparation, oven burnt - five sagittae, lapilli and asterisci were placed in the oven for 16 hours at 65°C.

3) Ground (dorsal ventral plane) - six sagittae, lapilli and asterisci were fixed to a glass slide, dorsal surface upwards, using a cyanoacrylate adhesive, ground to the level of the primordium using two grades of imperial lapping film (9 µm followed by 3 µm), then polished with silk. Otoliths were observed throughout different stages of grinding to check for the visibility of internal structure. Three ground sagittae, lapilli and asterisci were placed in the oven for 16 hours, and the remaining three ground sagittae, lapilli and asterisci were rapidly waved over an open flame several times.

4) Ground (transverse plane) - six sagittae, lapilli and asterisci were fixed to the edge of a slide, overhanging the slide edge to the level of the primordium, and ground along the transverse plane to the primordium. Otoliths were re-mounted, ground face upward and examined. Three sagittae, lapilli and asterisci were placed in the oven for 16 hours, and the remaining three sagittae, lapilli and asteriscus were rapidly waved over an open flame several times.

After preparation, all otoliths were examined using a dissecting and compound microscope (100 - 400× and polarising filter) for the presence of annuli and/or increments. Internal structure was clearly observed only in the asterisci using the two preparation techniques that did not involve grinding (see section 5.2). Techniques involving grinding were unsuitable to observe the internal structure because the sagittae and lapilli shattered readily owing to their dense crystalline nature and the ground asterisci were too dense. Asterisci were therefore used in subsequent analysis for ageing of all other pipehorses examined.

Validation

Most pipehorses are in a very poor condition when emptied from the trawl net, therefore age validation by laboratory growth trials was not possible. Capture-recapture validation techniques would also be difficult, given the depth distribution and low density of *S. hardwickii* (see section 5.1). Four late stage embryos (which were attached to a captured male) were dissected and the otoliths examined to validate the location of annuli in relation to the core size, and to increase confidence in the identification of internal structure.

Estimating age

Asterisci were classified according to the ease of interpretation of their structure using the four classes defined by Fowler (1990). The interpretable annuli were counted to estimate the age of the pipehorse. Counts were repeated twice by one reader. When counts differed by less than two, the mean was used as an estimate of the number of potential annuli. When the difference was greater than two, further counts were made until a satisfactory estimate of the number of annuli was achieved, otherwise the otolith was rejected. When potential annuli were situated in from the otolith edge at a distance approximately equal to half the distance between annuli, half a year was added to the potential annuli count. All otoliths were observed blindly in respect to pipehorse length and location captured. To establish if there was any relationship between estimated age and pipehorse length, the number of annuli in the asterisci of each pipehorse was related to total length using regression analysis.

5.0 Results

5.1 Distribution, Catch and Trade

Distribution

Bycatch of *Solegnathus hardwickii* was recorded from just south of Innisfail to Mooloolaba (Figure 1). The northern region processors provided greater precision about bycatch locations than the southern region processors. Too few boats recorded syngnathid bycatch in the logbooks north of Innisfail to obtain the catch for this region, despite considerable fishing effort (section 5.1, Catch rates), and no pipehorse purchases were made from any ports north of Townsville. Bycatch of *Solegnathus dunckeri* was recorded from offshore of Fraser Island to Mooloolaba. Some overlap in the distribution of the two species occurred in the Mooloolaba region, with *S. dunckeri* contributing 93 and 71% of two separate batches of mixed *Solegnathus* species from this area (total of 194 individuals).

Only *S. hardwickii* was caught within the QFS survey regions, and the distribution varied between years. Pipehorses were caught from two discrete locations in 1999, and from a more widespread region in 2000 (Figure 2). Other syngnathids caught during the QFS surveys included five pipefish and six seahorses. The pipefish species were *Filicampus tigris* (1), *Trachyrhamphus bicoarctatus* (3), and *Trachyrhamphus longirostris* (1). The six seahorses represented two presently unidentified species, belonging to the *Hippocampus whitei* complex (Lourie et al. 1999).

Trawls during the QFS surveys covered depths from 12 m to 89 m. Combining both years, trawls that caught pipehorses occurred at depths significantly different to the depths of all trawls (Figure 3, K-S test: $p = 0.042$). *S. hardwickii* was not caught at depths less than 27 m (Figure 3). Too few trawls were done at the deeper end of the distribution to establish any limit to pipehorse depth distributions.

The frequency distribution of scallop catch was not significantly different between trawls that caught pipehorses and all trawls (Figure 4, K-S test: $p = 0.993$). In total, 64% of all trawls, and 61% of trawls that caught pipehorses did not catch any scallops.

During the QFS surveys, all pipehorses were caught either in, on or proximate to seabeds with a high carbonate fraction. In 1999, pipehorse catch was positively correlated with carbonate fraction of the seabed (chi square: $p = 0.015$, Figure 5), however in 2000, the relationship between pipehorse catch and carbonate fraction was not significant ($p = 0.332$).

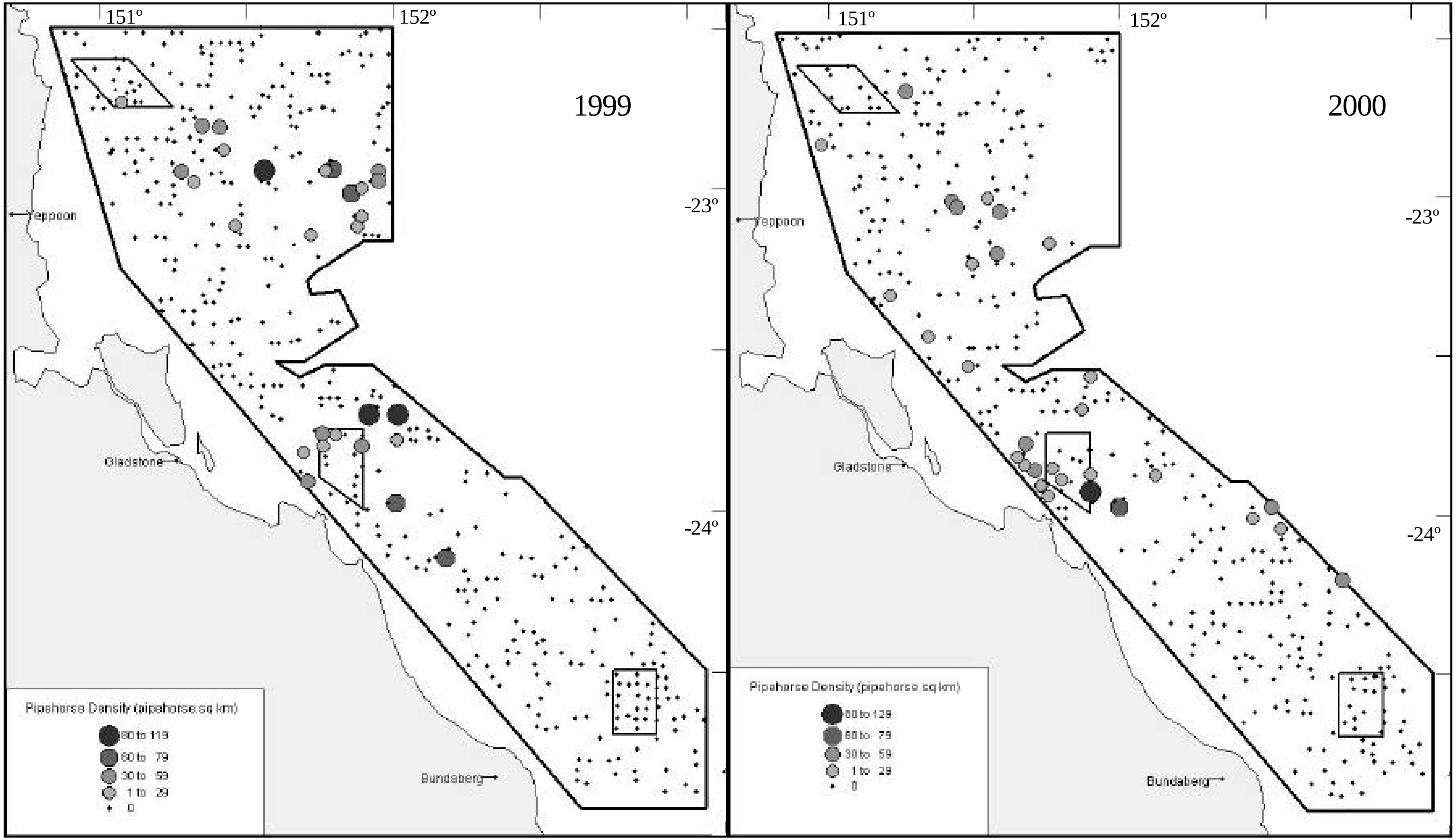

Figure 2: Trawl locations and pipehorse densities during the QFS surveys in 1999 and 2000. The three polygons within the QFS survey area are the Scallop Replenishment Areas.

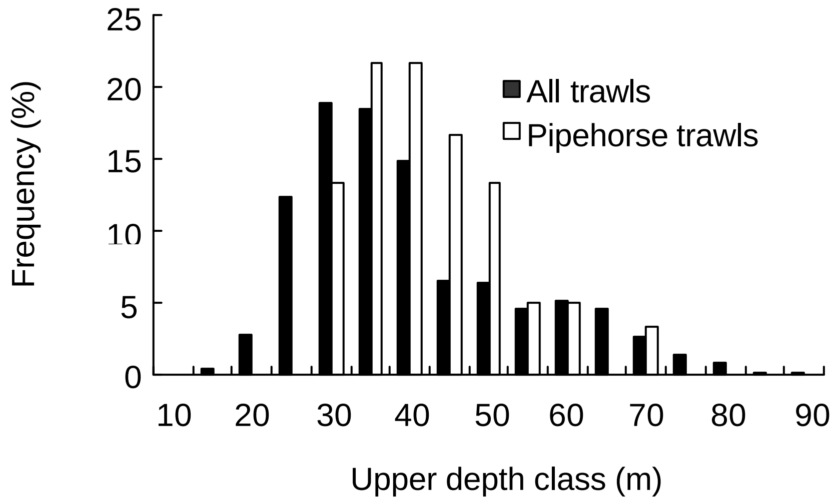

Figure 3: Depth distribution for the combined 1999 and 2000 QFS surveys, for all trawls and trawls that caught pipehorses.

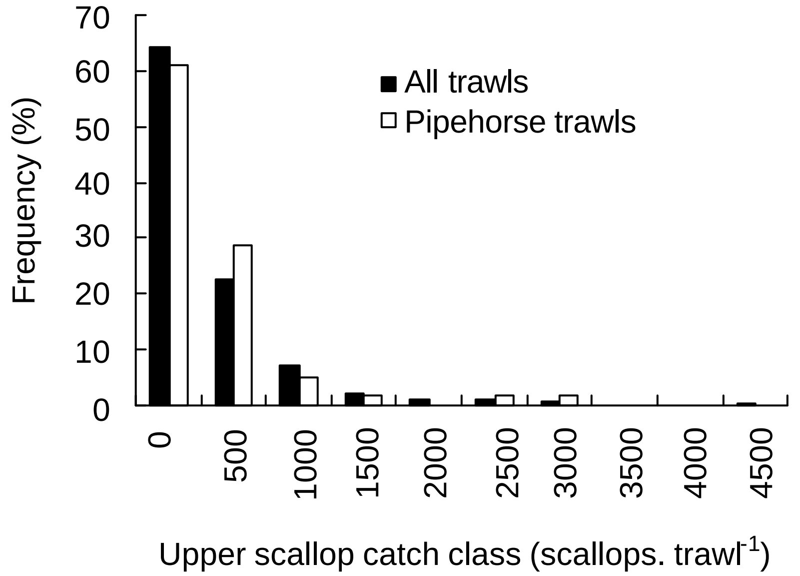

Figure 4: Distribution of scallop catch for the combined 1999 and 2000 QFS surveys, for all trawls and trawls that caught pipehorses.

Catch rates

In the region north of Innisfail, fewer than five boats recorded syngnathid catch over the whole of 2000 in trawl logbooks, despite an annual effort of approximately 4 362 boat days. CPUE is either zero or very low in this region. Between July and December 2000, monthly average logbook CPUEs in the region between Innisfail to Gladstone ranged from 0.1 to 0.4 syngnathids. boat day^{-1}, and in the region south of Gladstone ranged from 0 to 0.8 syngnathids. boat day^{-1} (Fig. 6). In general, fewer boats caught more syngnathids in the region between Gladstone and the NSW border than the region between Innisfail and Gladstone (Figure 6). Within the combined regions encompassing Innisfail to the NSW border the proportion of fishing effort that actually caught syngnathids ranged between 2 and 8.3% (average 5.6%, n = 11 months), and syngnathid CPUEs ranged from 1.8 to 16.7 syngnathids. boat day^{-1} (average 7.2 syngnathids. boat day^{-1}, n = 11 months). Analysis of the syngnathid bycatch frequencies from OT07 logbooks for the entire QECTF from March to December 2000, provided a mode of 1 syngnathid. boat day^{-1}, with 25% of trips recording only one syngnathid, 84% recording ten or less syngnathids, and one trip reporting a catch of 100 syngnathids (Table 2).

Table 2: Catch frequencies of syngnathids reported during Mar – Dec 2000 in OT07 logbooks.

Number of syngnathids	Catch frequency	% of total effort catching syngnathids
1	267	24.8
2-5	720	42.1
6-10	187	17.4
11-15	65	6.0
16-20	43	4.0
21-40	48	4.5
41-60	9	0.8
61-80	2	0.2
81-100	1	0.1

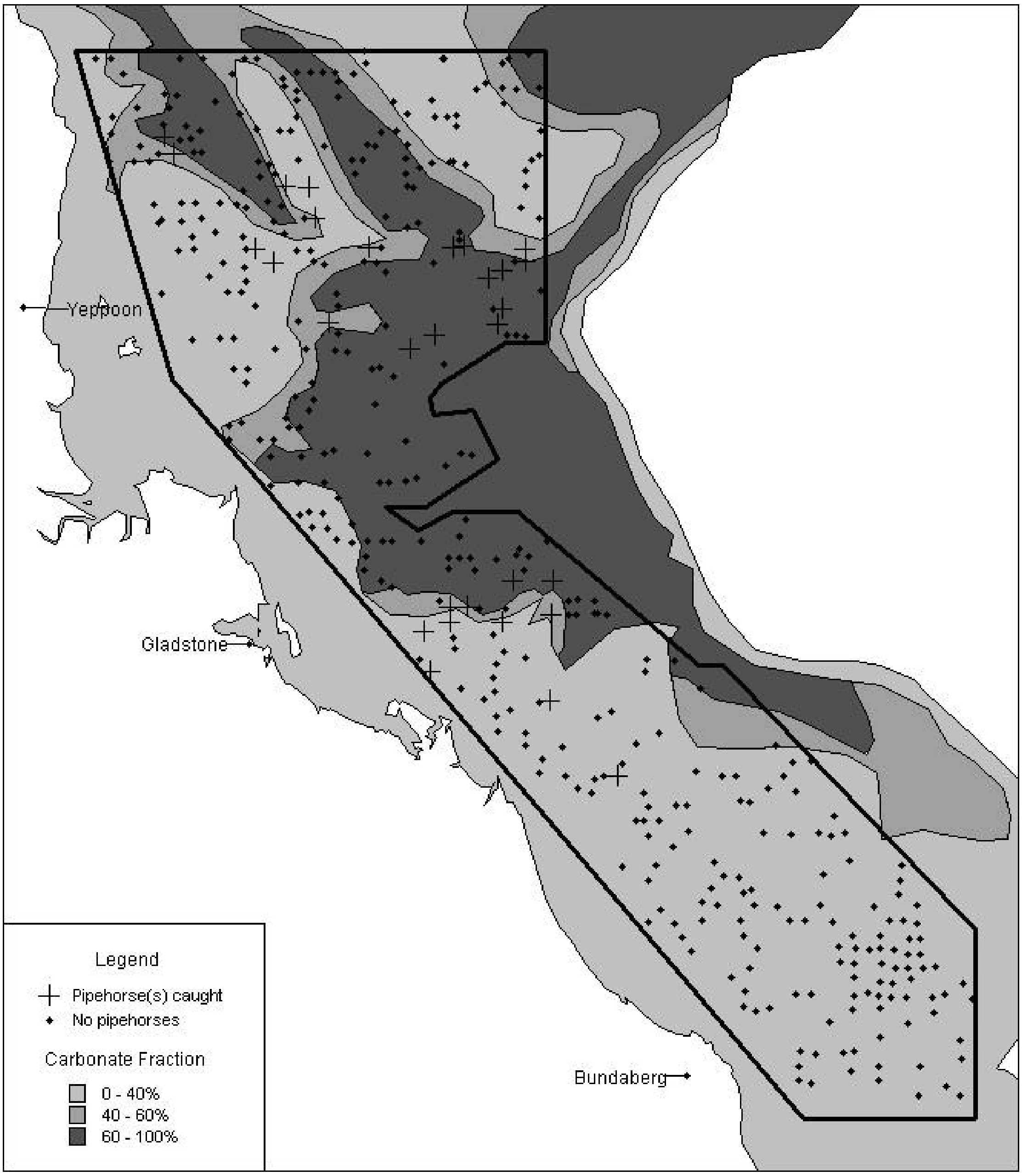

Figure 5: Carbonate fraction of the sediment, and locations of trawls that did (crosses) and did not (dots) catch pipehorses during the 1999 QFS survey (sediment data from Stevens 1995)

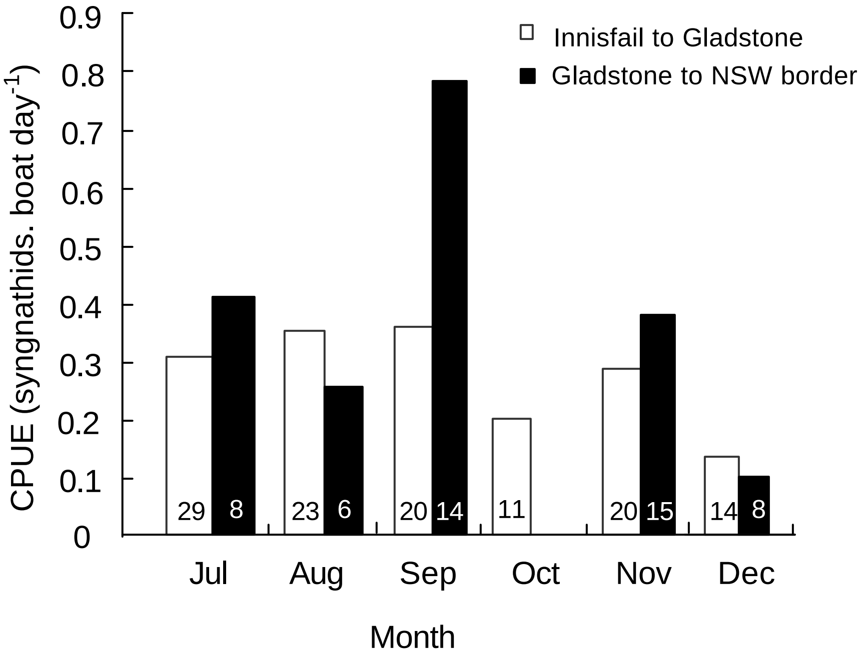

Figure 6: Logbook CPUE in the QECTF, Jul - Dec 2000. In the region between Gladstone and the NSW border, no syngnathids were caught in October, otherwise the number of boats per month catching syngnathids in each region is shown at the base of the columns.

The CPUE calculated for the northern region (1.29 pipehorses. boat day^{-1}) and southern region (0.57 pipehorses. boat day^{-1}) processors and the QFS survey (0.95 pipehorse. boat day^{-1}) was greater than the CPUE calculated from the logbooks for comparable regions encompassing this catch (0.24, 0.23 and 0.27 syngnathids. boat day^{-1} respectively) (Table 3).

Pipehorse catch rate during the QFS surveys rarely exceeded one pipehorse per 20 min trawl, with a maximum of four pipehorses caught per trawl. In both years, less than 8% of trawls (30/421 and 30/374, in 1999 and 2000 respectively) caught pipehorses (51 and 42 pipehorses, respectively). The resultant pipehorse densities (entirely different to CPUE, as they are calculated as catch per unit area rather than catch per unit fishing effort) averaged 3.2 pipehorses. km^{-2} (± 12.9 (s.d.), n = 795 shots), with a maximum density of 128.4 pipehorses. km^{-2} (Figure 2).

Table 3: Catch, effort and CPUE for regions within the QECTF and for the entire QECTF.
[a] estimated no. of *S. hardwickii* from processors purchase weight (assuming 1 dried pipehorse = 27g), [b] averaged from September and November 2000 (for a comparable period to the October QFS survey), as scallop fishery closed to commercial trawlers from 20 September to 31 October 2000.

Description	Period	Area (Fig. 1)	Source		Catch	Effort	CPUE
			Catch	Effort	(no. of pipehorses)	(no. of boat days)	(pipehorses. boat day^{-1})
Northern region	July – Dec 2000	A	Logbook	Logbook	1 307	5 358	0.24
		B	Processors	Logbook	6 910[a]	5 358	1.29
Southern region	Nov – Dec 2000	C	Logbook	Logbook	279	1 228	0.23
		D	Processors	Logbook	704[a]	1 228	0.57
QFS survey	Oct 2000	E	Logbook	Logbook[b]	186	685	0.27
		F	QFS survey	QFS survey	42	44	0.95

Trade

Exports

From June 1999 to December 2000, 1459 kg of dried pipehorses (S. *hardwickii* and *S. dunckeri* combined) were exported from processors in Queensland (Table 4). Exports predominantly consisted of *S. hardwickii*, however one processor exported mainly *S. dunckeri*. Assuming an average dry weight of 27 g per dried pipehorse (from section 5.2), this equates to 54 037 pipehorses exported during the investigation period of 18 months, including 31 000 pipehorses in 2000.

Table 4: Dry weight of *Solegnathus* pipehorses purchased and exported for all processors combined in 1999 and 2000, showing the proportion of *S. hardwickii* of the total export. [a] includes wet weight purchases converted to dry weight assuming wet:dry = 62:27. [b] purchase amounts are less than export amounts because some processors did not provide purchase data, only exports. n/a (not available), as species not specified by all processors.

Period	Purchased[a,b] (kg)	Exported (kg)	% *S. hardwickii*
1999 (Jun – Dec)	362	622	n/a
2000 (Jan – Dec)	700	837	61
Total	**1062**	**1459**	

Purchases

Purchases in 2000 amounted to 700 kg, which equates to 25 926 pipehorses (assuming an average dry weight of 27 g per dried pipehorse (from section 5.2)). Pipehorses are traded at nine ports along the Queensland coast (Figure 1). No records of purchases were made from the ports of Mooloolaba and Southport during this study, however anecdotal evidence provided by fishers indicated that trade occurred from these ports prior to this study. Processors made purchases either directly from trawlers at the wharves, from wholesalers, or from one another. In total, 77 parties were recorded as selling pipehorses to processors, however much of the catch from the southern ports was purchased from wholesalers, therefore sales direct from trawlers went unrecorded and the total number of parties selling pipehorses was underestimated. All four processors purchased pipehorses, however only three of these exported.

5.2 Biology

Morphological measurements

Dry weight had a significant linear relationship with wet weight, allowing accurate estimations of dry weight from wet weight (Figure 7). On average, a pipehorse weighed 62 g (wet weight), corresponding to 27 g (dry weight). For pipehorses between 320 and 494 mm, and 23 and 121 g (ww), there was a linear relationship between wet weight and total length for both males and females (Figure 8), and a significant difference in the slope of the length-weight relationship between males and females (ANCOVA: interaction term testing homogeneity of slopes, $p = 0.043$).

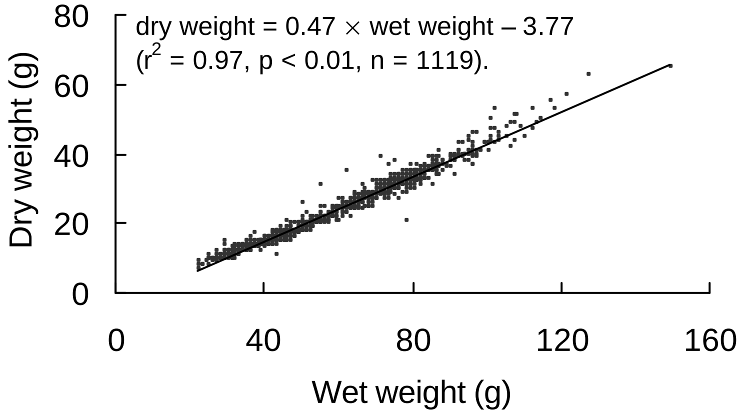

Figure 7: Relationship between wet and dry weight of *S. hardwickii*.

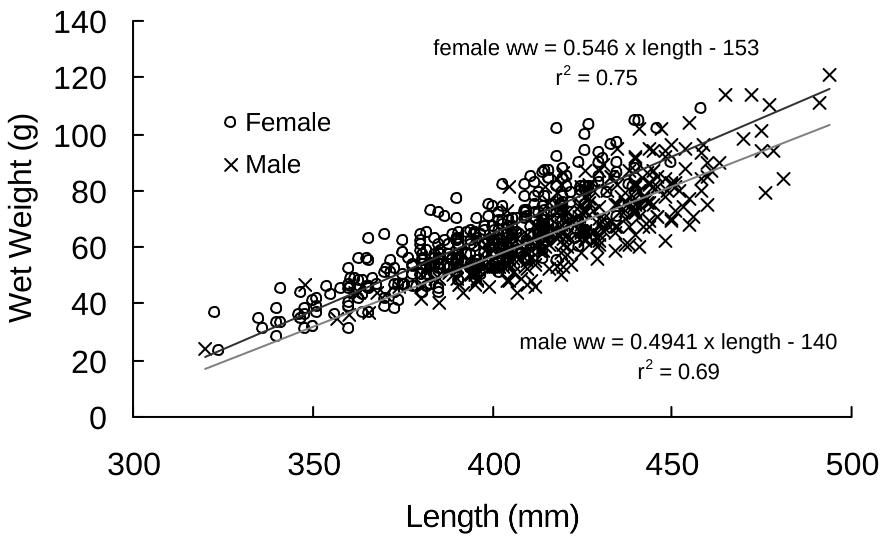

Figure 8: Relationship between wet weight and length of male (n = 327) and female (n = 322) *S. hardwickii*.

Male *S. hardwickii* were consistently larger (in length and weight) than females (Figure 9, Table 5, K-S test, p<0.001 for both length and weight). The length (Figure 9) and weight (Table 5) of male *S. dunckeri* were not significantly greater than females (K-S test: p = 0.40 and p = 0.14, respectively), however far fewer *S. dunckeri* were measured. *S. hardwickii* were significantly larger (length and weight) than *S. dunckeri* (K-S test: p < 0.001 for both length and weight).

Overall, size distributions of pipehorses measured from the northern region processors were significantly smaller (K-S test: p<0.001) than those measured by the southern region processors (Figure 10).

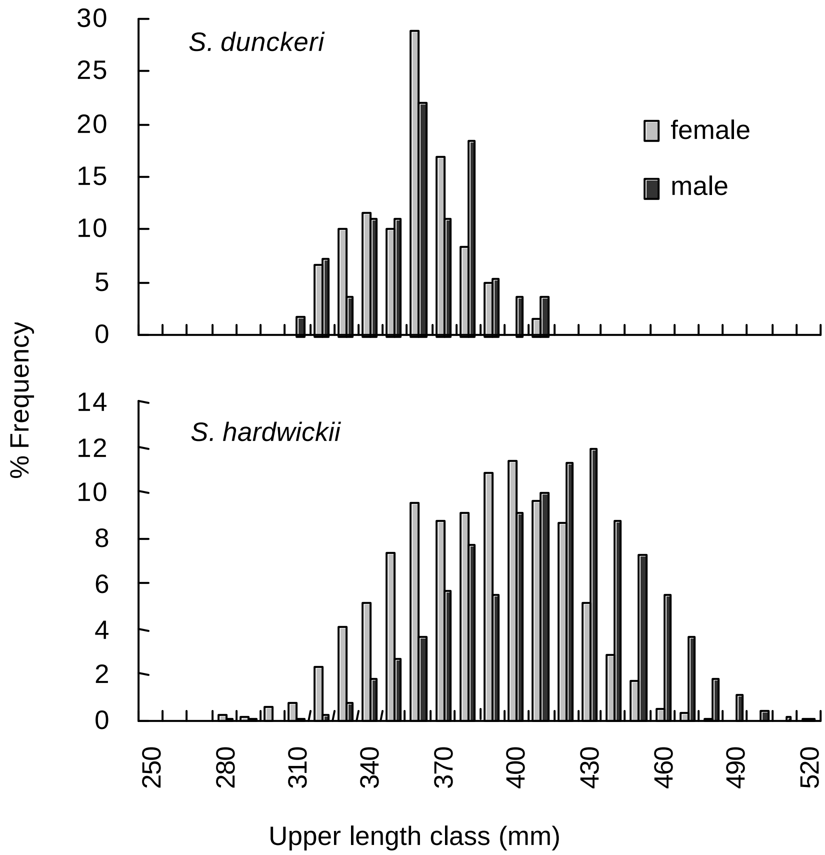

Figure 9: Lengths of *S. dunckeri* males (n = 54) and females (n = 59) and *S. hardwickii* males (n = 1247) and females (n = 1220).

Table 5: The wet weight (g) of male and female *S. hardwickii* and *S. dunckeri*.

Species	Sex	n	Mode	Mean	Standard Error	Range
S. hardwickii	M	1247	70	64.5	0.6	19-149
	F	1221	50	55.4	0.6	13-127
S. dunckeri	M	54	30	30	1.8	6-60
	F	59	30	35	1.7	10-65

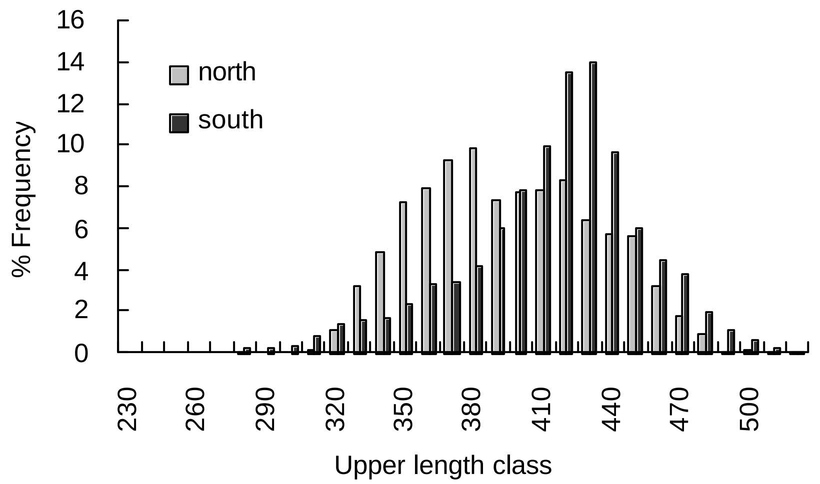

Figure 10: Comparison of *S. hardwickii* lengths from the northern (n = 1051) and southern (n = 2852) regions.

Reproductive biology

Pipehorses with sexes identified were available for 14 of the 20 months of study. Males with egg scars were present in all of these 14 months (Figure 11). Compressing the information by month identifies only two months where data were not provided (February and March), however, in adjacent months (January and April) approximately 30% of the males had egg scars suggesting that breeding occurs throughout the year. The percentage of egg-scarred males was lowest in June (0% in 1999 and 3% in 2000), then increased in the following three months (peaking at 63% in July 2000 and 67% in September 1999), and then decreased to around 30% from November to January 2001. This identifies mid-winter (July) to spring (September) as the peak breeding period, and early winter as the period with fewest egg scarred males. For the remainder of the year, egg scarred males represent 20 to 40% of all males.

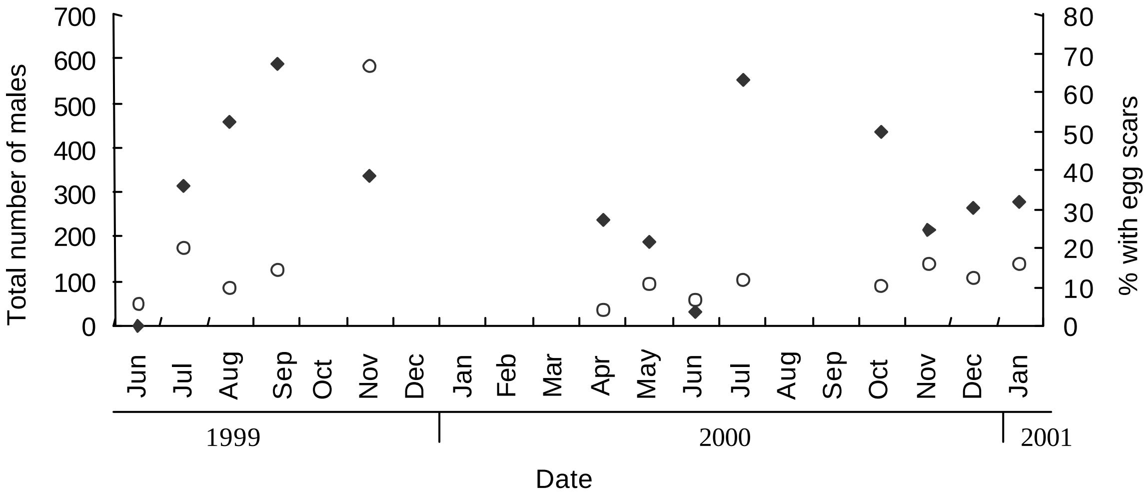

Figure 11: The total number of males (circles), and percentage of males with egg scars (diamonds), for the period June 1999 to January 2001. Only four pipehorses from the total were less than 320 mm (the minimum length at maturity).

Pipehorses less than 320 mm in length were present in 13 of the 15 months where data were available, and occurred with no apparent annual or seasonal trends. Three pipehorses (measuring 214 – 225 mm, that could not be sexed) were caught by a deep water trawler operating in October. Six pipehorses less than 240 mm were caught during the October 2000 QFS survey, only one of which could be sexed (female, 239 mm), whilst all others (average 170 ± 1.6 (s.e.) mm, range 136 – 230 mm) were considered juveniles. The presence of small pipehorses throughout the year is a consequence of breeding throughout the year, however a recruitment pulse is expected in response to the peak breeding period. Analysis of length frequency distributions from the region north of Bowen (see Growth rate, below) identifies April as the time of peak recruitment. The minimum size at maturity for males was 322 mm and the size at which 50% of pipehorses had egg scars was 420 mm.

The lengths of mature *S. hardwickii* males with egg scars were significantly greater than the lengths of males without egg scars (K-S test: p< 0.001, Figure 12), however the lengths of *S. dunckeri* males with and without egg scars were not significantly different (n = 33 with egg scars, n = 21 without egg scars, K-S test: p = 0.177). The number of egg scars ranged between 19 and 207 (mean 117 ± 64 (s.d.), n=6) on *S. hardwickii* and between 29 and 120 (mean 84 ± 24 (s.d.), n= 16) on *S. dunckeri*. We could not demonstrate a correlation between egg numbers and male length for either species (Regression test: p = 0.057 for *S. dunckeri*, insufficient data for *S. hardwickii*).

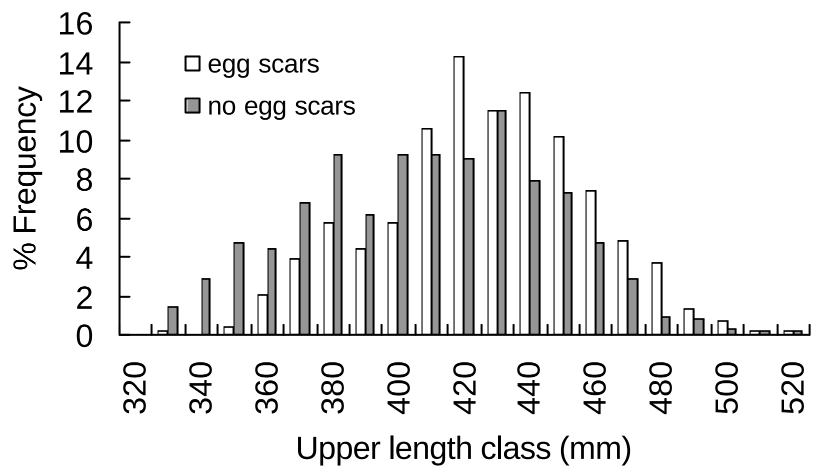

Figure 12: Lengths of mature *S. hardwickii* males with (n = 434) and without (n = 617) egg scars.

The pregnant *S. hardwickii* male caught during the 1999 QFS survey had 42 embryos attached and a total of 97 egg scars. Whilst still attached to the male the embryos were coiled into an oval shape measuring an average of 6 × 4 mm. When straightened the embryos measured 33 ± 0.9 (s.d.) mm (n = 14) from the tip of the snout to the tip of the tail. All embryos possessed a tiny yolk sac, indicating a late developmental stage, hence they were considered late stage embryos, and the lengths were used for growth rate determinations.

Growth rates

Data for length frequency distributions for the region north of Bowen were available for only 10 months of the 20 month study period because of the northern fishing closure which excludes fishing during January to March (Table 1) and the limited information supplied by processors in some other months. Length frequency distributions of male and female pipehorses in June and July 1999 and males in April 2000 show two cohorts in the population (Figures 13 and 14). The cohort of larger fish cannot be identified after July, however the modal lengths of the smaller cohort gradually increase throughout the latter half of 1999, progressing by 60 to 90 mm for females and males respectively (Figure 13 and 14). This equates to a growth rate of 0.33 mm. d^{-1} for females and 0.5 mm. d^{-1} for males, from June to November 1999 (Figure 15). During April to November in the following year, modal length progressed by 60 and 70 mm for females and males respectively, equating to growth rates of 0.25 mm. d^{-1} for females and 0.29 mm. d^{-1} for males (Figure 15). In both years, modal lengths approach 400 and 430 mm by November/December, which is the overall modal length for female and male *S. hardwickii*, respectively (Figure 9). For pipehorses greater than about 400 mm, modal progression is slight and growth rates difficult to determine.

If the peak reproductive period is assumed to be from mid-winter to early spring (July to September), hatchlings may appear as early as August. The modal lengths of females (350 mm) and males (360 mm) in April 2000 were lower than the modal lengths in November 1999, signalling the arrival of a new cohort (Figure 15). Therefore, hatchlings averaging 33 mm, arriving in August, reach approximately 355 mm by April, giving a corresponding growth rate of 1.2 mm. d^{-1}. For the remaining period (May to November) when adult sizes are attained (415 mm, averaged for males and females), the growth rate is 0.3 mm. d^{-1}.

Otolith ageing

Otolith preparation

There was little size difference between asterisci, lapilli and sagittae. The sagittae were elongate to rectangular in shape, the lapilli diamond shaped, and the asterisci circular to square (Figure 16). Analysis of the asterisci, which displayed the clearest resolution of internal structure (Table 6), identified three to five alternating opaque and translucent zones toward the periphery of the otolith (Figure 17) which corresponded with changes in the otolith surface. Fine increments were visible in 30% of asterisci, but never along the entire otolith profile, whereas alternating opaque and translucent zones (potential annuli) were visible in 100% of the unprepared asterisci (Table 6). Burning of unprepared asterisci increased the visibility of potential annuli, however it did not reveal annuli in ground otoliths that did not display potential annuli before burning.

Otoliths from embryos had a radius similar to the radius of what was identified as the core (identifiable by a prominent check in the profile) in adult otoliths, validating the structural interpretation of adult asterisci and supporting the interpretation of annuli. Estimates of age (below) were made assuming the interpretation of annuli were correct, however this needs further verification.

Estimating age

Using Fowler's (1990) classification system, 37% of asterisci had an uninterpretable internal structure (class 1), and 38% were difficult to interpret and had potential annuli that were hard to identify (class 2), largely due to the small, dense nature of the otolith. An age range of 3 to 5 years was estimated for otoliths containing interpretable annuli (class 2 and 3). For the pipehorses investigated (380 to 510 mm in length), the relationship between estimated age and pipehorse length was not significant ($r^2 = 0.06$, $p = 0.22$, $n = 26$).

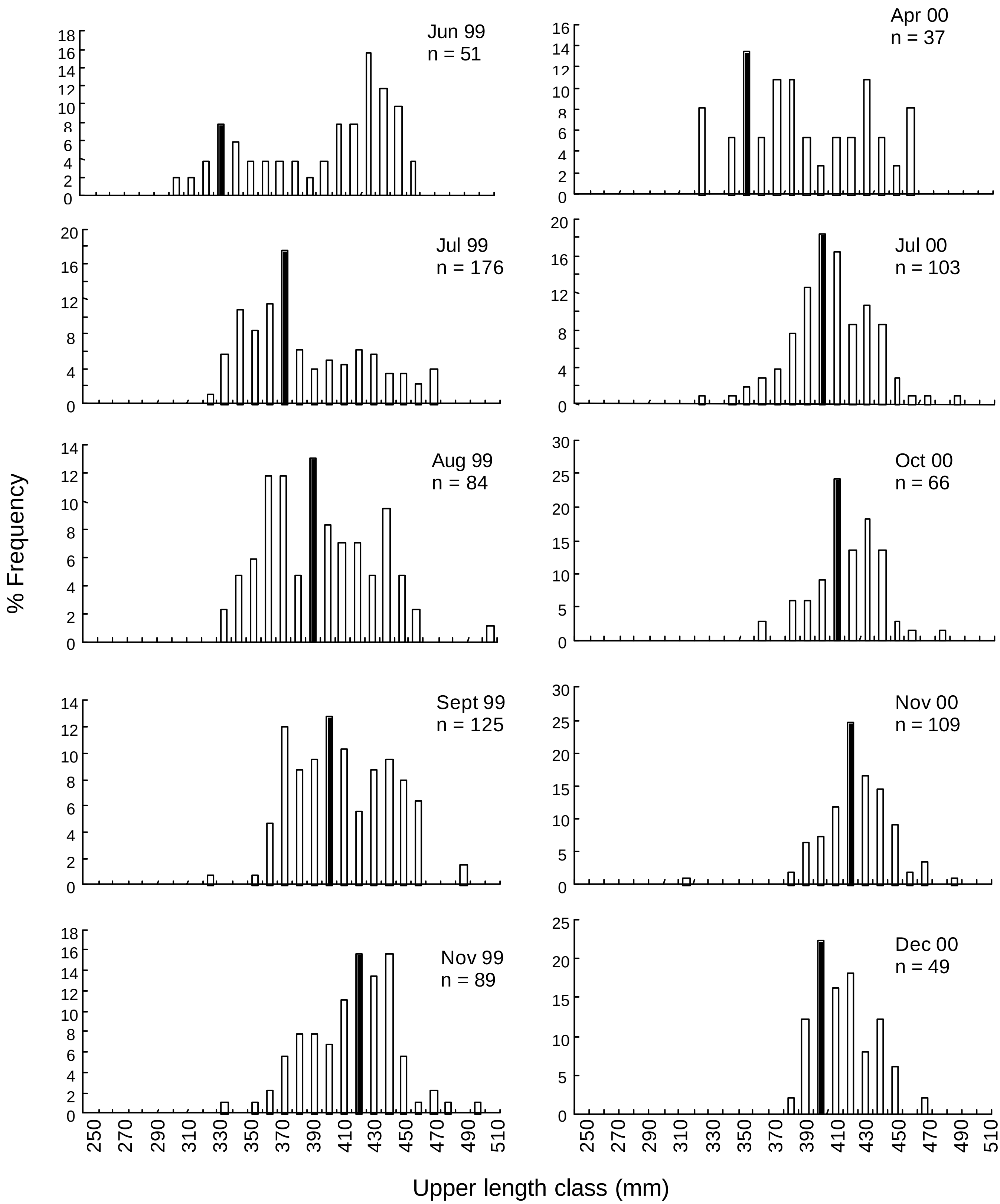

Figure 13: Monthly length frequency distributions for male *S. hardwickii* during June 1999 to December 2000. Shaded columns indicate the modal length of the smallest cohort.

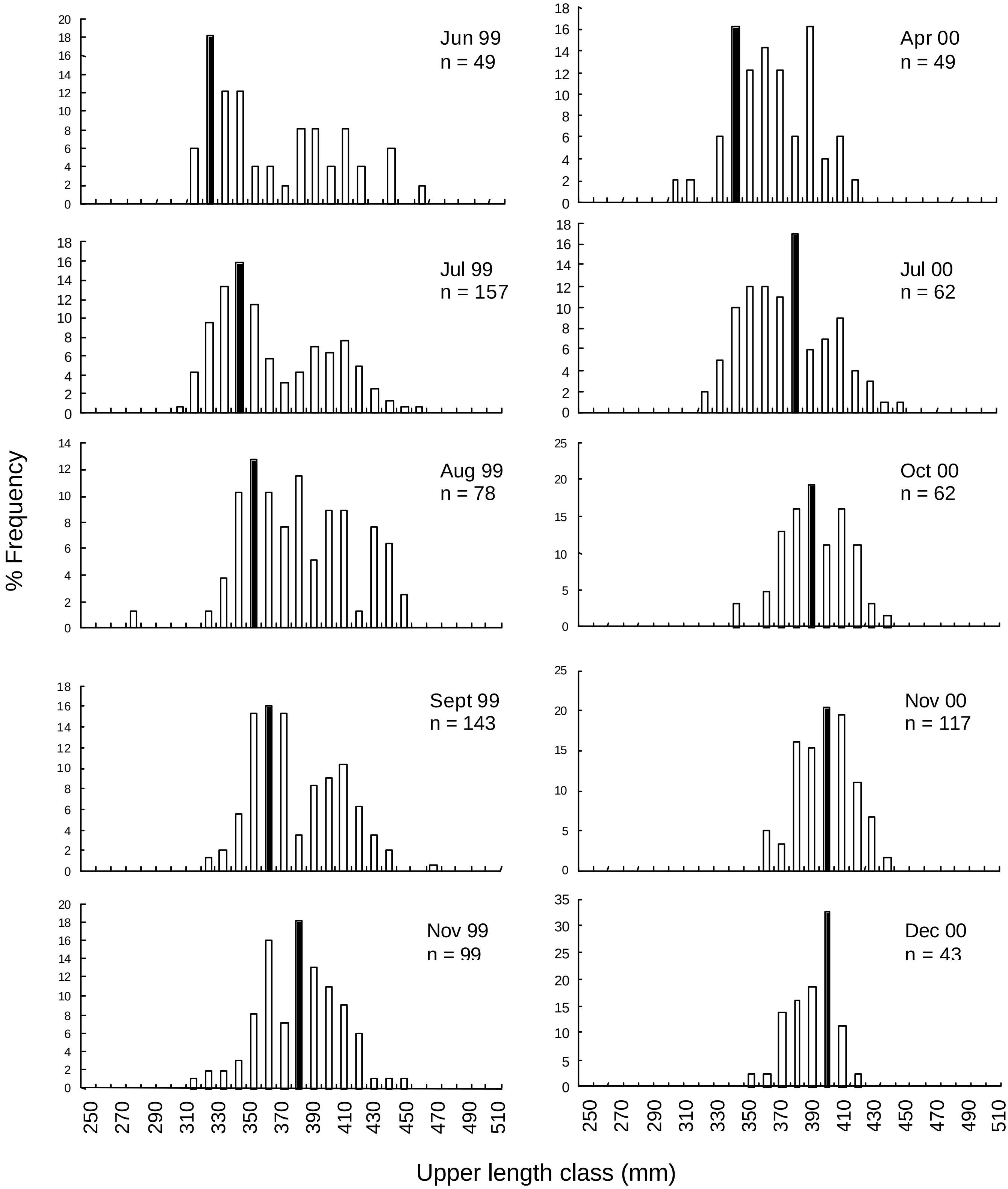

Figure 14: Monthly length frequency distributions for female *S. hardwickii* during June 1999 to December 2000. Shaded columns indicate the modal length of the smallest cohort.

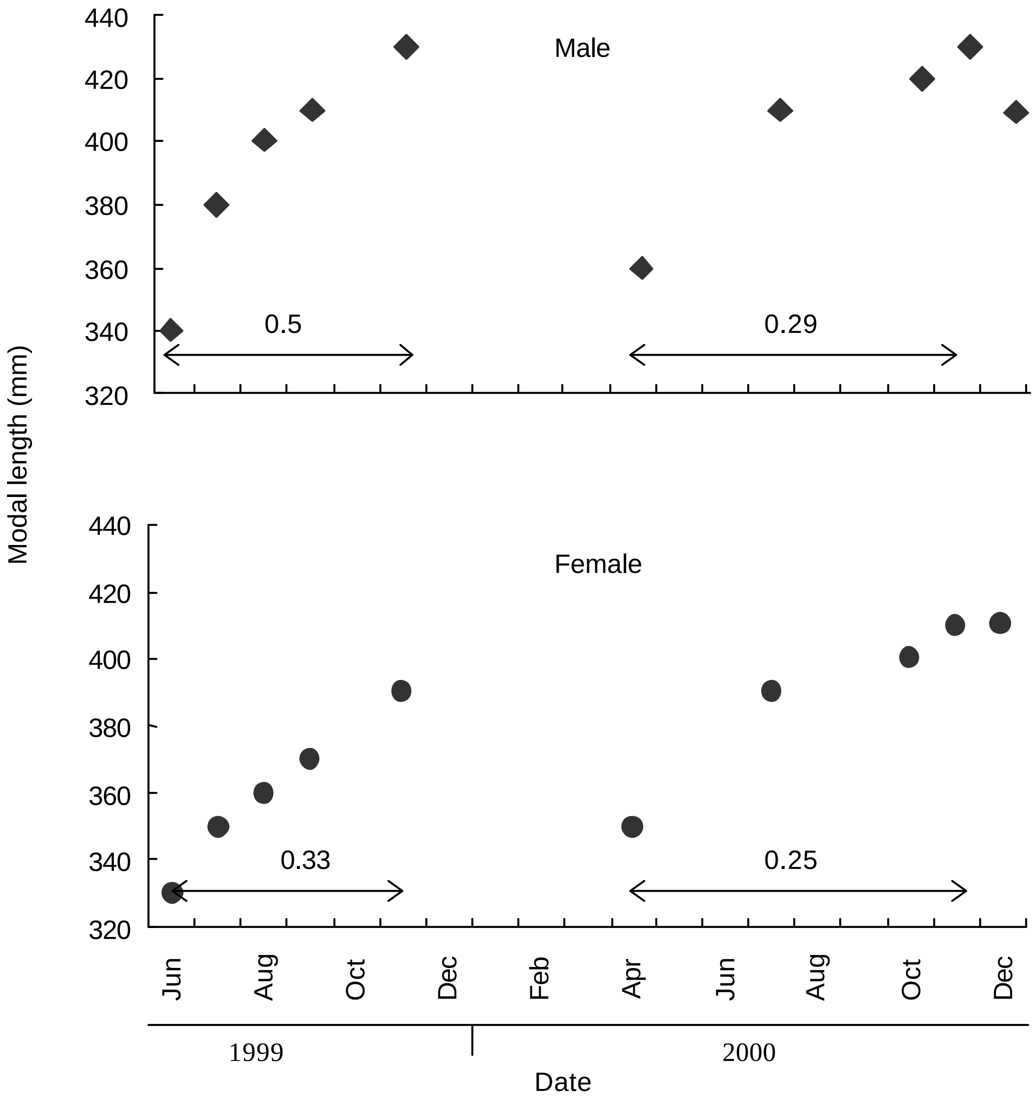

Figure 15: Modal progression for male and female *S. hardwickii* for the period June 1999 to December 2000. Growth rates (mm. d^{-1}) are shown above arrows, which indicate the period over which they are calculated.

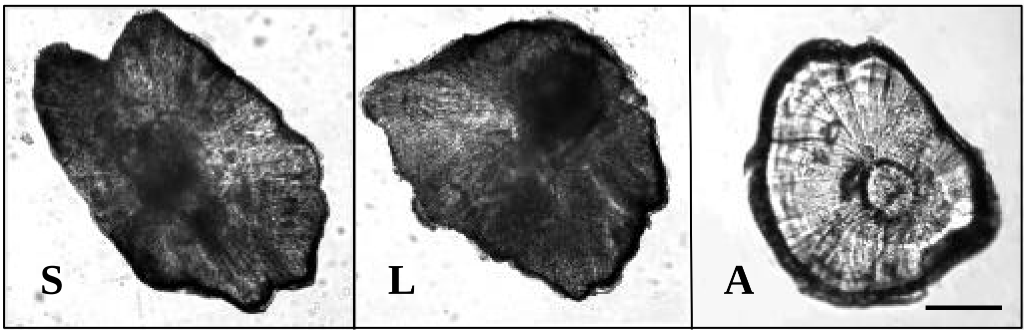

Figure 16: Sagitta (S), lapillus (L) and asteriscus (A) of *S. hardwickii*, showing the very dense structure of sagittae and lapilli and small size difference between the otolith types. All otoliths on same scale, scale bar = 100 µm.

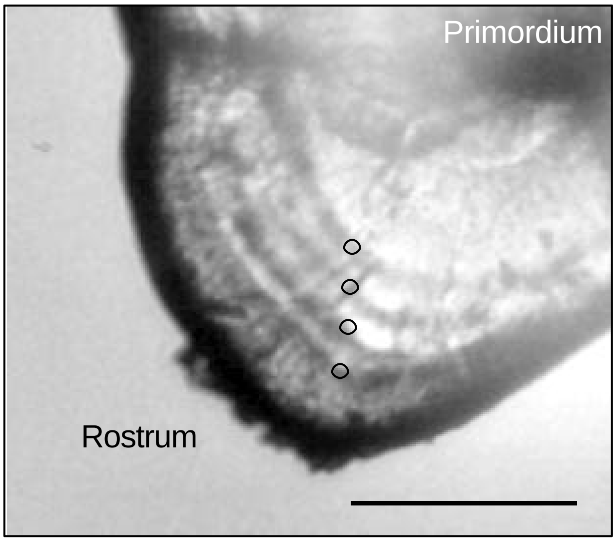

Figure 17: *S. hardwickii* asteriscus showing four opaque and translucent bands which were termed potential annuli (circles). Scale bar = 100 µm.

Table 6: Number of annuli/increments observed in *S. hardwickii* otoliths for the two preparation techniques where internal structure was observed (S = sagittae, L = lapilli, A = asterisci).

Preparation	No. of otoliths	Otolith type	Structure observed	Percentage of otoliths with potential annuli/ increments
No preparation	10	S	increments	0
			annuli	0
	10	L	increments	0
			annuli	0
	10	A	increments	30
			annuli	100
No preparation oven burnt	5	S	increments	0
			annuli	10
	5	L	increments	0
			annuli	0
	5	A	increments	30
			annuli	100

6.0 Discussion

6.1 Distribution, Catch and Trade

Distribution

The distribution of *S. hardwickii* bycatch determined in the present study is well within the extensive distribution of this species from Cairns (16°55'S) to south of the Tweed River (28°10'S) in NSW recorded by the Australian museum (Pogonoski 2001). Bycatch locations of *S. dunckeri* offshore from Fraser Island were consistent with the northernmost distribution recorded by the Australian museum, however the southernmost distribution could not be determined as only the port of purchase, and not the location of catch, was recorded for much of the material sourced from this region. *S. dunckeri* has been recorded as far south as Booti Booti near Forster, in northern NSW (32°16'S) (Pogonoski 2001).

Neither *Solegnathus* species was caught at depths less than 25 m, suggesting that they do not inhabit shallow inshore waters. Fisheries operating in these waters (Banana, Tiger, Endeavour and Bay Prawn, Table 1) are therefore unlikely to catch these *Solegnathus* species. An investigation into bycatch in the Banana Prawn Fishery did not record any syngnathids (Stobutzki et al. 2000), and syngnathids are not mentioned in other reports on bycatch in trawl fisheries operating on Queensland's east coast (Jones and Derbyshire 1988, Watson et al. 1990, Poiner et al. 1998). The locations and depths of other fishing sectors in the QECTF (Red Spot and Eastern King Prawn, Scallop and Stout Whiting, Table 1) overlap with the depth distribution of *Solegnathus* species and future investigations should focus on these sectors.

The extent of pipehorse bycatch seems to depend on the topography of the seabed trawled. An anecdotal account by a trawl fisher, reported by Vincent (1996), indicates that few pipehorses are associated with open sandy seabeds where trawlers traditionally operate, whereas selective trawling among rocky reef and sponge bed areas results in greater pipehorse bycatch. This opinion was reiterated during interviews with trawl fishers in the present study (P. Seib and J. Rogers pers. comm.). Advances in fishing gear technology (depth sounders that give seabed profiles) that enable trawling among or close to reefs are likely to result in greater *Solegnathus* bycatch. For example, an unusually large catch of *Solegnathus* (reportedly 1000 kg ww) was made during six days of selective scallop trawling among reefs near Double Is. Point (25°54'S) (P. Seib, pers. comm.). There are also reports of greater numbers of pipehorses being caught following storms or unusual tidal patterns as a result of pipehorses being forced off reefs and onto adjacent sand areas (P. Seib, pers. comm.). The pipehorse distribution reported is indicative only of bycatch densities in trawled regions (with the exception of the QFS survey), and our greatest knowledge gap is that the actual population densities and distributions are unknown. The relatively low bycatch rate in trawled areas implies pipehorses are sparsely distributed in these regions, however, nothing can yet be concluded regarding their distribution in non trawled areas and considerable effort will be required to sample such areas. It is possible that areas unfavourable to trawling (such as reefs or soft sediment with three-dimensional sessile biota) are favoured habitats for pipehorses, harbouring significant populations from which the bycatch proportion is sourced.

Catch rates

Monthly logbook CPUE for syngnathid bycatch varied between regions and with time of year, but was notably lower than the CPUE calculated from northern and southern processor purchases and from the 2000 QFS survey. Logbook fishing effort recording syngnathid bycatch represented only a small fraction of the total fishing effort, and catch frequencies of syngnathids, whilst highly variable, were generally very low. Logbook catch includes all syngnathids, of which approximately 15% are likely to be species other than *Solegnathus* if results from the QFS survey are used as a guide. Other studies have not reported syngnathid bycatch in trawl fisheries operating in Queensland's east coast waters (Jones and Derbyshire 1988, Watson et al. 1990, Poiner et al. 1998, Stobutzki et al. 2000), however pipefish species other than *Solegnathus* pipehorses were recorded, although very infrequently, from the Northern Prawn Trawl Fishery and Torres Strait Prawn Fishery (Stobutzki et al. 2000).

The use of logbooks to quantify bycatch is a simple but potentially unreliable method (Jermyn and Robb 1981, Hudon 1990). Admittedly, the introduction of syngnathid bycatch to the OT07 logbook is only recent, and such a change in the method of reporting catch should be taken into consideration when interpreting the CPUEs reported. However, the future of the industries (both trawl fishing and syngnathid exports) are reliant on obtaining accurate information about fishing practices. Therefore the detail requested is important and necessary in order to instigate management regimes to ensure sustainable fishing practices. Ideally, independent validation of the logbook data is necessary to confirm the data reported, however this would involve considerable costs. The distribution of the identification kit (Appendix 3) would assist with accurate completion of logbooks.

Trade

The monthly export rate for *Solegnathus* species in 2000 averaged 70 kg (dw) per month (837 kg. y^{-1}). If we assume that the exports from June to December 1999 are representative of exports throughout the year, the monthly export rate in 1999 was 89 kg (dw) per month (1 068 kg. y^{-1}). These figures are consistent with annual import data from Hong Kong and Taiwan of 857 kg in 2000 and 1 241 kg in 1999 (Martin-Smith, unpubl. data). The monthly export figures from this study are comparable to the preliminary export estimates of 80 – 90 kg (dw) per month during the years leading up to 1992 (Vincent 1996). However, records from Environment Australia (unpublished) indicate that exports in 1998 were 238 kg per month, meaning that exports (and presumably catch) were 70% lower in 2000 than in 1998. During the present study, lower than average catches have been commented upon by some processors, as evidenced by companies exporting less frequently than usual due to insufficient material being available to warrant a shipment. It should be noted, however, that the decline in exports does not necessarily indicate a decline in CPUE. Furthermore, we emphasise that even if CPUE was lower in 2000 than 1998, there is no evidence that this is due to effects of fishing.

Lower pipehorse exports and the presumed lower catch could result from either fewer pipehorses being present (due to environmental factors or fishing pressure) and/or fewer pipehorses being caught because of characteristics of the target fishery and/or recent management regulations such as regional or seasonal closures, the introduction of bycatch reduction devices (BRDs), and limiting the number of trawl licenses and fishing days (QFS 2001). Temporal variation in species abundance depends partly on environmental disturbances (e.g. unfavourable conditions including unusual currents and lower temperatures), and a decline in pipehorse catch could result solely from environmental fluctuations. A longer period of investigation is necessary to determine baseline data on pipehorse abundance. Alternatively, characteristics of the target species fishery may affect bycatch, resulting in variable bycatch rates that may not reflect actual variability in pipehorse abundance over time. Characteristics of the trawl fishery that may influence the rate of bycatch include: the fishery not being in its peak prior to the authority period, the trawl fleet experiencing lower than expected catches in target species, the trawl fleet chasing inshore target species where pipehorses are generally not caught, market demand influencing prices and hence fisheries targeted (i.e. tiger prawns targeted instead of king prawns because of higher market price of tiger prawns), and temporary closures of fishing sectors.

Management implications

The 2000 bycatch of *Solegnathus* species (1 610 kg (ww), estimated from purchases) constitutes only a small fraction of the annual target fisheries catch (5 317 t, averaged for 1997 and 1998 (DPI, 2001b)) for fisheries that trawl at depths where *Solegnathus* are distributed (Eastern King Prawn, Red-spot King Prawn, Stout Whiting and Scallop). Nevertheless, concern for the control of syngnathid bycatch resulted in a draft recommendation to limit catch to a maximum of 5 kg (ww) pipehorses per boat per day (QFMA 1998). This recommendation, however, had to be made without knowing catch rates, and the suggested limit is 100 times greater than the overall CPUE of approximately 50 g (ww) pipehorses. boat day^{-1} estimated in this study (assuming 0.8 pipehorses. boat day^{-1}, and 62 g (ww) per pipehorse). About 6% of the effort in the QECTF actually catches syngnathids. Syngnathid catch frequencies are highly variable (1-100 syngnathids. boat day^{-1}), however 84% of boats catch ten or fewer syngnathids (620 g or less, assuming 62 g ww per syngnathid), which is 12% of the catch limit formerly suggested (QFMA 1998). In 2000, only one incident was reported in the logbooks where more than 5 kg ($\geq$81 syngnathids) was caught. The implementation of a catch limit for pipehorses is, in any case, problematic, given that the majority of specimens are in very poor condition when they are emptied from the net and less than 10% are likely to survive if returned to the sea (M. Dredge, unpubl. data). Currently the arrangements for permitted fish are under review, however the implementation of a catch limit is not seen as practical because of the relatively low catch and high mortality of pipehorses, and because they are not a targeted species (QFS 2001).

The introduction of BRDs has resulted in substantial reductions in the total bycatch associated with trawl fishing (QFMA 1996), however the introduction of BRDs designed specifically for pipehorses are problematic given the relatively low catch rate of *Solegnathus* and their elongate shape (which makes them susceptible to entanglement in nets). Bycatch of *Solegnathus* could be minimised by restricting fishing in regions favourable to pipehorses. Pipehorse distribution is likely to be related to proximity to reefs, however the preferred habitat and actual distribution of *Solegnathus* needs further investigation. This would involve a more extensive study over a longer period and a wider area, comparing CPUE of pipehorses in trawled and un-trawled areas (in a manner similar to the QFS surveys). The ultimate objectives should be to determine the proportion of the total population of pipehorses caught by trawlers, identify favourable habitat, and therefore justify decisions regarding the restricting of fishing in these areas, if such measures were deemed necessary. Management strategies introduced by QFS, including restricting the number of fishing days and fishing licenses, the introduction of BRDs, gear restrictions and regional and seasonal closures (QFS 2001) are aimed at cumulatively reducing the catch of all species by the QECTF and therefore reducing impact of the fishery to ensure its sustainability for the future.

6.2 Biology

Spatial variation

On average, larger *S. hardwickii* were caught from the southern region. Differences in environmental variables such as temperature could favour larger pipehorses in the cooler southern region, since lower temperatures are in general correlated with slower growth rates and larger adult sizes. The greater frequency of larger pipehorses caught in the southern region could result from smaller pipehorses escaping from the larger mesh size used for scallop trawling in comparison to the smaller mesh size used for prawn trawling.

The extent of movement by *S. hardwickii* or *S. dunckeri* is unknown, but movement patterns have been measured in other syngnathid species, with home ranges varying from 1 m^2 for a seahorse during the breeding season (Vincent and Sadler 1995) to 100 m^2 for a pipefish (Gronell 1984). Seasonal migrations have also been recorded. *Syngnathus fuscus* migrates seasonally up to hundreds of kilometres into deeper offshore waters during winter (Lazarri and Able 1990) and *Syngnathus leptorhynchus* migrates away from lower estuarine sites in summer (Bayer 1980). Greater mobility and a wider habitat range are characteristics of species possessing a well developed caudal fin, whereas species that lack a caudal fin and have prehensile tails are likely to be more sedentary (Howard and Koehn 1985). This suggests that *Solegnathus* species (which lack a caudal fin) do not move large distances, however whether this limits migration and interbreeding of populations remains to be investigated. Such behaviour has implications for the rate of repopulation of an area, if numbers are depleted either by environmental factors or by trawling.

Reproductive biology

S. hardwickii was shown to breed throughout the year, with the continual presence of pipehorses with egg scars. Although the possibility exists that egg scars on pipehorses persist long after breeding, this has not been noted for other syngnathid species, and we are confident that the interpretation of year round breeding is correct. Breeding throughout the year is documented for only one other syngnathid species, the seahorse *Hippocampus comes*, however other species from the tropics typically have longer breeding seasons than their temperate counterparts (Lourie et al. 1999). Assuming that breeding occurs throughout the year, recruitment also occurs year round. A peak in breeding activity was detected as a higher proportion of males with egg scars, and an associated peak in recruitment is expected to follow. Since relatively few small pipehorses were measured (either because of their greater likelihood of escaping the net and/or occurrence in habitats other than those trawled), analysis of length distributions to identify the arrival of new cohorts was difficult.

Comparisons of reproductive biology of *S. hardwickii* were made with two similar - sized syngnathid species which occur in Australian waters: the weedy seadragon (*Phyllopteryx taeniolatus*) and the leafy seadragon (*Phycodurus eques*), in addition to several other large syngnathids (Table 7). The length of late stage *S. hardwickii* embryos is greater than the length of double ended pipefish hatchlings (*Syngnathoides biaculeatus*) (Takahashi 2000) and weedy seadragon hatchlings (Kuiter 1987), but comparable to the length of leafy seadragon hatchlings (Kuiter 1987) (Table 7). Both *P. taeniolatus* and *P. eques* attain adult sizes similar to *S. hardwickii* and all have simple external glueing of the eggs to the male's tail. Brood size estimates from egg scars on *S. hardwickii* and *S. dunckeri* are similarly comparable to the brood size of the weedy and leafy seadragon (Table 7). The brood size of these pipehorses and seadragons is small in comparison to some seahorses (Vincent 1996) and pipefish (Campbell and Able 1998), which produce over a thousand eggs per brood. However, the total fecundity of *S. hardwickii* may be large given that breeding can occur throughout the year.

The significantly greater length of mature *S. hardwickii* males with egg scars compared to those without suggests that mate selection is occurring. Mate selection may occur by females choosing to mate with larger males, as is the case in *Syngnathus typhle* (Berglund et al. 1986). Alternatively, larger males may out-compete smaller males for access to females. Male *Hippocampus zosterae* (Lourie et al. 1999) and *Hippocampus fuscus* (Vincent 1994) compete to a greater extent than females for access to mates. In *H. fuscus*, aggressive behaviours (wrestling and snapping) are exhibited between rival males and larger males are dominant (Vincent 1994), thus gaining access to females more often. Aggressive dominance by larger *S. hardwickii* males may result in a greater proportion of larger males with egg scars.

Growth rates

Growth rates of *S. hardwickii* were compared with syngnathids of similar size, viz. the seadragons *Phyllopteryx taeniolatus* and *Phycodurus eques* (Table 7). The estimated growth rate of *S. hardwickii* during the first eight to nine months (1.2 mm. d^{-1}) is similar to the growth rates of seadragon juveniles (Table 7). The juvenile growth rate of 1.2 mm. d^{-1} is equivalent to the first year growth rate of the northern pipefish, *Syngnathus fuscus,* collected from the field (Campbell and Able 1998), and comparable to the growth rate of 0.8 – 2.3 mm. d^{-1} for laboratory-reared juvenile *Syngnathoides biaculeatus* (Takahashi 2000). The growth rate of pipehorses approaching adult size (0.3 - 0.5 mm. d^{-1}), is comparable to the growth rate of 0.3 mm. d^{-1} for mature female *Syngnathus typhle* (Berglund et al. 1989), and within the range of 0.3 – 0.8 mm. d^{-1} calculated for *S. biaculeatus* adults collected from the field (Takahashi 2000).

Otolith ageing

The asteriscus was identified as containing the clearest internal structure for age determination of *S. hardwickii*, even after burning and grinding of all otolith types. This is highly unusual, as the sagitta and/or lapilli are usually used for age determination in teleosts (Secor *et al.* 1992). The otoliths of *S. hardwickii* were exceptionally small (less than 550 µm maximum diameter), especially considering the average pipehorse length (456 mm), and their high density meant annuli resolution was poor in comparison to other species (e.g. Fowler and Short 1998). *S. hardwickii* otoliths were also unusual, in that the asteriscus was only marginally smaller than the sagittae, whereas in other species of fish, sagittae are often much larger than asterisci (e.g. 10 times larger in cod, Campana 1999). Age estimates of three to five years made from potential annuli are within the range estimated by population studies of other syngnathids (Lourie et al. 1999). One possible technique for validating pipehorse annuli is to mark pipehorses underwater using a tetracycline injection and retain them in underwater cages for several months. Another possibility is to inject pipehorses and re-capture them later using ultrasonic tracking devices. There was no significant relationship between age estimated from *S. hardwickii* asteriscus and pipehorse length, most likely because of the low number of interpretable otoliths and the limited size range of pipehorses (380 – 509 mm). Future studies should encompass larger sample sizes and a greater range of pipehorse lengths.

Management implications

Although pipehorses breed throughout the year, they appear to have a peak breeding period from mid-winter to early spring. Further investigation is required to determine the proportion of the population resulting from the peak breeding season in comparison to the remainder of the year. Fishing restrictions could be implemented during the peak breeding period to reduce the likelihood of capturing a pregnant male and therefore increase the potential fecundity of the species. However, the majority of the bycatch averaged 400 mm in length and was probably at least one year old, few immature pipehorses (<320 mm) were caught, and at least some of the pipehorses were 3 to 5 years old, therefore many pipehorses have most likely reproduced several times prior to capture. We cannot make a clear recommendation about the effect a closure during the peak breeding period would have without knowing the contribution offspring born at that time make to the whole population.

Biological information about a bycatch species, such as that collated for *Solegnathus hardwickii*, can be used to predict the sustainability of a species to bycatch. Stobutzki et al. (2000) assessed numerous bycatch species, and based upon the characteristics of each species, rated their susceptibility to, and potential recovery from, incidental bycatch in trawl fisheries. Characteristics of species that are highly susceptible to capture and mortality by trawls include: a benthic or demersal distribution, inhabiting soft sediments, greater night-time activity, a low rate of survival following capture, a diet that may include prawns, and a low likelihood of breeding prior to capture (Stobutzki et al. 2000). Conversely, species that are less susceptible to capture by trawls are pelagic, have a broad depth distribution, and are caught more frequently during the day than night. Analysis of the sustainability to bycatch by trawls has been conducted for only one syngnathid species, the pipefish, *Trachyrhamphus longirostris* (Stobutzki et al. 2000). Based on species characteristics, *T. longirostris* had a moderate to high susceptibility to capture and mortality, and a relatively low capacity to recover, in comparison to the 128 other teleost species investigated (Stobutzki et al. 2000). This resulted in the positioning of *T. longirostris* towards the middle of the scale of sustainability to bycatch by trawl fishing. Information from the present study identifies *Solegnathus* species as having a broad depth range, associating with both reef and soft sediment habitats, and having a high probability of breeding prior to capture. This mixture of characteristics of susceptibility and recovery to bycatch identifies *Solegnathus* as moderately sustainable to incidental bycatch by trawl fishing, similar to the rating for *T. longirostris*. To enable a better assessment of the sustainability of *Solegnathus* to bycatch by trawl fishing, future investigations should focus on clarifying species characteristics, particularly those of susceptibility to capture and mortality. This would require a more thorough investigation of the biology of *Solegnathus* to confirm the age at maturity and proportion of the bycatch that has bred prior to capture, and the distribution of both species relative to trawling activity.

In conclusion, data on CPUE and pipehorse sizes should continue to be recorded for at least the next 5 to10 years. These data should be used to establish whether population densities or sizes are changing, and to separate any effects of fishing from changes resulting from environmental fluctuations. An additional short-term solution is to estimate pipehorse densities and size distributions in un-trawled areas and compare these with estimates from trawled areas. A more thorough investigation of the biology of *Solegnathus* species is needed to clarify the age at maturity, the proportion of the population resulting from the peak breeding period, and to confirm the age structure of *Solegnathus* bycatch.

Table 7: Sizes, reproductive characteristics, and growth rates of some pipefish, pipehorses and seadragons. Ranges are given where available, otherwise only means are provided.

Species	Max. length (mm)	Length (mm)	Brood size	Egg size (mm)	Hatchling size (mm)	Growth rate (mm. d^{-1})	Reference
Syngnathoides biaculeatus	300	120-190	60 – 200 (153)	1.5	21	0.8 – 2.3 (juveniles) 0.3 – 0.8 (adult)	Takahashi 2000
Syngnathus typhle		155 (m) 156 (f)	23			0.3 (adult)	Berglund et al. 1989
Nerophis ophidion		197 (m) 295 (f)	396				Berglund et al. 1989
Syngnathus fuscus	85 - 245	<10 - 200				1.2 (first yr)	Campbell & Able 1998
Phycodurus eques	300		250	4 (late stage embryo)	35	1.8 – 3.3 (first 3 wks) 1.0 (first 4 mths) 0.5 (first yr)	Kuiter 1987
Phyllopteryx taeniolatus	460		200 - 300		25	3.6 (first 3 wks) 0.9 (first 6 mths) 0.6 (first yr)	Kuiter 1987
Solegnathus hardwickii	**515**	**430 (m) 400 (f)**	**19 – 207 (117)**	**5 (late stage embryo)**	**34**	**1.2 (hatchling to juvenile) 0.3 (adult)**	**present study**

7.0 Benefits

This study provides the first estimates of pipehorse catch rates and trade resulting from bycatch in the QECTF, and reports information about the distribution, size and age structure, reproductive characteristics and growth rate of two *Solegnathus* species. Given that pipehorse bycatch is the major source of export material from Australia for the Traditional Chinese Medicine market, it is important that pipehorse harvests are sustainable. Results from this study are being used by QFS in the revision of the management regime for syngnathid species caught incidentally as bycatch in the QECTF. QFS drafted management arrangements (QFMA 1998) prior to the current project, but had to do so without knowledge of catch rates or biology. This study will assist in the development of a sound management regime for syngnathid bycatch, based on scientific data, by directing discussions to key issues regarding syngnathid bycatch. This will contribute to the overall management and viability of the QECTF.

Information from this study will also assist Environment Australia, by providing information to assist with decisions regarding export authorisation. Benefits also extend to the public and scientific community. Conservation icons such as seahorses, pipefish and seadragons fuel public awareness regarding conservation issues, and the presentation of scientific data about syngnathid bycatch is necessary to properly educate and inform the community of appropriate conservation issues. The scientific community will benefit from the increased knowledge about the biology of a deep water syngnathid species resulting from this study.

8.0 Further Development

The results of this study are contributing to a management regime for syngnathid bycatch being prepared by QFS. This study provides the first estimates of pipehorse bycatch rates and trade in the QECTF and makes the link between catch and export. It reports information on distribution, size and age structure, reproductive characteristics and growth rate of two *Solegnathus* species. The outcomes of the study highlight gaps in knowledge, which need to be addressed in future investigations relating to syngnathid bycatch. To identify any fishery-induced changes in pipehorse populations, catch rates need to be collected over periods of at least 5-10 years. In order to maximise the collection of biological and fisheries information on *Solegnathus* bycatch, we believe that a sample of the *Solegnathus* purchased by processors should continue to be measured (using the information kit, Appendix 3). The current recording of syngnathid data in logbooks should continue, and be expanded to include the Stout Whiting fishery, preferably with common syngnathid species identified (at least to genus) and counted separately. This would enable a more accurate determination of the proportion of *Solegnathus* species represented within the syngnathid column in the logbooks, and so provide a more accurate record of the catch of these commercially important species. We therefore recommend a long-term, low intensity monitoring program on pipehorses. This will further our knowledge about the biology of *Solegnathus,* and in particular will determine if the size structure of the population is changing as a result of incidental bycatch. We strongly recommend that pipehorse densities and size distributions be measured in un-trawled areas and especially in any areas where trawl closures are being implemented. Comparing pipehorse densities in different areas will, however, require considerable sampling effort because of their relatively sparse distribution. In the absence of such research, management strategies introduced by QFS (QFS 2001) which aim to cumulatively reduce the catch of all species by the QECTF and therefore reduce impact of the fishery are being implemented to endeavour for sustainability for the future.

9.0 Conclusion

This project provides the first reliable estimates of catch rates and the resulting trade of *Solegnathus* species caught as incidental bycatch in the QECTF. This study also documents hitherto unknown information regarding the distribution, size and age structure, reproductive characteristics and growth rate of two species of *Solegnathus*. The objectives and our achievement with respect to them are detailed below.

1. Quantify catch rates and determine distribution of the two pipehorse species taken incidentally in trawl fisheries in Queensland.

- Bycatch of *Solegnathus hardwickii* was recorded from Innisfail to Mooloolaba, and bycatch of *Solegnathus dunckeri* from Fraser Is. to Mooloolaba. During the QFS surveys, pipehorses were caught only at depths greater than 25 m.

- During 2000, the CPUE calculated from processor plant purchases and the QFS survey ranged from 0.57 and 1.29 pipehorses. boat day^{-1}, and the CPUE determined from logbooks ranged from 0.23 to 0.27 syngnathids. boat day^{-1}.

- In 2000, 700 kg or about 25 900 pipehorses were purchased from the QECTF. Approximately the same quantity was exported, and this matched records of imports to the main markets in Hong Kong and Taiwan.

- For fisheries that overlap with the depth distribution of pipehorses, about 6% of the fishing effort actually catches syngnathids. For boat days on which syngnathids were caught, the modal catch frequency was 1 syngnathid. boat day^{-1}, with 25% of trips catching only one syngnathid and 84% catching between one and ten syngnathids. Logbook catch includes all syngnathids, of which approximately 15% are likely to be species other than *Solegnathus*.

2. Determine basic biological characteristics of pipehorses, including age structure, fecundity, longevity and recruitment timing.

- *S. hardwickii* caught in the southern region were larger than those from the northern region, and males are larger than females.

- The presence of egg scars on males throughout the year indicates that breeding occurred year round, with a peak from mid-winter to spring. Males became mature at about 320 mm.

- Growth rates of 1.2 mm. d^{-1} for juveniles and 0.3 mm. d^{-1} for adults were calculated from length frequency analysis. A sub-sample of adults was shown to have 3-5 potential annuli in their otoliths, possibly indicating ages of 3-5 years, although it remains for these annuli to be validated.

- Examination of the distribution and biological characteristics of *S. hardwickii* indicates that this species is moderately sustainable to incidental bycatch by trawl fishing.

3. Contribute to a management regime for syngnathid bycatch, based on new knowledge of catch rates, distribution and basic biology.

Prior to this study the lack of knowledge about the rate of bycatch of *Solegnathus* and the paucity of information regarding their biology meant that recommendations regarding syngnathid bycatch in the QECTF could not be substantiated. This study has provided the first account of the distribution, catch rate and basic biology of *Solegnathus*, all fundamental to guiding future management decisions in the fishery. As a result of this study, the following recommendations regarding syngnathid bycatch, based on demonstrable catch rates, levels of trade and consideration of biological characteristics of the species, are suggested.

- Future investigations regarding pipehorse bycatch in Queensland should focus on fishing sectors operating at depths greater than 25 m and therefore on the following species: red spot, blueleg and eastern king prawn, scallop and stout whiting.

- The current recording of syngnathid data in logbooks should continue, but should be expanded to include the Stout Whiting fishery, preferably with common syngnathid species identified (at least to genus).

- Data on CPUE and pipehorse sizes should continue to be recorded for at least the next 5 to10 years to be able to separate fishing effects from the effects of environmental fluctuations influencing population (and catch) densities. Even this long-term project may be inconclusive if fishing has already altered population densities or sizes.

- We strongly recommend that pipehorse densities and size distributions be measured in un-trawled areas and especially in any areas where trawl closures are being implemented. Comparing pipehorse densities in different areas will, however, require considerable sampling effort because of their relatively sparse distribution.

- Further investigation of the biology of *Solegnathus* species is needed to clarify the age at maturity, the proportion of the population resulting from the peak breeding period, and to confirm the age structure of *Solegnathus* bycatch.

- Presently, a catch limit for *Solegnathus* is not a practical solution to managing bycatch of syngnathids in the QECTF, and alternative strategies introduced by QFS (QFS 2001) aimed at cumulatively reducing the catch of all species and therefore reducing the impact of the fishery are supported.

10.0 References

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Appendix 1 – Intellectual property

No intellectual property issues have arisen or are expected to arise from this project.

Appendix 2 – Staff

The following is a list of staff who were was involved in this project. All are from Griffith University.

Principal Investigator

Dr Rod Connolly

Paid Staff

Dr Emma Cronin, Rodney Duffy, Keith Preston, Bonnie Thomas

Voluntary assistance

Karen Rudkin

Appendix 3 – Kit for recording pipehorse information

Instructions for recording fisheries data and biological information on pipefish (seadragons)

Fisheries information

This information is about obtaining an overall perspective of where along the QLD coast pipefish are landed, and at what times of the year. The quantity of pipefish catch will also be estimated. These data will be recorded for two species, *Solegnathus hardwickii* and *Solegnathus dunckeri.*

- In monthly summaries, please record the total dry weight (or wet weight) of all fish brought into the processing plant by each fisher, fisher company or wholesaler. Also, record the ports from which the trades took place (see examples in data sheet). Please use the sheet labeled "Fisheries data sheet" to record this information.

Biological information

Selection of two areas

- Please choose two areas, each approximately one Cfish grid number (e.g. L21) in size, which you think will be a reliable source of pipefishes over the six-month authority period. If possible, pipefish from these areas will be used to collect biological information throughout the six-month authority period. At any time if supply is low, measurements can be taken on pipefish from other areas. If you are unable to record the location of catch (logistical reasons or because trawlers are "roaming"), then measurements can be done on any 200 pipefish.

When to collect biological information:

- By the end of each month, if supply permits, **100 fish from each of the two areas are to be measured** (a total of 200 pipefish measured per month). For a particular area, if a sample of 100 pipefish can be obtained from one time (pipefish caught on one day or within a few days), then these will be the pipefish that get measured. If in that month, pipefish cannot be obtained from the chosen areas, please collect pipefish from other areas. If there are more than 100 pipefish from the same area and time, then a procedure for randomly choosing100 pipefish from the total catch is to be used (see below).

- To take a random sample of 100 fish when catch exceeds 100 for a particular area, spread total catch (from which 100 fish will be selected) out along a table. Starting at one end of the table select, for example, every 4th pipefish until you have 100 pipefish. When selecting the sample, at least one length of the table must be done, to ensure fish from all areas of the table are selected. This is because similar sized fish may be clumped together in one area of the table and may bias the sample if fish are chosen only from that area of the table.

Measurements on each sample of 100 fish:

- The data sheet labelled "Biological Information" is to be used to record this information.

Please record the following (see example in data sheet):

1) Species (hardwickii or dunckeri – see last page of this booklet for identification of these two species)

2) Length (mm - always measure with tail curled, to the point furthest from the snout)

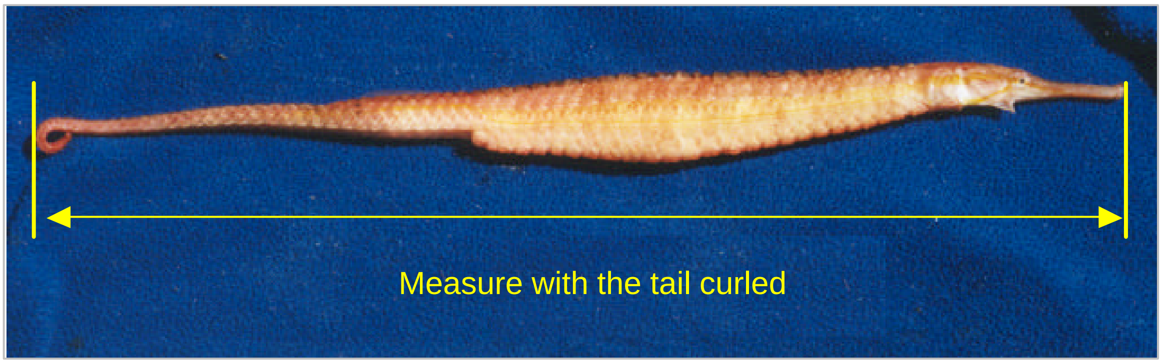
3) Wet weight (in grams)

4) Sex ("M" or "F")

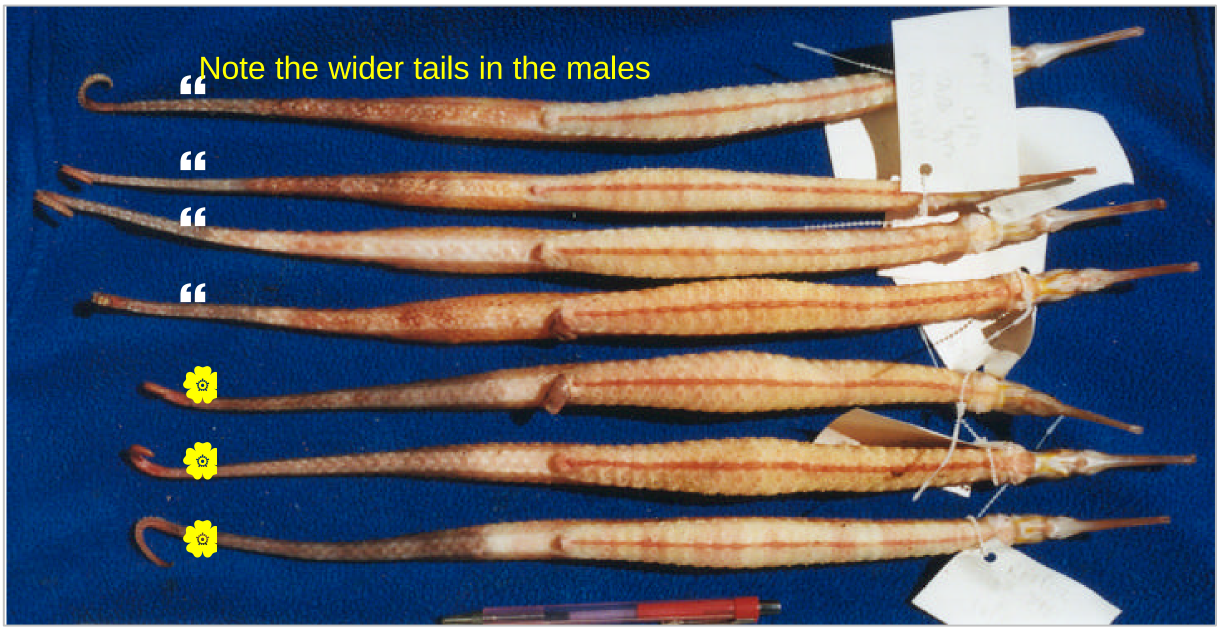
5) Presence or absence of eggs or egg scars (egg imprints) on males ("P" for males with eggs or egg scars, or "A" for males without eggs or egg scars)

6) Location (where fish were caught, Cfish grid number and site – e.g. L19 – 19)

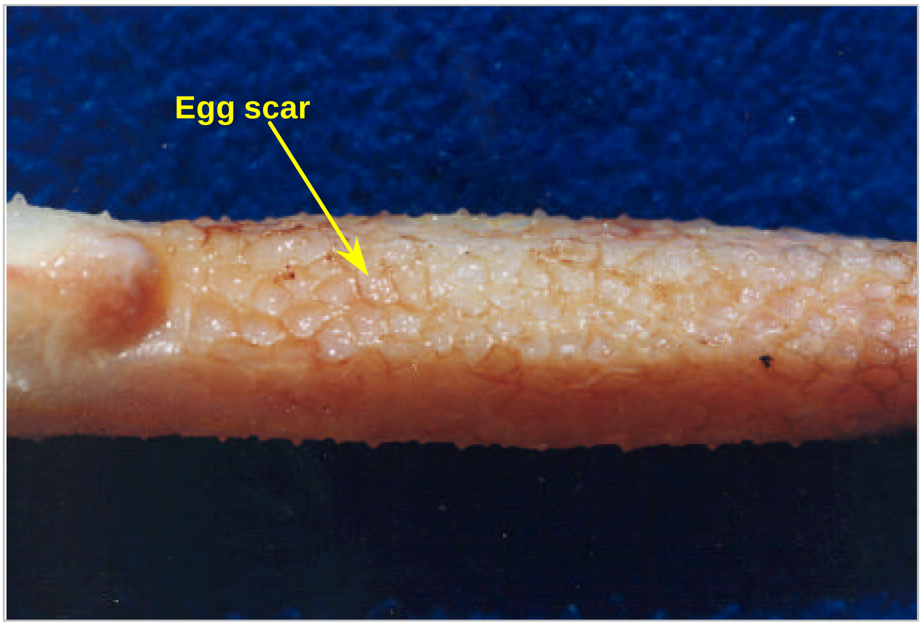
Measuring length



Determining the sex of the fish



Egg scars on the underside of male's tails



Identification of the two pipehorse species, *Solegnathus hardwickii* (left) *and Solegnathus dunckeri* (right).