INTERNAL REPORT

TASMANIAN RECREATIONAL SCALLOP FISHERY: 2005–2008

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Tasmanian recreational scallop fishery: 2005–2008

Executive Summary

The 2008 recreational scallop season took place between 15th March and 31st July; this was the fourth consecutive year in which there has been a recreational scallop fishery in Tasmanian waters. Since the re-opening of the fishery in 2005, management has taken a 'conservative' approach, with bag limits initially set at 40 scallops and an extended season of approximately three months. This management arrangement was altered in 2008; with an increase in the length of the season by 45 days, an increase in the daily bag limit from 40 to 50 scallops, and a decrease in the possession limit from 200 to 100 scallops. All Tasmanian waters (apart from marine reserves) remained open, and dive collection was the only permitted harvest method.

Status of the scallop populations in the D'Entrecasteaux Channel was assessed by a dive survey immediately following the closure of the 2008 season, as has been done at the end of the previous three seasons. A post-season telephone survey of randomly selected recreational licence-holders with scallop endorsements was again conducted to collect information on fisher success, fishing effort by region and to gauge opinions on the health of the stocks and the management of the fishery.

The telephone survey indicated that almost 39% of licence holders did not dive for scallops during the 2008 season. This was a similar proportion to 2007, though increased licence sales meant that, in absolute terms, there were more active fishers in 2008. Dive effort was estimated at 22,478 fisher days for the 2008 season, up slightly from 21,992 fisher days in 2007, and represented an average of 5.5 days per fisher.

Dive effort was again heavily concentrated in the D'Entrecasteaux Channel, accounting for 95% of state-wide fishing effort. Since 2005 there has been a notable north-south shift of fisher effort within the Channel in response to a significant decline in scallop numbers in the northern areas of the Channel (especially Commercial scallops) and is considered an indication of serial depletion. Diver success rates remained high with 85% of active divers taking their bag on each of their dives.

Commercial scallops remained the most abundant species in the D'Entrecasteaux Channel, although their number had declined significantly, in particular legal sized scallops. The distribution of Commercial scallop beds throughout the Channel has also decreased significantly since 2005, with the main bed now found in the Great Bay/Isthmus Bay area. This bed is almost exclusively comprised of a single cohort of sub-legal adults, spawned in 2006.

In response to the decline in legal sized Commercial scallops, fishers shifted much of their focus to Queen scallop beds during the 2008 season. The main Queen scallop beds are located around the popular and easily accessible stretch of the Channel adjacent to Middleton and Gordon on the western shore and Alonnah and Satellite Island on the eastern shore of the Channel. The Queen scallop population has experienced negligible recruitment over the last four years and as a result the average size (age) continues to increase and it is likely that natural senescence will decrease

their abundance to critical levels in the near future, even in the absence of fishing pressure.

The population of Doughboy scallops in the Channel has remained relatively stable due to low levels of annual recruitment replenishing stock loss from natural mortality and low levels of fishing pressure, the species being the least targeted of the three species. Nevertheless, the relative abundance of Doughboy scallops compared with the other scallop species was low.

There was some evidence that the population of the introduced Northern Pacific sea star had expanded in the Channel region and that aggregations observed in previous seasons have increased in density. The implications for the scallop stocks are unclear but as a potential predator of scallops, the sea stars could put additional pressure on the stocks.

Management Implications

Overall recreational fishers experienced a high degree of success during the 2008 scallop season, which is consistent with previous years, and were generally satisfied with the current management. The number of fishers taking out scallop licences and actively participating in the fishery has continued to rise. Of concern for the future of the fishery, however, is the continuing decline in scallop numbers, particularly Commercial scallops, the mainstay species over the first three seasons, as well as the lack of recruitment for Queen scallops. The remaining Queen scallops are primarily large individuals which are close to their anticipated maximum age, and hence mortality rates are expected to be high in coming years regardless of any fishery impacts.

The effect of the significant decline in the number of legal sized Commercial scallops since 2005 became particularly evident during 2008, with the majority of fishers reporting a shift from Commercial to Queen scallops as the main species retained. However, the Queen scallop distribution is now quite localised and the population has experienced no significant recruitment for many years, making the remaining Channel stock particularly vulnerable to overfishing. It should be noted that even though relatively dense areas of adult Queen scallops remain, there is no guarantee of future recruitment success. Thus, if these remaining scallops fail to produce a successful settlement event within the next couple of years, noting many are near assumed maximum age, this stock is expected to collapse and future recovery will be dependent on settlement derived from populations outside of the Channel.

The settlement pulse of Commercial scallops spawned in 2006 has reached a mean length of 88 mm SW within two years and it is likely that a proportion of this cohort will attain legal size during 2009. However, to date there has been no evidence for follow-up settlement and the population is now effectively comprised of a single cohort, with just a remnant of older year classes remaining. The fact that these scallops are restricted to a localised area will make them particularly vulnerable to heavy fishing pressure in future years.

In order to increase the likelihood of sustaining future fisheries it would, therefore, be prudent to adopt a management strategy that uses information about population

structure to determine whether or not areas such as the Channel should be opened to fishing each year. It is perhaps important to recognise that at the opening of the 2005 season both Commercial and Queen scallop populations were comprised of at least two year classes each, a population structure that has sustained the fishery for four years. Dependence upon a single cohort of adult stock without evidence of additional settlement to replenish the stock, as is the current situation for Commercial scallops, would appear to be a high risk strategy, despite an overall cautious management approach in regard to size and bag limits.

To reduce the possibility of stock collapse and protracted closures, as has already occurred several times in the history of the Channel fishery, a management approach that protects the adult stock until there is evidence of adequate recruitment would appear a more precautionary approach. This would help insure against fishing stocks down to a point where the adult biomass no longer represented a viable spawning population, with resultant dependence on settlement derived from populations outside of the area. Such a strategy is particularly important in semi-enclosed areas such as the D'Entrecasteaux Channel where populations are more likely to be self-recruiting as opposed to more open coastal waters, where there is evidence that recruits are derived from adjacent scallop beds.

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1. General Introduction

The 2008 recreational scallop season took place between 15th March and 31st July; the fourth consecutive year in which there has been a recreational scallop fishery in Tasmanian waters. Since the re-opening of the fishery in 2005 after more than a decade of closure, a 'conservative' management approach has been taken, with daily bag limits initially reduced to 40 scallops per diver and the season extended over approximately three months. This was in marked contrast to the management of the previous D'Entrecasteaux Channel scallop fishery (1992) where a daily bag limit of 200 scallops applied and the season lasted just 15 days, promoting a rush to take the catch.

Management arrangements were further altered in 2008; with an increase in the daily bag limit from 40 to 50 scallops, and a decrease in the possession limit from 200 to 100 scallops, and an increase in the length of the season by 45 days. These changes were made in part to address fisher concerns (social values) indicated in post-season telephone surveys of scallop licence-holders whilst balancing the conservation requirements of the scallop stocks. These surveys indicated that an increased bag limit would make engaging in this fishery more feasible in light of increasing fishing costs. Opening the season earlier and extending the overall duration was implemented to allow for divers to engage in the fishery during the warmer months, particularly over the popular recreational fishing period of Easter. By extending the season to the end of July it was also recognised that the condition of the scallops would be improved.

The recreational scallop fishery continues to increase in popularity with the number of recreational licences with scallop endorsements more than doubling over the last four years the fishery has been open (Fig. 1).

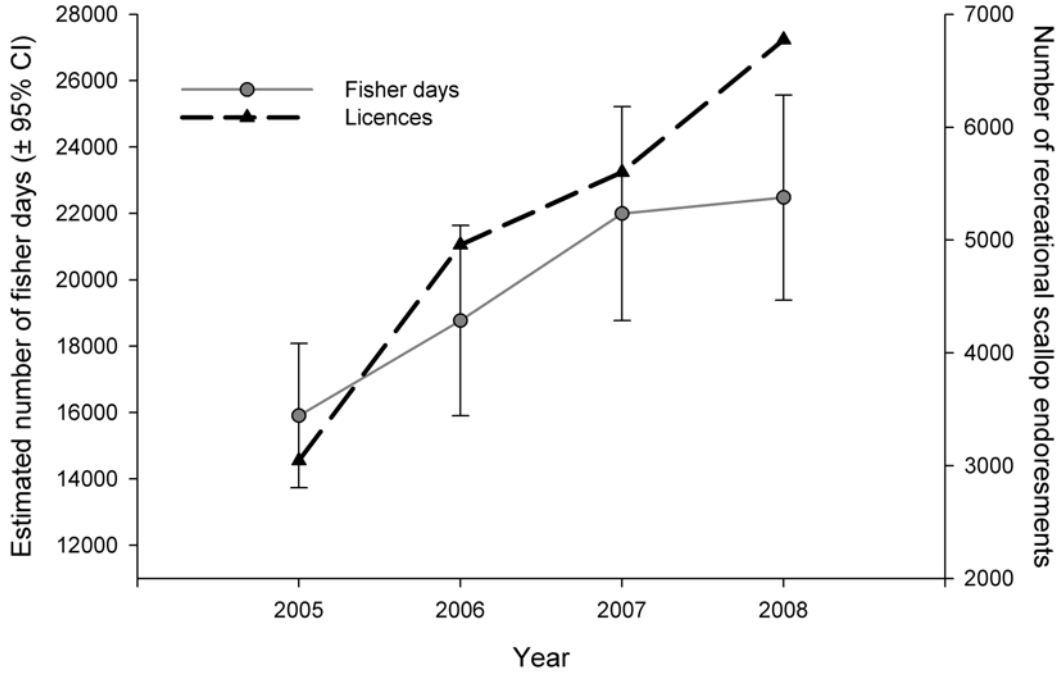

Fig. 1. The number of recreational fishing licences endorsed for scallop diving that have been issued and the estimated number of fisher days for each fishing season since 2005. Error bars represent 95% confidence limits.

TAFI has conducted a series of dive surveys of inshore scallop stocks each year since 2004 and post-season telephone surveys of scallop licence-holders annually since 2005, including 2008 (Lyle & Morton 2005; 2007; Tracey & Lyle 2008). Dive surveys have been designed to provide basic population information on the scallop stocks whereas the phone surveys have been used to collect fishery and attitudinal information from fishers. Since the telephone surveys have consistently indicated the significance of the D'Entrecasteaux Channel to the fishery, this region has been the focus of dive surveys conducted since 2006.

2. Scallop Population Surveys

2.1 Introduction

A diver based transect survey was undertaken to examine abundance, size and species composition of scallop populations within the D'Entrecasteaux Channel at the end of the fishing season in late July/August 2008. Similar surveys have been conducted both pre- and post-season since 2005 (Lyle & Morton 2005, 2007; Tracey & Lyle 2008). The Tasmanian Scuba Diving Club (TSDC) conducted the pre-season dive surveys in 2007 and 2008 and assisted with the 2005 pre-season survey, all other surveys have been conducted by TAFI. The surveys undertaken in 2005 were based on timed swims and, in terms of scallop abundances, these data are not comparable to data collected from transect surveys conducted in all latter surveys (Lyle & Morton 2005). Only size composition data from the 2005 surveys is used in this report as a non-relative assessment of size based modal progression. A diver based transect survey was also conducted in 2004; this survey was exploratory to assess the feasibility of opening the fishery in 2005 (Morton & Lyle 2004). Survey sites from 2004 were not replicated in subsequent surveys; hence, again only scallop size data is reported from that survey.

2.2 Methods

2.2.1 Site selection

Since the pre-season survey conducted in 2006 there have been 23 sites replicated in each subsequent survey (Fig. 2A). This group of comparable sites was initially selected by a modified stratified random procedure whereby the Channel was sub-divided into areas that were likely to hold scallop beds based on historical data and results from the 2004 exploratory survey. A number of sites were then randomly selected from within each area, with bottom depths of greater than 18 m excluded from selection. Additional non-random sites have been added in subsequent surveys in order to help define boundaries of particular scallop beds. Some sites have also been dropped over time since surveys consistently detected negligible quantities of scallops.

For the 2008 post-season survey an effort was made to replicate all sites that had been surveyed since the pre-season 2006 survey, as well as adding further non-random sites to better delineate the extent of identified scallop beds, with particular focus around the areas known to have been heavily fished (reported from the 2007 post-season telephone survey and anecdotal evidence from fishers during the 2008 season). Consequently, 62 sites were sampled during the 2008 post-season survey (Fig. 2B), with sites in all four sampling regions indicated in Fig. 2A.

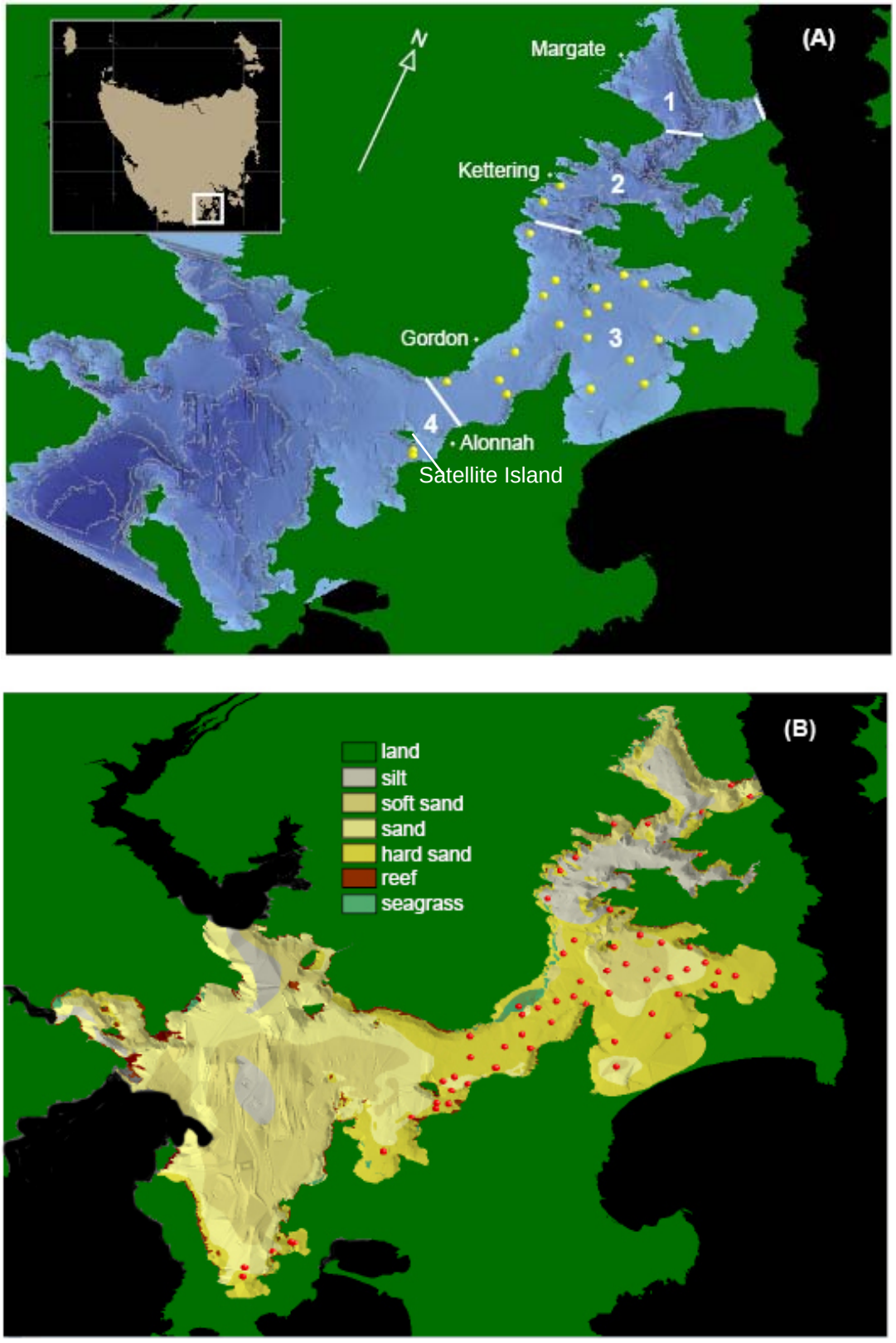

Fig. 2. (A) Bathymetric profile of the D'Entrecasteaux Channel (Grey lines represent 10m depth contours); yellow points show the 23 comparable sampling sites from the 2006 pre-season survey through to the 2008 post-season survey. (B) Substrate habitat of the Channel region, red points indicate the 62 sites sampled during the 2008 post-season survey.

2.2.2 Survey method

At each site (located by GPS) a weighted 100 m strip transect was laid from the boat in a haphazard direction (or following the depth contour on sloping bottom). Two divers swam along either side of the transect line collecting all scallops within one metre of the line (representing a total searched area of 200 m^2) (Zacharin 1991). The scallops were brought to the surface, identified to species and their shell width (SW) measured. A small sample of Commercial scallops was collected to assess maturity of the recruitment pulse; all other scallops were returned to the water.

Three seastar species, the introduced Northern Pacific sea star *Asterias amurensis*, and the native species *Coscinasterias muricata*, and *Uniophora granifera*, were also counted on each transect.

2.2.3 Analysis

To visualise the spatial distribution and density of scallop beds in the D'Entrecasteaux Channel a triangle-based cubic interpolation algorithm was run using MATLAB R14. The model fits an interpolated surface to the results from the survey site data. To assess changes over time the model was run for both the 2006 pre-season data (33 sites) and, for comparison, the same sites sampled at the 2008 post-season survey. The model was also run for all sites sampled during the 2008 survey to provide the highest resolution of the current distribution and density of each species.

To aid in the identification of recruitment pulses, Gaussian distributions were fit to the shell width size frequency modal groups, the models were fit according to Haddon (2001).

2.3 Results and Discussion

2.3.1 Scallop abundance

Sixty-two sites were sampled during the 2008 post-season survey, covering an area of 12.4 km^2. During the survey 4,652 scallops were measured. Commercial scallops, *Pecten fumatus* remained the most abundant species in the Channel, accounting for 53% of scallops sampled, followed by Queen scallops, *Equichlamys bifrons* (27%) and Doughboy scallops, *Mimachlamys asperrimus* (20%).

Although the survey methodology was not designed to provide a quantitative assessment of abundance, the sampling design that has been employed consistently since 2006 does provide a relative index of abundance and thus insight into the overall trend in scallop numbers over time. Clear changes in scallop density and distribution were evident at the 23 comparable sites sampled over six surveys conducted since the 2006 season. Commercial scallop numbers have more than halved and despite a significant recruitment pulse, first evident in the 2007 post-season survey, the data suggest that the pulse is not of sufficient size to rebuild numbers to pre-2006 season levels (Fig. 3). There has also been a 61% decline in Queen scallop numbers since 2006 (Fig. 3) while the number of Doughboy scallops has increased slightly since 2006 although relative numbers remain low compared with the other two species (Fig. 3).

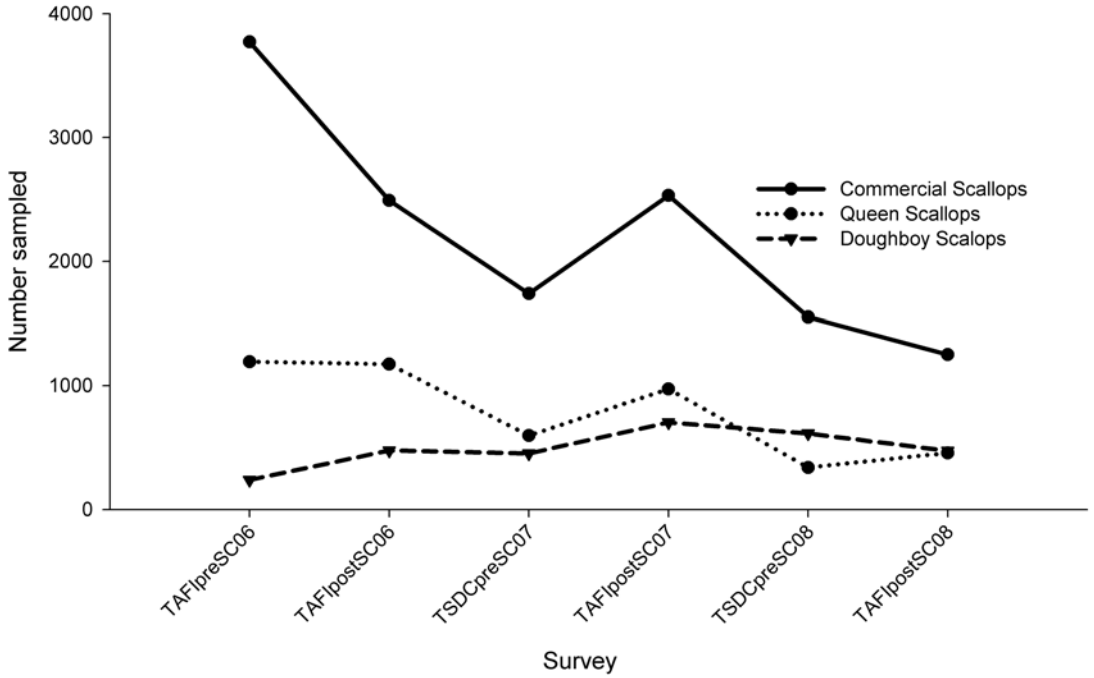

Fig. 3. Numbers of scallops collected from the D'Entrecasteaux Channel from 23 comparable sites. Numbers are allocated from the 2006 pre-season survey to the 2008 post-season survey inclusive. TAFI or TSDC refers to who conducted the survey and 'pre' or 'post' refers to whether the survey was conducted pre-season or post-season.

2.3.2 Size composition

Commercial scallops

Commercial scallops measured during the 2008 post-season survey ranged in size from 36-144 mm SW and displayed a bi-modal distribution (Fig. 4). The mean size was 88 mm SW, 12 mm below the current legal minimum size limit. The majority of scallops sampled occurred in the modal group of smaller individuals, which is comprised of the cohort that recruited in late 2006 (Fig. 4; red distribution). The second modal group was comprised of larger scallops. Legal-sized individuals only accounted for 21% of all Commercial scallops sampled during the 2008 post-season survey. This latter group is comprised of at least two significant recruitment pulses, evident from the 2004 survey (nominally aged 6 and 7 in 2008 based on the initial growth of the large cohort spawned in 2006) and at least two other small pulses, one from 2004 (Fig. 4; dark blue distribution) and the other 2005 (Fig. 4; green distribution). Although disparity in the number of sites included in each graph means that relative abundance cannot be inferred, there is a clear decline in the number of legal sized Commercial scallops in 2007 and 2008. As a result of low numbers of large scallops in 2008 the probability model is a poor fit to these cohort aggregates.

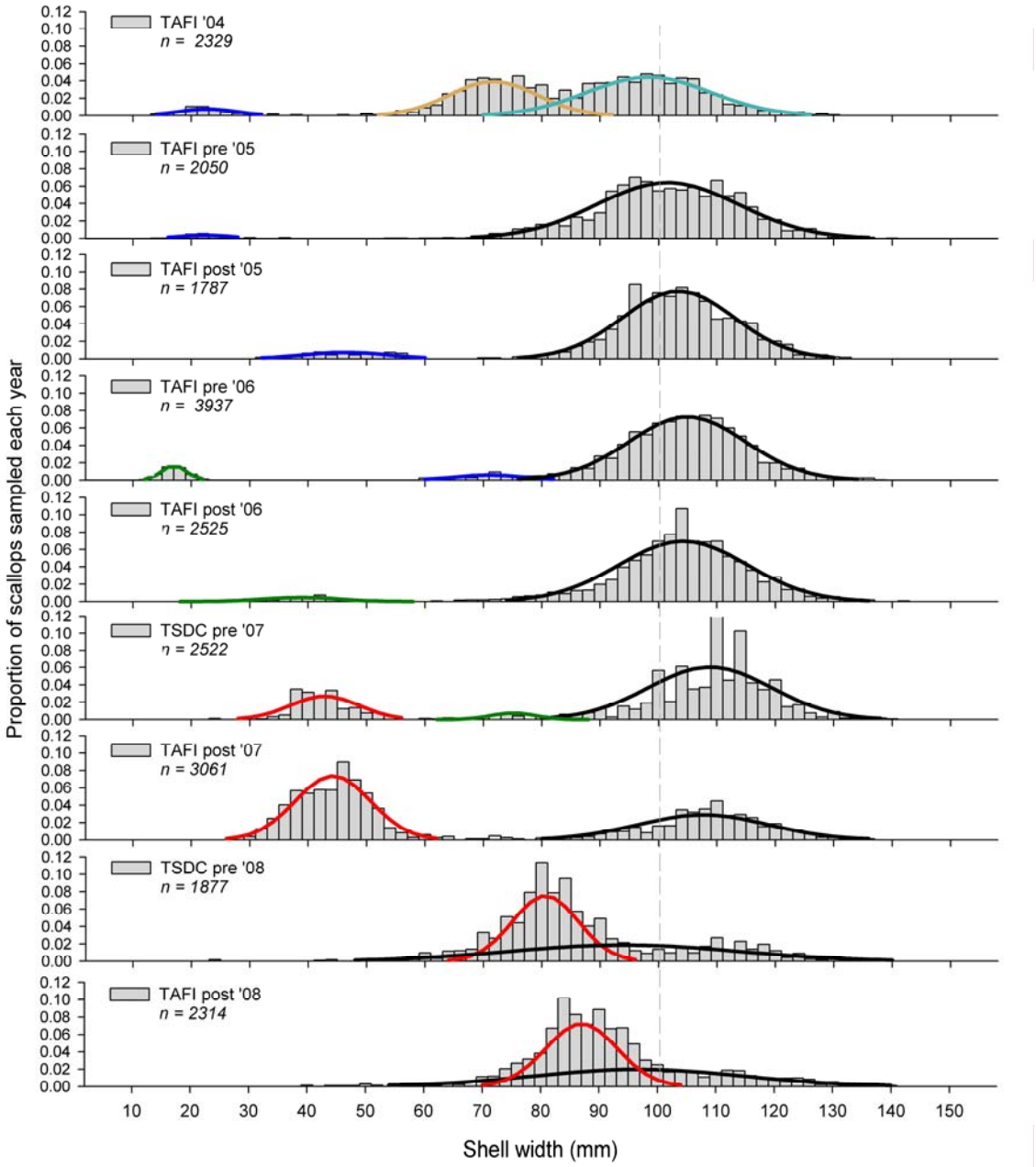

Fig. 4. The size composition of Commercial scallops sampled from the D'Entrecasteaux Channel since 2004. The dashed vertical line indicates the minimum legal size limit. Relative abundance is not comparable as there is disparity in the number of sites from each survey. Black distributions represent cohort aggregates that could not be separated based on size. Refer to Fig. 3 for key to sampling details, *n* is sample size.

Queen scallops

Queen scallops measured during the 2008 post-season survey ranged in size from 12-142 mm SW and displayed a uni-modal distribution (Fig. 5). The mean size was 116 mm SW, well above the MLS. Only one significant recruitment pulse of Queen scallops has been observed since the surveys commenced in 2004 (Fig. 5; blue distribution). This cohort is assumed to have resulted from a spawning event in 2002, based on the mean size of the cohort in 2004 (Fig. 5). Since then there has only been low levels of recruitment, not of sufficient size to replenish the Queen scallop population, even in the absence of fishing. In effect the adult population is ageing, with

no evidence of replacement through recruitment and at the end of the 2008 fishing season 92% of all Queen scallops sampled were legal sized.

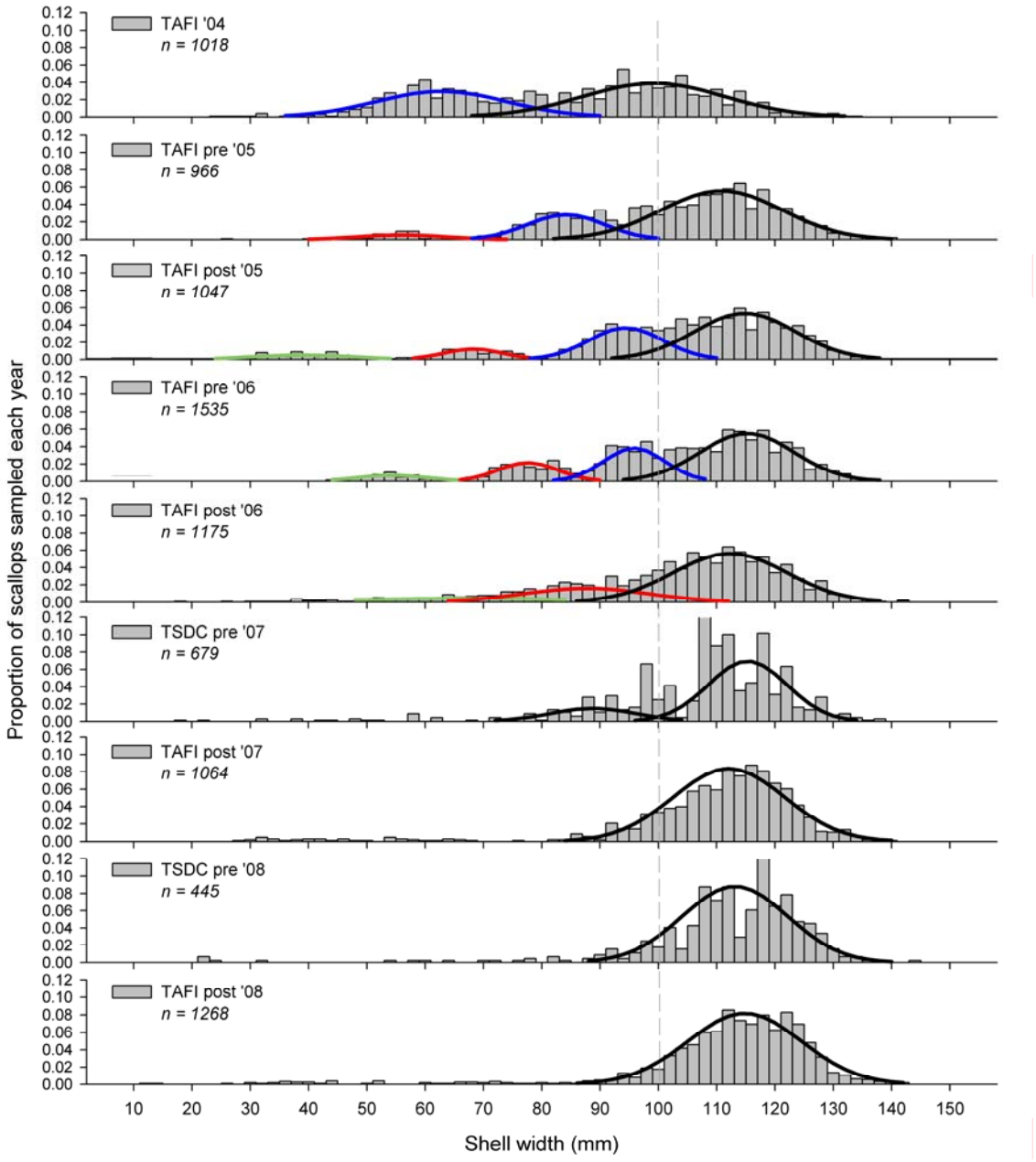

Fig. 5. The size composition of Queen scallops sampled from the D'Entrecasteaux Channel since 2004. The dashed vertical line indicates the minimum legal size limit. Relative abundance is not comparable as there is disparity in the number of sites from each survey. Black distributions represent cohort aggregates that could not be separated based on size. Refer to Fig. 3 for key to sampling details, *n* is sample size.

Doughboy scallops

Doughboy scallops have been present in relatively low numbers compared to the other two species in the Channel since 2005. Doughboy scallops measured during the 2008 post-season survey ranged in size from 10-108 mm SW. The length frequency distribution in 2008 was tri-modal with the larger size class dominated by a relatively large recruitment pulse from 2006 (Fig. 10; aqua distribution), and two smaller

recruitment pulses from 2007 (Fig. 6; green distribution) and 2008 (Fig. 6; maroon distribution). Based on length-at-age estimates for the species reported by Zacharin (1995), the 2006 and 2008 spawning events probably occurred significantly earlier (April –May) than the reported spawning season in late September – early October (Zacharin 1995). The proportion of legal size (greater than 80 mm SW) Doughboy scallops had decreased to 16% by the end of the 2008 season. The relatively constant low level of recruitment appears to be accounting for the current mortality levels, maintaining a *status quo* within the Doughboy scallop population.

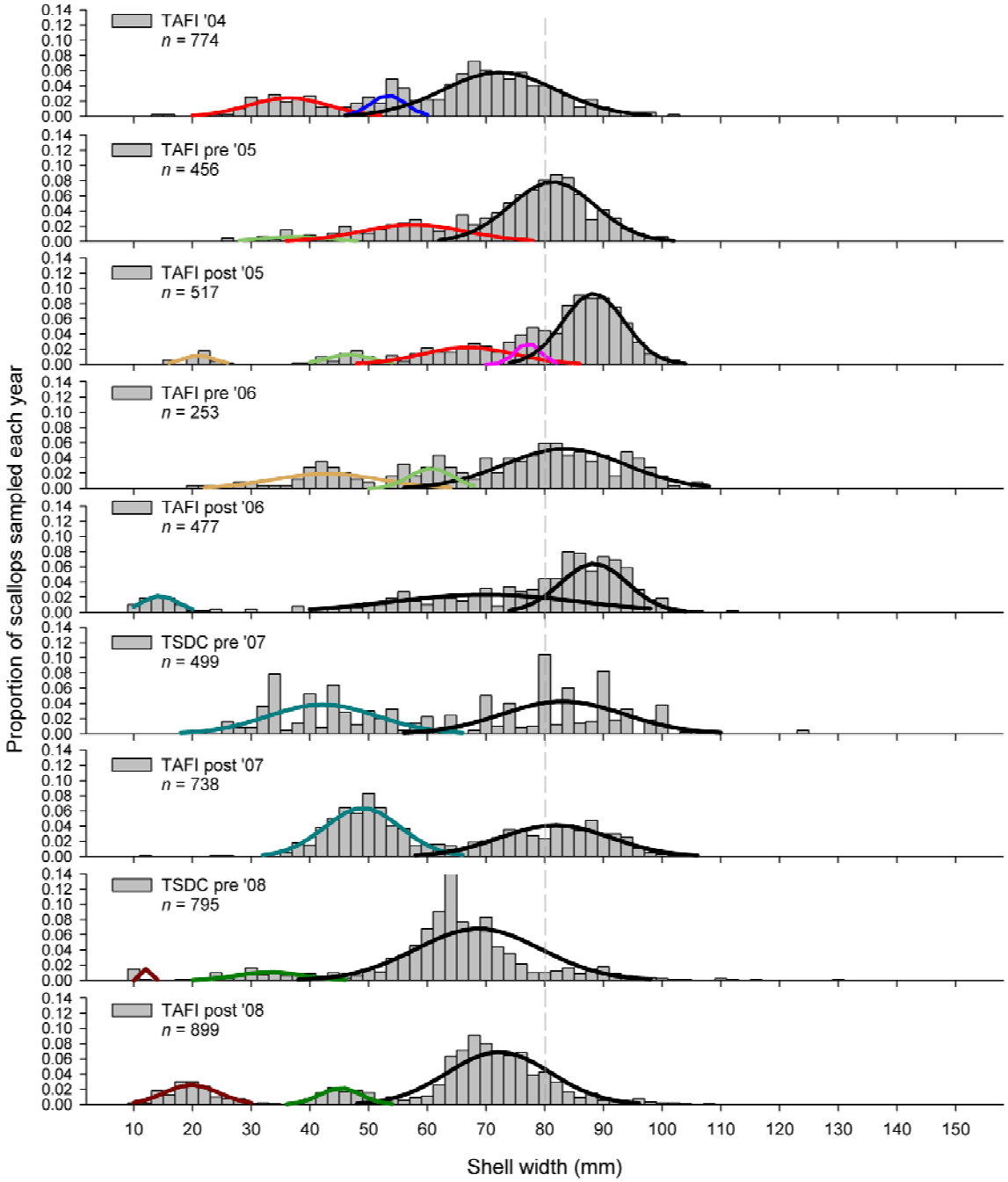

Fig. 6. The size composition of Doughboy scallops sampled from the D'Entrecasteaux Channel since 2004. The dashed vertical line indicates the minimum legal size limit. Relative abundance is not comparable as there is disparity in the number of sites from each survey. Black distributions represent cohort aggregates that could not be separated based on size. Refer to Fig. 3 for key to sampling details, *n* is sample size.

The comparative trends in size frequency distribution and species composition based on samples derived from the 23 comparable sites highlight the initial abundance of Commercial scallops available to the fishery within the Channel and the subsequent decline in scallop numbers, including an absence of significant recruitment for Queen scallops over following seasons (Fig. 7).

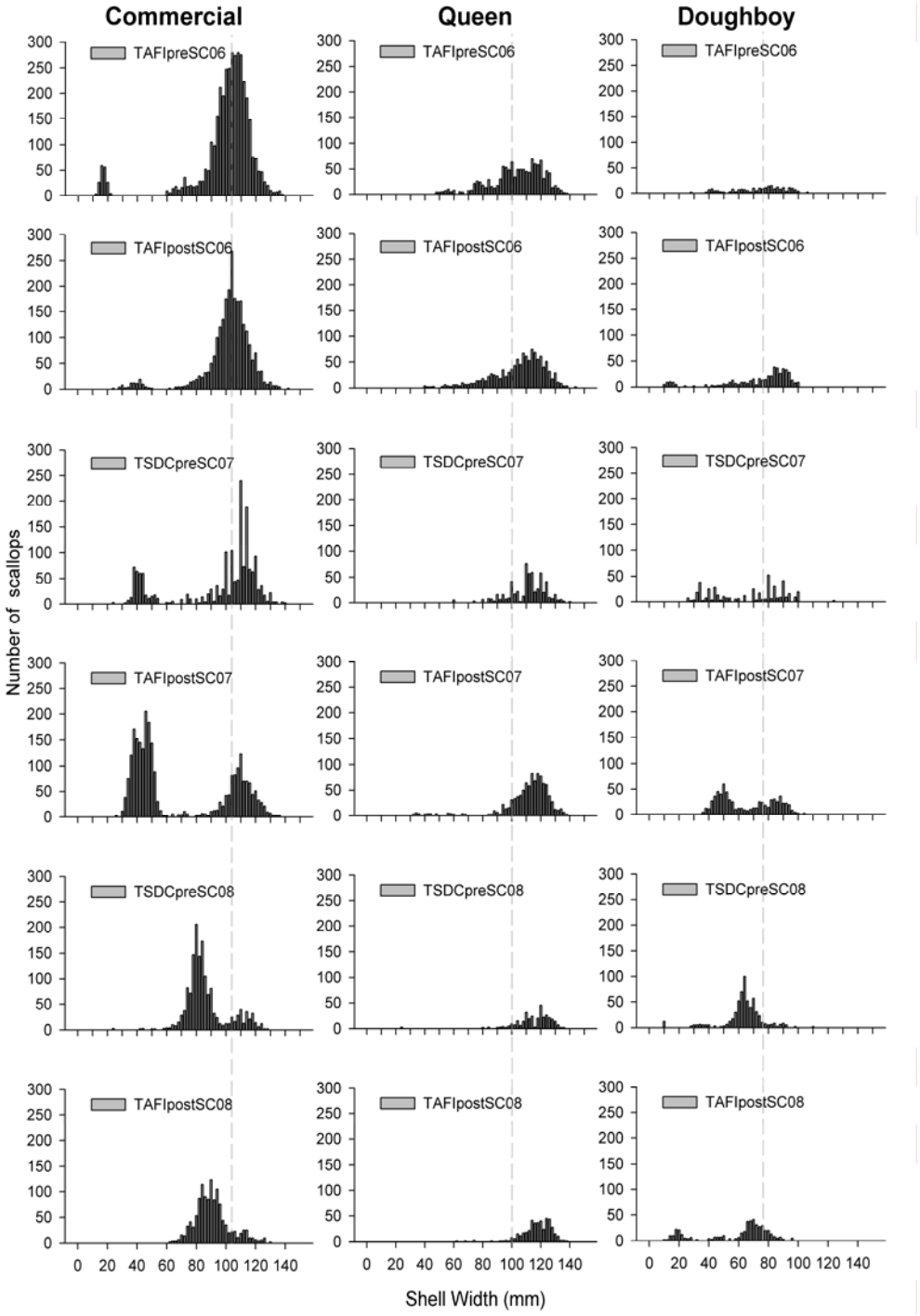

Fig. 7. The relative size composition of Commercial, Queen and Doughboy scallops sampled from 23 comparable sites within the D'Entrecasteaux Channel since 2004. The dashed vertical line indicates the minimum legal size limit for each species.

2.3.3 Species composition

At the conclusion of the 2008 recreational fishing season all three species of scallops were present in the D'Entrecasteaux Channel (Fig. 8). Their distribution was generally focused around the mid-Channel region, subsequent species specific analyses focuses in on this area.

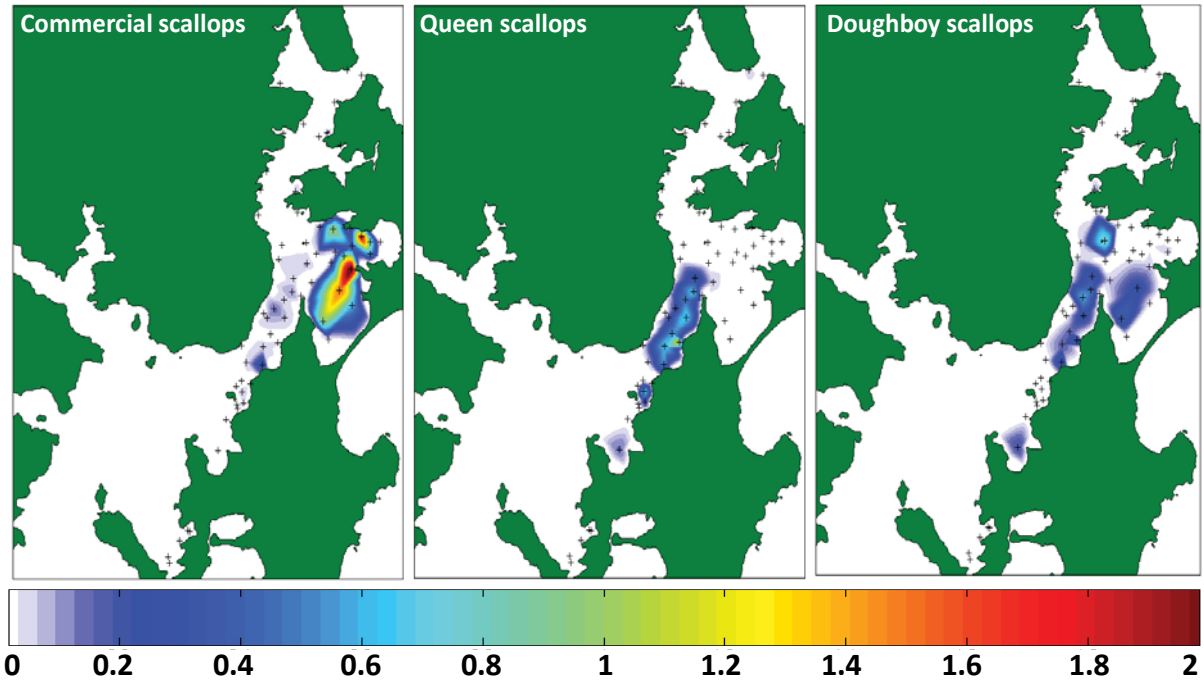

Fig. 8. The interpolated distribution and density (sc. m^2) of the Commercial, Queen and Doughboy scallops throughout the D'Entrecasteaux Channel at the conclusion of the 2008 recreational scallop season. The black crosses indicate the 62 sample sites.

Commercial scallops

Prior to the start of the 2006 season Commercial scallops were distributed throughout the expansive, mid-region of the Channel (region 3). Dense beds (approximately 2 Sc. m^2) were located at Missionary Bay and Great Bay on the eastern side of the Channel and around Woodbridge and Birches Bay on the western side of the Channel (Fig. 9A). At the time a large proportion of the scallops within this area were of legal size and as such available to the fishery (Fig. 10A). Post-season telephone surveys conducted in 2006 and 2007 indicated that a significant proportion of the total state-wide fishing effort, 65 and 61% respectively, was focused on these areas (refer section 3.3.3). The combined effects of natural mortality and targeted fishing pressure facilitated a precipitous decline in scallop numbers in region 3, such that by July 2008 the dense beds on the western side of the Channel were virtually absent while those on the eastern side were reduced to maximum densities of approximately 0.2 Sc. m^2 (Fig. 10B).

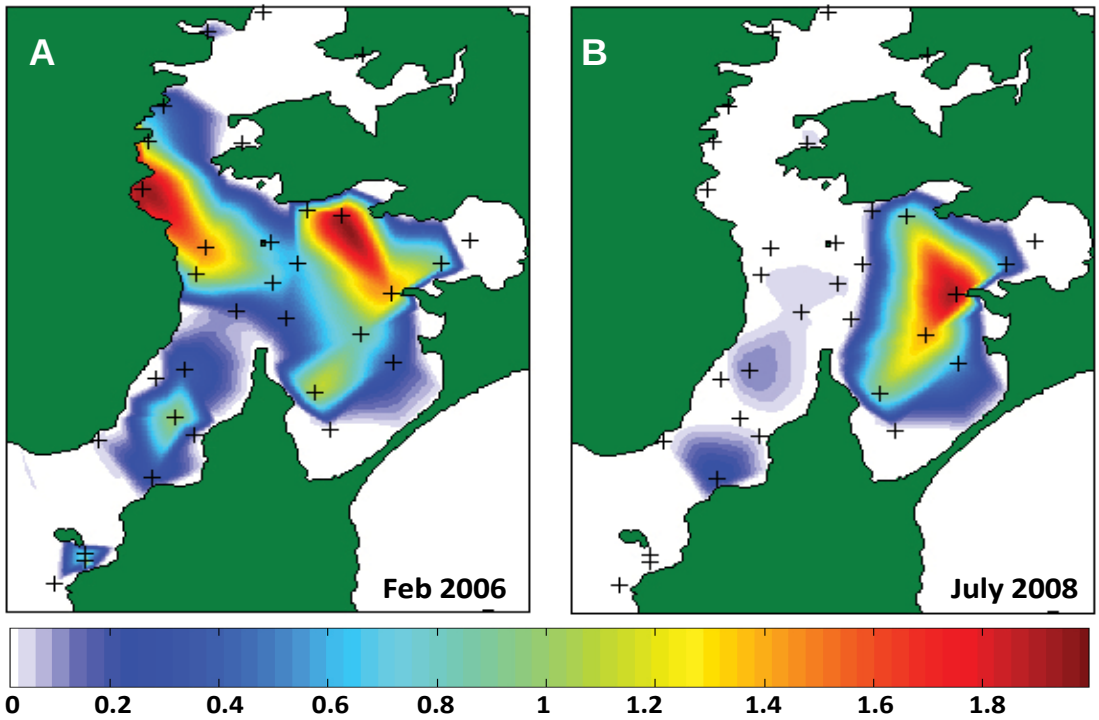

Fig. 9. The interpolated distribution and density (Sc. m^2) of Commercial scallops in the central region of the D'Entrecasteaux Channel. The black crosses indicate sample sites.

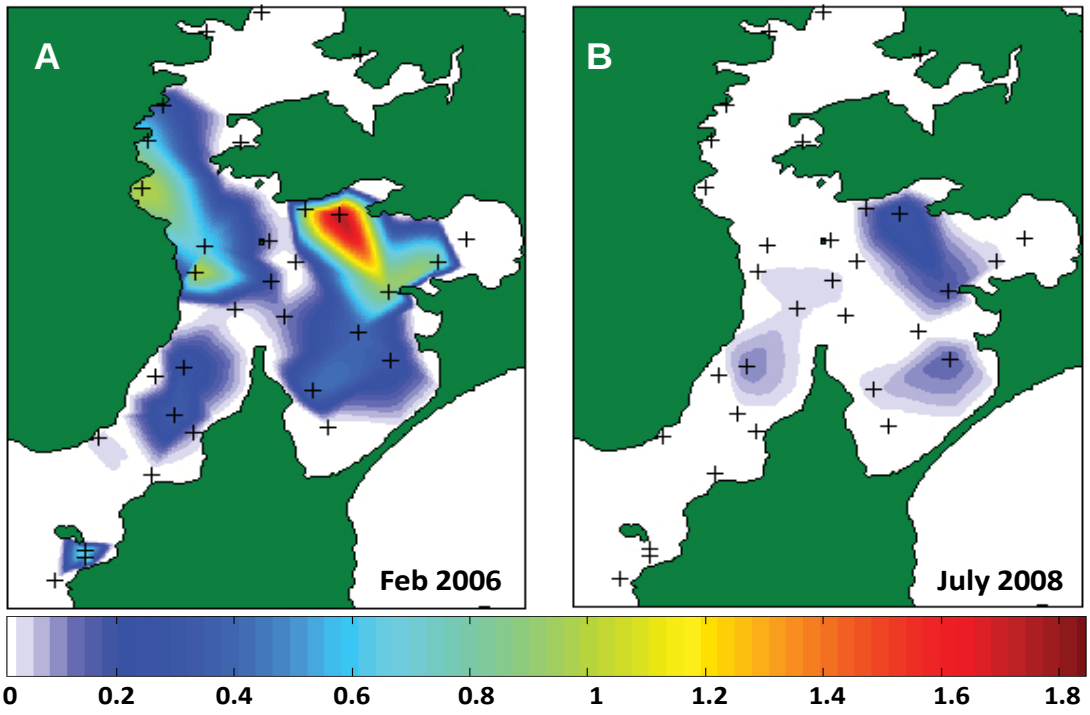

Fig. 10. The interpolated distribution and density (Sc. m^2) of Commercial scallops greater than 100 mm in shell width (legal size) in the central region of the D'Entrecasteaux Channel. The black crosses indicate sample sites.

Since 2006 there has been one significant recruitment pulse of Commercial scallops identified within the Channel, this recruitment event is believed to have resulted from spawning in winter/spring 2006. Settlement was focused around Great Bay on the eastern side of the Channel, but individuals from the cohort were found southward in Simpsons Bay and westward as far as Missionary Bay (Figs. 8 & 9B). The reason for

such restricted distribution is unclear, however, there are several possible contributing factors, namely (i) the geographic profile of this area is likely to create retentive eddies that would accumulate spat prior to settlement (Herzfeld *et al.* 2005); (ii) the presence of relatively dense adult Commercial scallop beds within the vicinity provides a cue for settlement; (iii) larval transport is limited and thus under favourable conditions self-recruit to the area occurs, and (iv) the combination of habitat and depth is optimal for scallop settlement and survival. This extensive, shallow mid-Channel region has in fact had a history of supporting high abundances of Commercial scallops (Olsen 1955).

Since the settlement pulse was identified in 2007, there has been little evidence of expansion of the settlement area, although scallops densities at each transect within the settlement area have declined. This decrease is assumed to be largely a consequence of high natural mortality rates (over 40% per year; Young & Martin 1989), rather than the effects of fishing and/or dispersal, noting that individuals from the cohort were still undersize at the end of the 2008 fishing season.

Queen scallops

Queen scallop distribution has been concentrated throughout the narrow southern section of region 3, as well as at two sites between Satellite Island and Alonnah (Fig. 11A). This area, particularly the narrow section, is characterised by high current flow, coarse sand and areas of complex benthic faunal assemblages. It is assumed that the Queen scallop beds were more continuous between the Satellite Island beds and those that the interpolation model suggests cease south of Gordon. This is a limitation of the model that is due to the lack of sample sites between these areas.

Prior to the 2006 fishery, high abundances of Queen scallops were found in the centre of the Channel adjacent to Gordon, with up to 3 Sc. m^2. Since that time the distribution of the beds has remained unchanged, with only negligible juvenile recruitment observed within the Channel, however, the densities of Queen scallops have declined significantly to below 1 Sc. m^2 (Fig. 11B). The combined effects of natural mortality and fishing pressure are likely to have contributed to this decline, noting that fishing effort increased in 2007 in this area, presumably as a response to a decline in the numbers of large Commercial scallops available further north in the Channel. The 2008 post-season survey indicated further concentration of fishing effort in the southern end of region 3 and in region 4 (labelled areas 4 and 5 for the regional description used for the telephone survey, refer to section 3.3.3) and anecdotal reports during 2008 also indicated that an increasing number of fishers preferentially targeted the large Queen scallops. This shift in the main species harvested by fishers was also confirmed in the 2008 telephone survey (refer section 3.3.6).

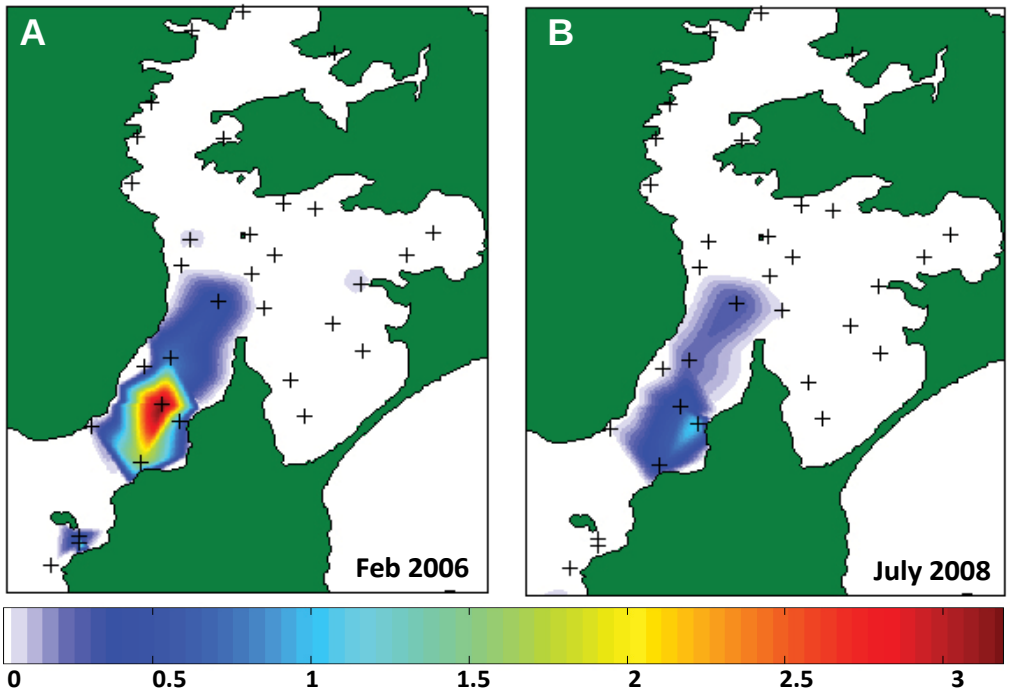

Fig. 11. The interpolated distribution and density (Sc. m^2) of Queen scallops in the central region of the D'Entrecasteaux Channel. The black crosses indicate sample sites.

Doughboy scallops

Doughboy scallop distribution has remained constant since 2006 and consecutive years of low but relatively constant recruitment have increased the density of Doughboy scallops (Figs 12A & B). The 2007 post-season telephone survey indicated that less that 5% of fishers actively targeted this species and as such it is assumed that fishing pressure on the species has been minimal.

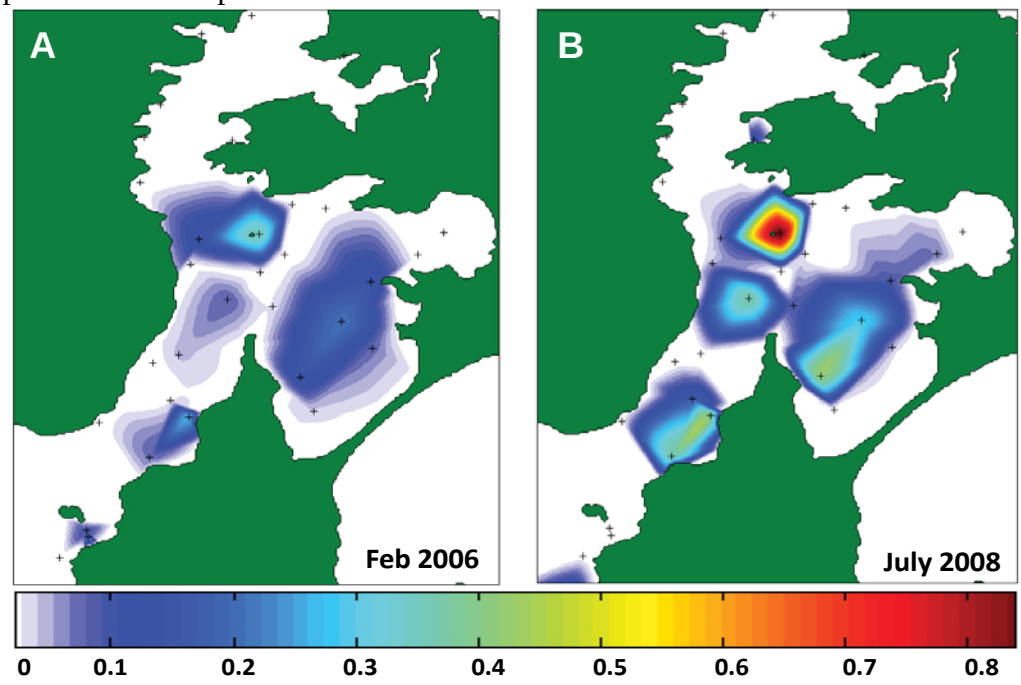

Fig. 12. The interpolated distribution and density (Sc. m^2) of Doughboy scallops in the central region of the D'Entrecasteaux Channel. The black crosses indicate sample sites.

2.3.4 Northern Pacific sea star

The impact of the introduced Northern Pacific sea star is a concern in regards to the future health of the D'Entrecasteaux ecosystem as well as the sustainability of the recreational scallop fishery. There were no Northern Pacific sea stars found in the northern Channel region during the 2008 dive survey and there were only three sites in the mid-Channel region where the sea star was found. The main infestation was around Satellite Island and Alonnah, adjacent to where the Huon River flows into the Channel (Fig. 13).

The density of the Northern Pacific sea star population, at the survey sites southeast of Satellite Island has increased sevenfold, from 0.07ss. m^2 in 2006 up to 0.5ss. m^2 in 2008. Comparatively low densities were also found at sites in Little Taylor's Bay and Great Taylor's Bay. Of perhaps greatest concern is the reasonably dense aggregation found at the survey sites south of Missionary Bay (0.2ss. m^2) because of their proximity to the dense Commercial scallop beds. As there is no continuity between the sea star aggregations found further south, this aggregation may be the result of larval settlement rather than migration. During the dive surveys no evidence of active Northern Pacific sea star predation on scallops was observed.

The density of the two native sea stars species; *Coscinasterias muricata* and *Uniophora granifera* was low at all sample sites with maximum recorded densities of 0.03ss. m^2 and 0.1ss. m^2 respectively.

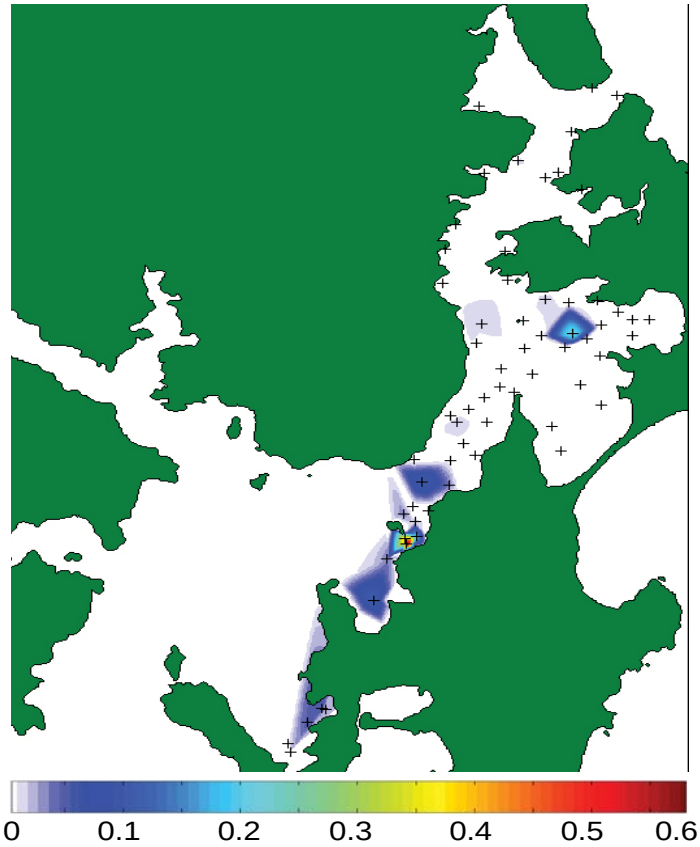

Fig. 13. The interpolated distribution and density (sea stars per m^2) of the introduced Northern Pacific sea star (*Asterias amurensis*) throughout the surveyed regions of the D'Entrecasteaux Channel in August 2008. The black crosses indicate 62 sample sites.

3. Telephone Survey

3.1 Introduction

A post-season telephone survey of licence-holders was conducted to assess the fishing effort and success of recreational fishers, and gauge opinions about stock status and management of the 2008 scallop season.

3.2 Methods

3.2.1 Survey sample

A random sample of 496 recreational scallop licence holders was drawn from the 2008 recreational licence database. While the majority of licence holders are Tasmanian residents, a small number of interstate and overseas residents also take out Tasmanian recreational fishing licences.

3.2.2 Questionnaire

Respondents were contacted by telephone during August 2008 and asked a series of questions based on a structured questionnaire. The questionnaire was divided into four sections, the first dealt with fishing activity, the second addressed issues relating to the management of the fishery, the third with perceptions about resource status and the fourth with other fishing activities.

In relation to fishing activity, respondents were asked to estimate the total number of days, and number of days by area(s), that they had dived for scallops during the 2008 season, regardless of whether they had caught any scallops or not. Fishing locations were grouped according to areas indicated in Fig. 14. While no attempt was made to estimate harvest, respondents were asked to estimate the number of days that they actually took the bag limit (a measure of fishing success) and species preferences. Key factor(s) that influenced the choice of where they dived for scallops were also determined.

In the second part of the questionnaire, general satisfaction with the current management strategy was assessed. Respondents who had fished in more than one season were then asked their perception of the current health of inshore scallop populations in terms of distribution and abundance of scallops. Finally, respondents were asked about other fishing activities that they undertook during 2008, including those that were combined with scallop fishing trips.

3.2.3 Data analysis

Total fishing effort (diver days) is reported as expanded estimates with 95% confidence limits calculated after Pollock *et al*. (1994). The expansion factor applied is the inverse

of the sample fraction (i.e. number of responding licence-holders divided by the total number of scallop dive licence-holders).

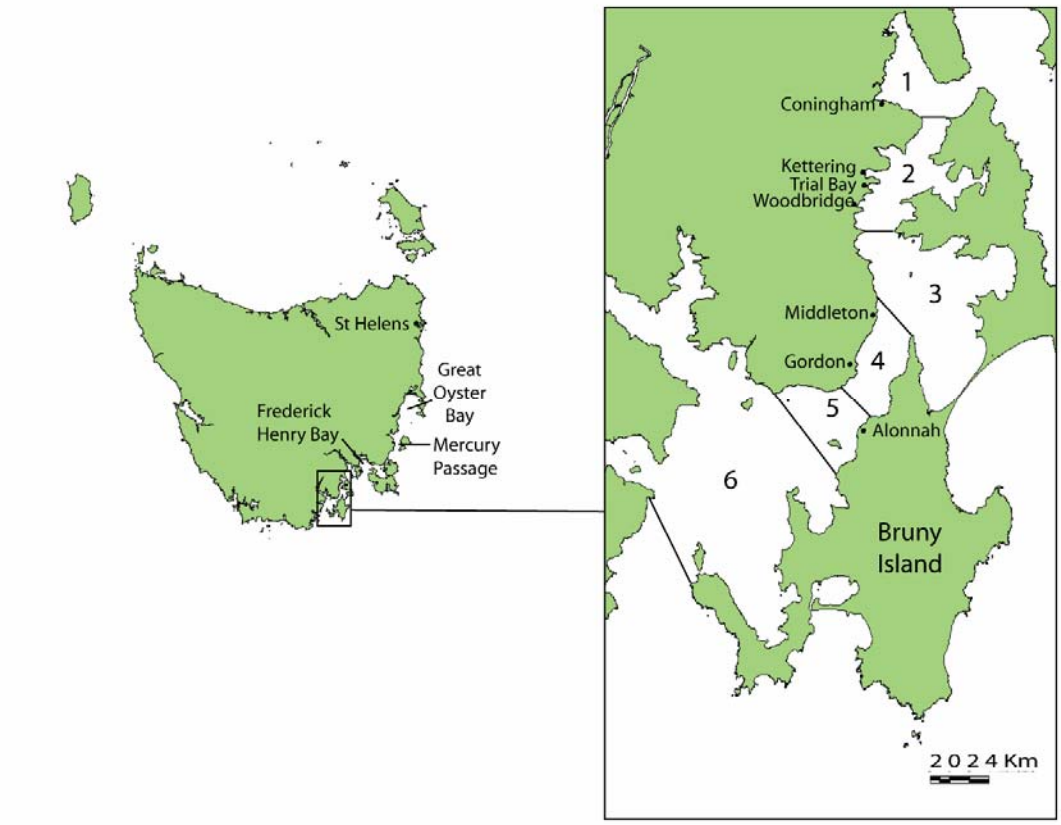

Fig. 14. Map of Tasmania showing the areas historically targeted by recreational scallop fishers, including a magnified view of the D'Entrecasteaux Channel fishing areas (1-6).

3.3 Results and Discussion

3.3.1 Survey response

The survey response profile is outlined diagrammatically in Fig. 15. From a total population of 6776, a gross sample of 496 licence-holders was selected. Of these, 25 had disconnected or incorrect numbers and alternative numbers were unable to be found. As such this represented sample loss, reducing the effective sample to 471. Contact was made with 406 licence-holders, of whom 392 fully responded, representing an overall response rate of 83% (or 97% of contacts), and a sample fraction equating to 6% of licence-holders. Non-contacts accounted for 14% and refusals 3% of the net sample.

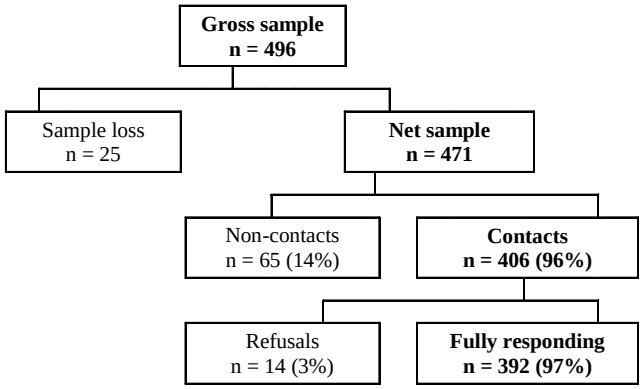

Fig. 15. Diagrammatic representation of the survey response profile (n is sample size).

3.3.2 Fishing effort

Based on response to the number of days dived for scallops it became evident that not all licence-holders used their scallop licences, in fact an estimated 38.8% (SE ±2.4%) or 2631 licence-holders did no diving for scallops during 2008. As a proportion of all licence holders, this was not a significant change from 2007 (34.5%) or 2006 (34.7 %) estimates but was a significant increase from the estimated 17% that did not fish during 2005. In terms of numbers, an estimated 4145 licence holders dived for scallops in 2008, a 13% increase in participation compared with 2007.

The total recreational dive effort for the 2008 season was estimated as 22,478 fisher days (95% CI 16,818-28,138), only 2% more than the estimate from 2007 (21,992) (Fig. 1). This represented an average 3.3 (SE ±0.2) days per licence-holder or, considering only those who actually fished in 2008, an average of 5.4 (SE ±0.3) days.

3.3.3 Regional distribution of effort

Dive effort was heavily concentrated in the D'Entrecasteaux Channel, accounting for 95% of the overall fishing effort, with Great Oyster Bay accounting for 2% and a further 3% of effort targeted at other sites around the state. This is a similar pattern to that observed each year since the fishery reopened in 2005 although the concentration of effort on the D'Entrecasteaux Channel was slightly less pronounced in the first season, when the region attracted 87% of the state-wide dive effort.

The distribution of fishing effort throughout the D'Entrecasteaux Channel was similar to 2007, with the focus on areas 2, 3, 4 and 5, which collectively accounted for 76% of the total state-wide effort (Fig. 16). Notable changes from the 2007 season were the proportional effort increase in area 5 to 39%, up 7% from 2007, offset by a decline of similar magnitude within area 2 down to just 8%. Effort in area 2 was most intense adjacent to Woodbridge. Throughout area 3; Great Bay, Simpsons Bay and Missionary Bay were targeted. In area 4 dive effort was targeted off Gordon (Gordon recorded the most diver days of any 'named' site within the Channel), while in area 5 beds off Satellite Island and Alonnah attracted significant effort.

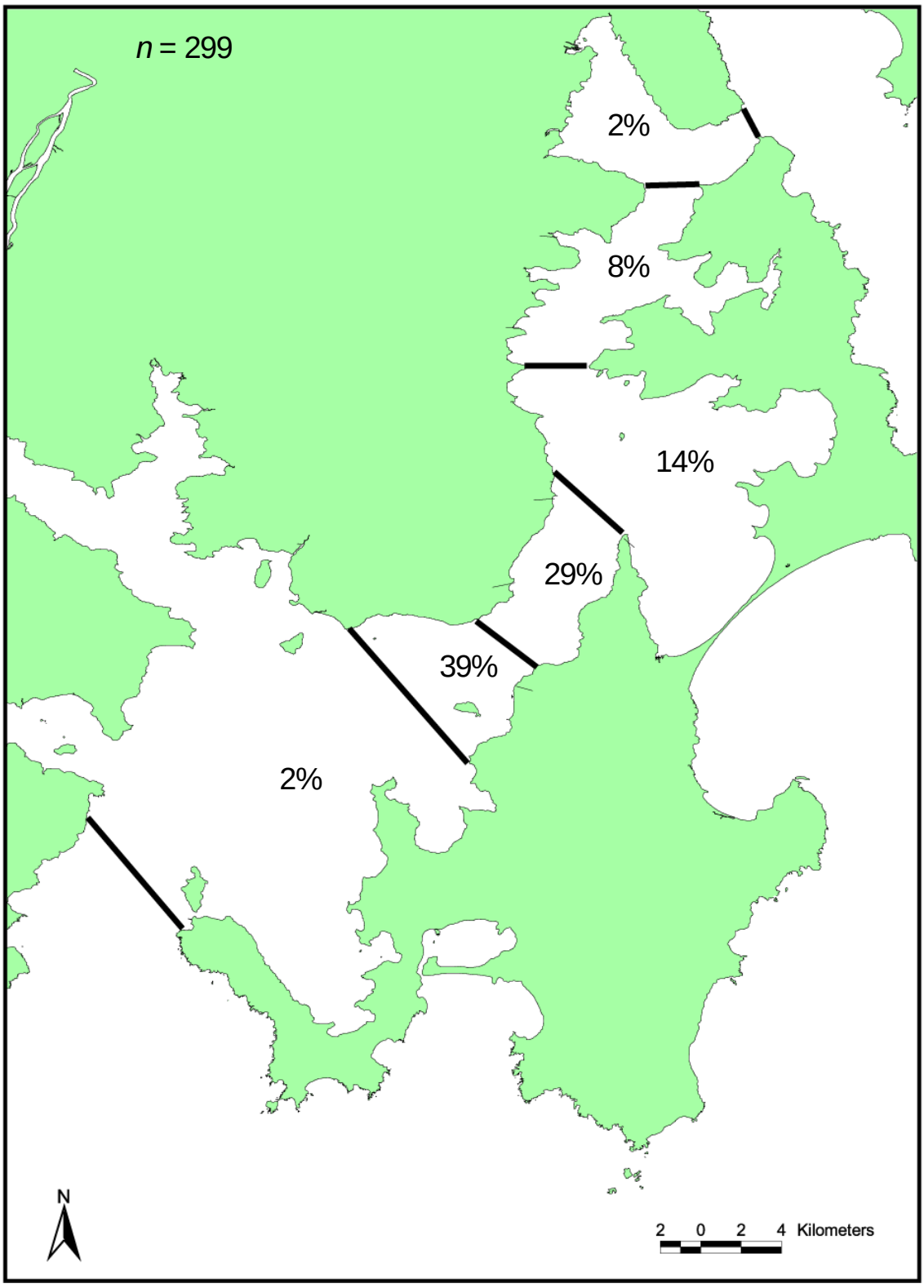

Fig. 16. Map of the D'Entrecasteaux Channel showing the areas targeted by recreational scallop fishers as % of total days fished. There were ambiguous responses by 6% of respondents that indicated they fished the D'Entrecasteaux and did not define their actual fishing locations, only responses that could be allocated to an area are included in this figure. *n* is the number of respondents.

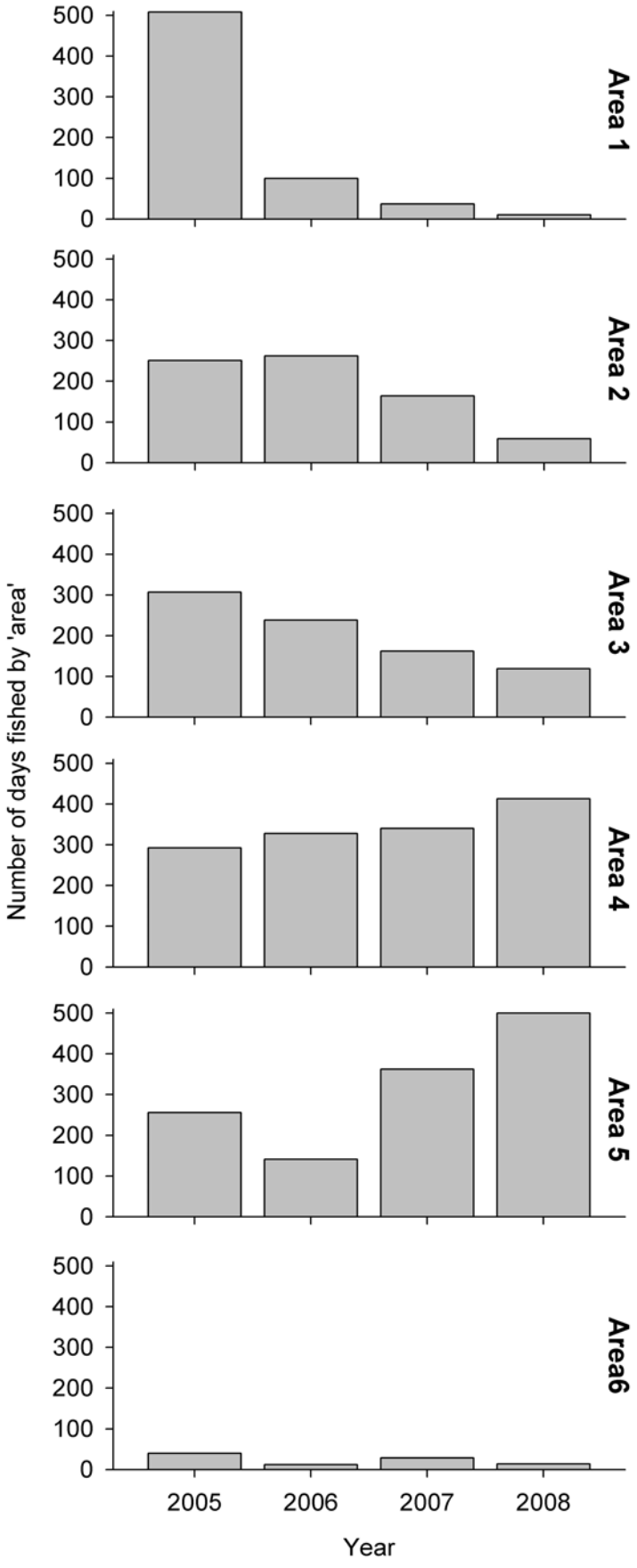

Fig. 17. Temporal trends in regional fisher effort within the D'Entrecasteaux Channel, areas are as described in Fig. 14.

There has been a clear north-south shift of fisher effort over the course of the last four fishing seasons, culminating in the concentration of effort in areas 4 & 5 during the 2008 season (Fig. 17), which is consistent with the depletion of key scallop beds observed during the scientific dive surveys.

As in previous seasons, residents from Greater Hobart and the Huon/Channel regions accounted for the vast majority of the fishing activity in the D'Entrecasteaux Channel (Fig. 18). The proportional increase of effort in the Channel from fishers residing 'elsewhere' reported in 2007 continued, up from 5% in 2006, 10% in 2007 to 14% in 2008.

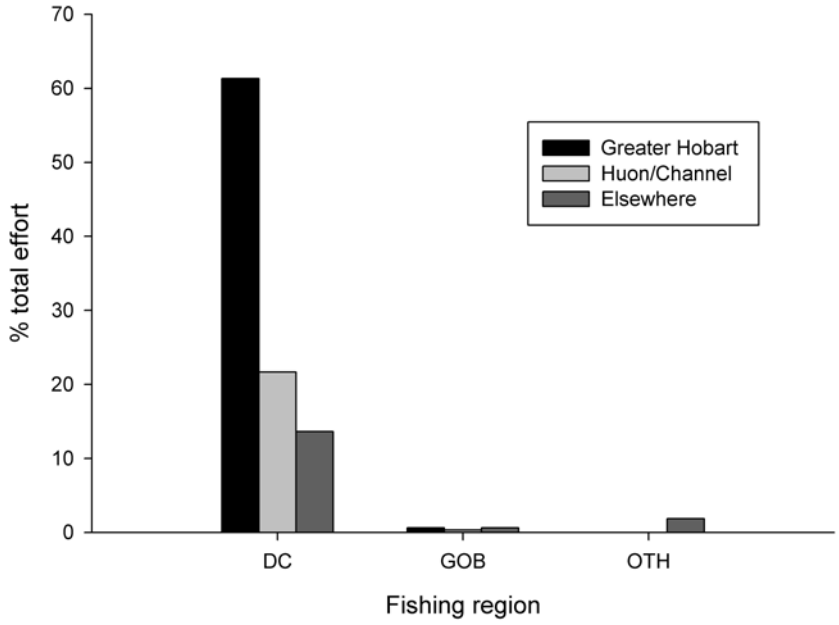

Fig. 18. Distribution of fishing effort based on place of residence. DC, D'Entrecasteaux Channel; GOB, Great Oyster Bay; OTH, all other regions. Total sample size equals 323 respondents.

3.3.4 Fishing success

Of those respondents who reported diving for scallops in 2008, 85% indicated that they took the bag limit on each day fished, this is consistent with the result reported in 2007 (84%), and implies a continued high level of fishing success.

3.3.5 Dive methods

Surface air (hookah) was used by 56% of divers targeting scallop during the 2008 season, followed by 44% who used scuba and 5% who dived on snorkel to harvest scallops. In terms of relative contribution to the total days fished, 58% of the effort was undertaken using surface air, 45% using scuba and 4% using snorkel.

3.3.6 Species preferences

Those respondents who fished during 2008 were asked to indicate whether they had a preferred target species of scallop. From 241 responses, 37% indicated no species preference. Amongst those respondents who indicated a species preference, 54% identified Queen scallops, 39% Commercial scallops and 7% Doughboy scallops. This was a significant change from 2007 when, amongst those respondents who indicated a species preference, Queen scallops were preferred by just 31% of respondents compared with 64% for Commercial scallops (Table. 1). Presumably this preference shift is a response to the relative size and availability of the different scallop species, with fishers preferring to harvest large scallops to increase meat yield.

Table 1. Preferred scallop species harvested by active fishers in 2007 and 2008.
2007; *n* = 175, 2008; *n* = 241

Answer	% 2008	% 2007
Commercial	24.5	45.7
Queen	33.6	22.3
Doughboy	4.5	3.4
No Preference/Unsure	37.3	28.6

Respondents were then asked to identify the species that had dominated their catch during the 2008 season. Over two-thirds indicated that their catch was dominated by Queen scallops, with Commercial scallops representing a further 20% (Table. 2).

Table 2. Actual scallop species harvested by active fishers in 2008.
n = 233

Answer	% 2008
Commercial	20.2
Queen	67.4
Doughboy	6.0
Unsure	6.4

3.3.7 Factors influencing the choice of where to fish

Respondents who reported fishing for scallops were asked to identify, from a list of options, which factor(s) influenced their decision about where they actually went diving for scallops. Approximately 74% indicated that prior knowledge of the location of scallop beds was an important factor (Table 3). Ease of access to the area and proximity to place of residence or holiday location were next in importance, followed by advice from other fishers. Trial and error (searching), observed activity by other fishers and environmental factors such as depth and water visibility were relatively minor factors. When compared with responses to the same question asked at the end of previous seasons, the most conspicuous change has been the steady increase of respondents noting prior knowledge of likely scallop beds. This presumably reflects

increased experience in the fishery. Increased experience is also reflected by a decrease in the percentage of fishers that rely on information from other fishers, trial and error and observed activity of other fishers.

Table 3. Response to factors mentioned as having influenced the decision of where to fish for scallops in 2008. Response profile from the 2007 (% in 2007), 2006 (% in 2006) and 2005 survey (% in 2005) are also indicated.
2008 sample size equals 241; percentages do not sum to 100 since multiple responses were possible.

Factors	% in 2008	% in 2007	% in 2006	% in 2005
Prior knowledge of likely scallop beds	74.2	68.5	58.9	51.6
Close to where you reside/holiday	24.1	32.9	38.7	37.2
Easy access (boat ramps/shore dives)	29.4	32.4	27.7	45.7
Advice from other fishers	14.5	30.6	47.2	54.6
Trial and error (result of searching)	9.5	13.4	8.7	23.0
Observed activity from other fishers	5.4	8.3	4.3	15.8
Other factors (water clarity, depth, etc)	2.9	2.8	5.7	3.6

3.3.8 Management of the fishery

Satisfaction with management

Respondents were advised that scallops have had a history of being over-fished in Tasmania and, in opening the fishery, a cautious approach has been taken by management; conservative bag limits, large minimum size limits and a relatively long fishing season intended to reduce the rush to take the catch that had characterised the fishery in the past. Respondents were asked how satisfied they were with this management approach and the majority (86%) indicated that they were at least quite satisfied (Table 4). Only 14% indicated dissatisfaction with the management strategy. Overall satisfaction has increased compared to 2007, and may have been linked with recent management changes that included an increase in the daily bag limit from 40 to 50 scallops. Of the few respondents that indicated they were dissatisfied the two main concerns were associated with the season being too long and the bag limit still being too low (Fig. 19).

Table 4. Response to satisfaction with the management of the scallop fishery since 2005.
2008 sample size equals 391.

Answer	% in 2008	% in 2007	% in 2006	% in 2005
Very satisfied	40.4	25.9	26.1	52.5
Quite satisfied	40.9	46.6	56.8	34.4
Not very satisfied	11.7	19.6	9.9	8.1
Not at all satisfied	2.3	4.1	2.8	2.2
Unsure	4.6	3.8	4.3	2.8

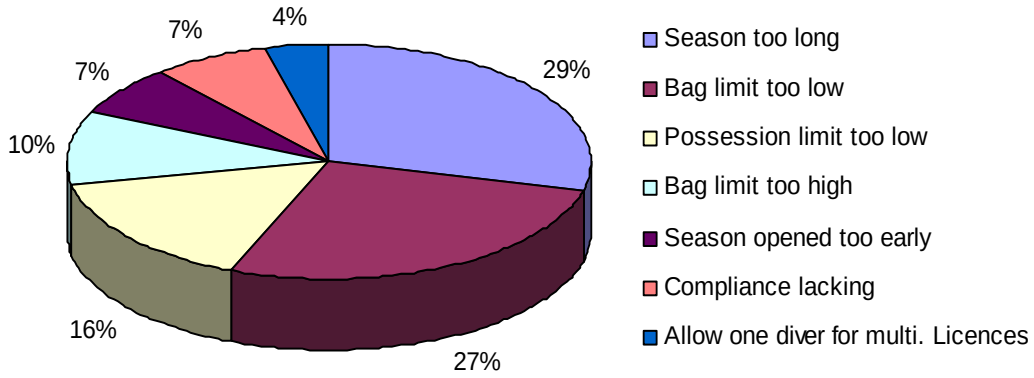

Fig. 19. The reasons for dissatisfaction in management of the recreational scallop fishery indicated by respondents interviewed during the 2008 post-season telephone survey.

3.3.9 Fisher perception on the health of inshore scallop populations

As an indicator of their experience with the fishery, respondents were asked how many of the recent scallop seasons they had actively participated in. Those who fished in 2008 and in at least one other season were asked whether they had fished more, less or about the same number of days in 2008 compared with previous seasons. They were then asked about their perception of the health of the scallop population in regards to trends in scallop abundance and distribution. As the vast majority of respondents had fished exclusively in the D'Entrecasteaux Channel, the following results are considered indicative of fisher perceptions for that region only.

Seventy seven percent of respondents who reported fishing in 2008 indicated they had also fished in one or more other season since 2005, with 38% indicating that they had fished in all four seasons (Fig. 20). For the remaining 23%, 2008 represented their first scallop season and they were not, therefore, asked about their perceptions on the health of the scallop populations, noting that they had no point of reference to compare current resource status.

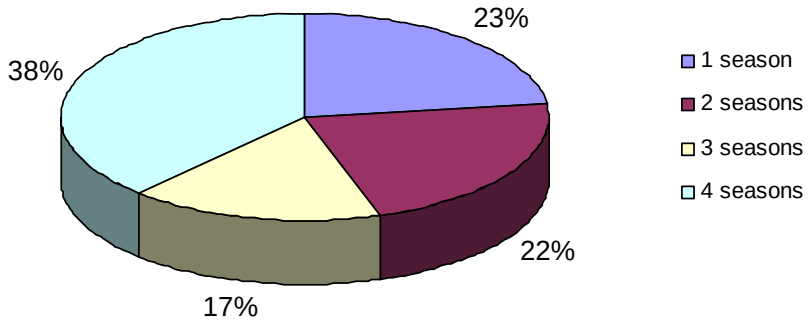

Fig. 20. Number of seasons fished by respondents since 2005, based on the 2008 telephone survey. Number of respondents equalled 241.

Of those who had fished in previous seasons, 48% indicated that they fished about the same number of days, 16% indicated that they fished more, and 35% indicated that they

fished less in 2008 compared with previous seasons.

In response to the question asking for perception of the trends in abundance of the scallop populations, 25% thought that the number of scallops had decreased, 49% thought that scallop numbers had remained unchanged and 18% thought that the available scallop numbers had increased in 2008 (Fig. 21).

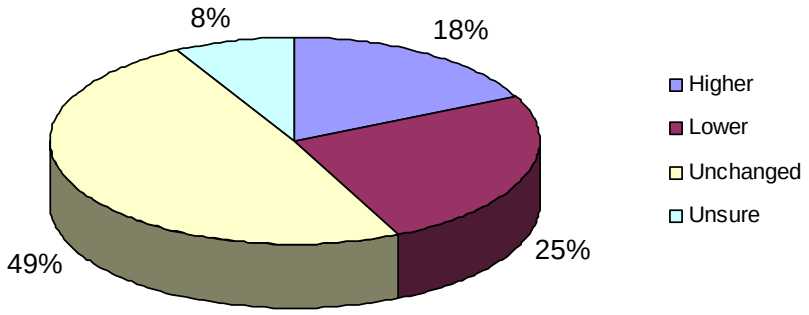

Fig. 21. Respondents perceptions regarding changes in abundance of scallop population available to recreational fishers.

A similar response was reported to the question asking their personal perception of the trends in distribution of the scallop populations, with 15% feeling that the scallop beds were less widespread, 52% feeling that the distribution of the beds remained unchanged and 12% feeling that the scallop beds were more widespread in 2008 than in previous seasons (Fig. 22).

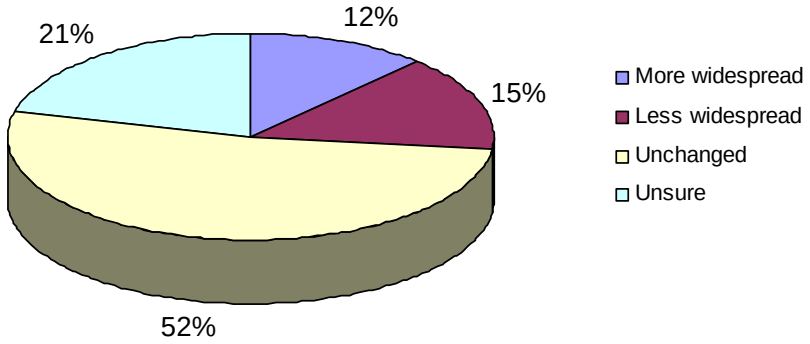

Fig. 22. Respondents perceptions regarding changes in distribution of scallop beds available to recreational fishers.

3.3.10 Other fishing activities

Respondents were asked to identify the types of saltwater fishing activities (other than scallop diving) they had undertaken during 2008. Line fishing was the most common fishing activity undertaken (86.5% of respondents), followed by diving for abalone and rock lobster (each about 60%). There was very little change between the responses from 2007 and 2008, the only exceptions being a slight declines in netting and spearfishing in 2008 (Table 5).

Table 5. Response to what fishing activities other than scallop fishing respondents undertook during the 2006, 2007 and 2008.

2008 sample size equals 392; percentages do not sum to 100 since multiple responses were possible.

Activity	% 2008	% 2007	% 2006
Line fishing	86.5	85.0	77.7
Abalone dive	63.8	62.4	58.6
Rock lobster dive	58.4	59.0	56.5
Rock lobster pot	57.9	57.2	39.7
Net	32.7	40.4	19.4
Spear	11.0	15.6	7.2
Rock lobster ring	15.3	14.4	9.3
None	5.6	6.1	6.4

Respondents who had dived for scallops during 2008 were also asked to identify which fishing activities, if any, they had combined with scallop fishing trips. The majority indicated that when diving for scallops they did not participate in any other fishing activities (Table 6).

Table 6. Response to the types of fishing activities respondents combined whilst on a scallop fishing trip during the 2006, 2007 and 2008 scallop seasons.

Sample size equals 290; percentages do not sum to 100 since multiple responses were possible.

Activity	% 2008	% 2007	% 2006
Scallop dive only	49.6	63.7	57.0
Line fishing	17.9	13.7	21.9
Abalone dive	13.1	14.1	15.3
Rock lobster dive	13.1	17.2	19.7
Other	6.2	8.2	7.1

4. Summary

The 2008 dive survey has provided further evidence of a decline in the number of scallops within the D'Entrecasteaux Channel since 2004. At the conclusion of the 2008 fishing season the combined effects of temporally and spatially erratic recruitment, natural mortality and targeted fishing pressure over the past four years has contributed to a decline in the total number of scallops at reference sites by 42%. The most notable change has been the decline in abundance and contraction in distribution of Commercial scallops (Figs. 9 & 10). Although still the most abundant species, by 2008 the previously high density beds of Commercial scallop located throughout the northern and mid-Channel, the mainstay of the fishery between 2005 and 2007, were all but absent (Figs. 9 & 10). The only known remaining dense bed of Commercial scallops is located in the Great Bay/Simpsons Bay area and is comprised almost exclusively of a single cohort spawned in 2006 which while mature, are still undersized.

It is perhaps relevant to put into a historical context what has been considered to be 'high' density beds during the past four seasons. For example, Commercial scallops densities within some beds peaked at around 2 Sc. m^2 in 2006 and were 'high' density in relation to densities reported from subsequent surveys. However, by comparison peak densities reported from the Channel in 1955, were as high as 6 scallops/sq. yd (5.5 Sc. m^2) (Olsen 1955).

In response to the decline in legal sized Commercial scallop numbers, divers have shifted focus to the Queen scallop beds. This shift in species preference was predicted in the 2007 report of the recreational scallop fishery, where it was noted that as the number of legal Commercial scallops declined, effort would shift to Queen scallops, rather than Doughboy scallops, to ensure that a comparable meat yield was maintained (Tracey & Lyle 2008). The distribution of Queen scallops is focused mainly around popular boat access points to the Channel, providing easy access to the beds as well as a means of observing where other fishers are active for inexperienced fishers.

Queen scallop numbers have declined since the fishery re-opened, although their distribution appears to have remained relatively constant (Fig. 11). Over the last four years there has been little recruitment of Queen scallops and as a result the average age of the population has increased steadily, to a point where natural senescence is now expected to have a significant impact on the future abundance of this species, even in the absence of fishing pressure. Anecdotal reports from fishers during the season as well as observations from the scientific survey support this prediction, with a number of 'clappers' (scallops shells still hinged, but with no meat, assumed to have recently died) found on the beds. There were also reports of very poor quality meats and shells showing signs of parasitic infection and 'blistering', all possible signs of senescence.

Doughboy scallop beds have remained relatively unchanged since 2005 (Fig. 12), possibly linked to the preference for habitat with bottom structure to attach to with their byssal thread. Relatively constant but low levels of annual recruitment and apparently low fishing pressure appear to have maintained a *status quo* situation for Doughboy scallop populations.

The expansion of Northern Pacific sea star numbers within the Channel has raised concerns about their potential impact on the endemic scallop populations. While no obvious predatory interactions have been observed between the introduced sea star and scallops during the scientific surveys, we cannot discount this possibility, especially for newly settled scallops. Scallops are a known prey species for sea stars, so further study would be required to define the actual impacts of their presence in the region.

Assuming a predatory effect on the scallop populations, it may be significant that the densest sea star aggregations are in close proximity to the Queen scallop beds. However, being mainly old, large individuals, the thicker shells and stronger adductor muscle of these large scallops may be a defence mechanism to predatory advances by the sea star. With that in mind, the aggregation of Northern Pacific sea stars south of Missionary Bay could pose more of a threat to the younger and smaller sized Commercial scallops that settled in the area approximately two years ago. The mid-region of the Channel has historically been a prime habitat for scallop settlement and the recent incursion of the sea star into this area may have future negative impacts on scallop populations in the D'Entrecasteaux Channel.

A telephone survey of recreational scallop licence-holders revealed key information about the 2008 fishery and general perceptions about the perceived health of the scallop populations and management of the fishery.

- Almost 39% of scallop licence holders did not fish during 2008, a similar proportion to 2007, though increased licence sales in 2008 meant that there were more active fishers in 2008.

- Recreational fishers dived an estimated 22,478 fisher days for scallops during the 2008 scallop season, representing an average of 5.5 days per fisher.

- The vast majority (95%) of the dive effort was again concentrated in the D'Entrecasteaux Channel, with Great Oyster Bay of minor importance (2%). Effort was focussed at the southern end of the central Channel region, in particular around Gordon, Satellite Island and Alonnah.

- Residents of Greater Hobart and Huon/Channel areas accounted for the vast majority of the scallop dive effort, with a slight increase in the proportion of fishers coming from elsewhere to fish the Channel compared with previous years.

- Using the bag limit as a measure of fishing success, 85% of all fishing effort resulted in the daily bag limit of 50 scallops being achieved.

- Surface air was the primary dive method used, followed by scuba and snorkel.

- The majority of respondents (86%) indicated that they were satisfied with the management approach for the 2008 season.

Fisher perceptions about scallops stocks

The perception by many fishers that status of the scallop stocks (in the Channel) were effectively unchanged or had improved in 2008 compared with previous seasons is in apparent contradiction to trends in distribution and abundance observed in the scientific surveys conducted since 2004. We believe there are two explanations for this contrasting view. Firstly, fishers have a vested interest in stating that the stocks are healthy to avoid the prospect of closures or introduction of more restrictive management measures. Secondly, and more likely, the population dynamics of scallops can create deceptive perceptions on overall health. Scallops are reasonably sedentary and tend to be aggregated in dense beds as a result of synchronised larval settlement. Therefore, by targeting such beds divers are able to easily take their bag limit, a phenomenon reported in each of the four previous seasons. To a point, even as beds are fished down it may still be possible to take the bag limit readily, if a dense patch is found, although the effective search area (dive time) may be larger. There have been many anecdotal reports by divers to support this observation. Thus as long as relatively high density beds of scallops are present, a fact confirmed by the 2008 post-season dive survey, it is not surprising then that many fishers will conclude that the stock is as healthy as it always has been. However, what tends to be overlooked (or forgotten) is the fact that beds in some areas are no longer productive and divers have moved onto 'new' areas and in the process even switched primary species targeted. This is a classic case of serial stock depletion, with catch rates remaining high but the number and spatial extent of the aggregations declines. Overall, the dive surveys and post-season telephone surveys provide a broader perspective of the resource and fishery status than that available to the individual fisher, noting trends that have occurred over the recent history of the fishery and scallop population structure.

The fish-down of a dense scallop bed off Conningham (Area 1) during the 2005 and 2006 seasons is a good example of serial depletion. A large number of divers fished this bed with a high degree of success (collected their bag limit in quick time) during the 2005 season. The proximity to the Margate boat ramp (and Hobart) and the large Commercial scallops found in the area made this bed an attractive prospect. At the beginning of the 2006 season this trend continued, however, the density of scallops had decreased to a point where it became increasingly difficult to collect a full bag. Fishers that targeted this bed eventually moved further south to other known productive beds. This redistribution of effort has been well documented in the telephone surveys, with decreasing effort in the northern Channel over time and increased effort in central and southern areas of the Channel. Further evidence of serial depletion has been observed at other beds further south, in particular around Woodbridge, Missionary Bay and to some extent Gordon. By 2008, much of the fishing effort was focussed on the remaining beds of Queen scallops off Gordon, Satellite Island and Alonnah, which although still productive, were characterised by reduced densities compared with earlier seasons.

Management Implications

Overall recreational fishers experienced a high degree of success during the 2008 scallop season, which is consistent with previous years, and were generally satisfied with the current management. The number of fishers taking out scallop licences and actively participating in the fishery has continued to rise. Of concern for the future of

the fishery, however, is the continuing decline in scallop numbers, particularly Commercial scallops, the mainstay species over the first three seasons, as well as the lack of recruitment for Queen scallops. The remaining Queen scallops are primarily large individuals which are close to their anticipated maximum age, and hence mortality rates are expected to be high in coming years regardless of any fishery impacts.

The effect of the significant decline in the number of legal sized Commercial scallops since 2005 became particularly evident during 2008, with the majority of fishers reporting a shift from Commercial to Queen scallops as the main species retained. However, the Queen scallop distribution is now quite localised and the population has experienced no significant recruitment for many years, making the remaining Channel stock particularly vulnerable to overfishing. It should be noted that even though relatively dense areas of adult Queen scallops remain, there is no guarantee of future recruitment success. Thus, if these remaining scallops fail to produce a successful settlement event within the next couple of years, noting many are near assumed maximum age, this stock is expected to collapse and future recovery will be dependent on settlement derived from populations outside of the Channel.

The settlement pulse of Commercial scallops spawned in 2006 has reached a mean length of 88 mm SW within two years and it is likely that a proportion of this cohort will attain legal size during 2009. However, to date there has been no evidence for follow-up settlement and the population is now effectively comprised of a single cohort, with just a remnant of older year classes remaining. The fact that these scallops are restricted to a localised area will make them particularly vulnerable to heavy fishing pressure in future years.

In order to increase the likelihood of sustaining future fisheries it would, therefore, be prudent to adopt a management strategy that uses information about population structure to determine whether or not areas such as the Channel should be opened to fishing each year. It is perhaps important to recognise that at the opening of the 2005 season both Commercial and Queen scallop populations were comprised of at least two year classes each, a population structure that has sustained the fishery for four years. Dependence upon a single cohort of adult stock without evidence of additional settlement to replenish the stock, as is the current situation for Commercial scallops, would appear to be a high risk strategy, despite an overall cautious management approach in regard to size and bag limits.

To reduce the possibility of stock collapse and protracted closures, as has already occurred several times in the history of the Channel fishery, a management approach that protects the adult stock until there is evidence of adequate recruitment would appear a more precautionary approach. This would help insure against fishing stocks down to a point where the adult biomass no longer represented a viable spawning population, with resultant dependence on settlement derived from populations outside of the area. Such a strategy is particularly important in semi-enclosed areas such as the D'Entrecasteaux Channel where populations are more likely to be self-recruiting as opposed to more open coastal waters, where there is evidence that recruits are derived from adjacent scallop beds.

5. Acknowledgments

We wish to thank Edward Forbes, Graeme Ewing, Dane Jones and Tom Berli for providing diving assistance and acknowledge our team of telephone interviewers; Neil O'Donnell, Shirley Lines, Jennie Holmes and Virginia Murphy, who produced high response rates and ensured data quality. The willing participation of the many recreational fishers in the telephone survey is also greatly appreciated.

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