Use of historic fisheries data to determine trends in relative abundance and body size of sailfish, *Istiophorus platypterus*, off northwestern Australia

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Abstract

Sailfish (*Istiophorus platypterus*) appear annually off northwestern Australia in large numbers, supporting substantial recreational and charter fisheries in which almost all fish are released. The main centres for this activity are the towns of Broome, Dampier and Exmouth. Examination of historic Japanese longline catch data from northwestern Australia indicated that relatively few sailfish were caught off this area between 1979 and 1998, although little fishing effort occurred during the peak sailfish 'season'. Long term recreational fishery data, consisting of tag and release and charter boat diary data, were used to investigate locations of captures, seasonality of the sailfish aggregations and trends in body size and relative abundance of sailfish through time. No trends in annual catch rates were discernible from the mid 1990s to the present. Sailfish may be caught in most months off Broome, with the average peak period being June through September. Sailfish caught off Broome, as determined from estimated weights at tag-and-release, are slightly, but significantly smaller than those caught off Dampier while fish caught near the Rowley Shoals, and in the Exmouth Gulf, are larger than those caught off Broome and Dampier.

Keywords: Sailfish, *Istiophorus platypterus*, northwestern Australia, recreational fisheries

Introduction

The sailfish, *Istophorus platypterus* (Shaw & Nodder 1792) is a member of the billifish family Istiophoridae, which also includes the marlins and the spearfishes, all of which are high trophic level predators. Sailfish occupy tropical, subtropical, and occasionally temperate waters throughout the Indian, Pacific and Atlantic Oceans (Nakamura 1985), mostly between 30°N and 30°S, with poleward expansions of range during summer months in both hemispheres (Beardsley *et al.* 1975). Recent taxonomic and phylogenetic research on billfishes, based on molecular genetics, supports the existence of a single circumglobal species of sailfish, *Istiophorus platypterus* (Collette *et al*. 2006).

Sailfish, unlike most species of billfish, commonly aggregate in relatively shallow nutrient-rich neritic waters (<150 m depths). Known areas of high seasonal concentration of sailfish include the Pacific coast of central America, including Mexico, the Gulf of Mexico, especially the coast of Florida, the Malaysian peninsula, several grounds inside the Great Barrier Reef, and off the northwestern Australian coast, especially in the region of Dampier and Broome.

Because of these seasonal aggregations of sailfish in coastal areas, a recreational fishery developed in the 1960s (Howard & Stark 1975) and 1970s in northwestern Australia that primarily targets sailfish. Dampier and Broome are now the main centres for this activity but significant numbers of sailfish are also caught off Exmouth. In all three areas, virtually all of sailfish caught are either tagged and released, or released. These fisheries are reputed to generate considerable economic benefits for the region. Very little is known, however, about the biology of sailfish in the region, especially in regard to the species' spatial and temporal distribution and movement patterns. Therefore, a study was undertaken to collate and analyse historic fishery data relevant to sailfish in the region with the aim of determining catch rates through time, size distribution of the catch and seasonality of the appearance of sailfish in these areas.

Methods

Data were derived from a range of sources. Commercial Japanese longline catch and effort statistics were derived from Campbell *et al.* 1998. Information on the Taiwanese gillnet fishery was also derived from Campbell *et al.* 1998, and Stevens & Davenport 1991. For

the recreational fishery, raw data on sailfish tagged between 1979 and 2009 were obtained under a data licence agreement from Industry & Investment NSW (Fisheries). Tagging data includes the following details for each fish tagged and released: Tag number, species, date, location, estimated size (weight and/or length) at release, boat and angler name.

Median weight estimates were compared using a one-way ANOVA on Ranks and post-hoc comparisons following Dunn's Method.

Catch and effort data for the annual Broome Sailfishing tournament were kindly extracted and supplied by the Broome Fishing Club for the period 1997 to 2009. These data were extracted from radio reports. At 10:00 am, 1:00 pm and 4:00 pm on each fishing day, each boat is contacted and asked to give a fishing report. Such reports record the position of the boat, and how many sailfish (or marlin) the boat has raised, struck, hooked and/or released in the previous period ('raised' means a sailfish or marlin observed following a bait or lure; 'struck' means a sailfish or marlin that attacks a lure or bait, but fails to become hooked). These data are consistent over the history of the data set (1997 to 2009) and provide some measure of catch per unit of effort (CPUE), and therefore relative abundance of fish, through time.

For the purposes of this study, two charter boat operators who have actively fished for sailfish off Broome over lengthy periods kindly provided their personal records of sailfish catches over time. These data recorded the number of days fished each year, and the number of sailfish caught (released, or tagged and released) on each day fished. (Note that these data are separate from compulsory logbook catch records required to be submitted to the Western Australian Fisheries Department by all charter operators since 2004).

Logbook charter data was obtained from WA Fisheries. It is important to note that due to confidentiality arrangements, sailfish release data are not included if there were less than three charter boats operating in any given statistical grid during the period under consideration.

Results

Historic commercial fisheries

Japanese longlining commenced off northwestern Australia in the 1950s, primarily targeting southern bluefin tuna, *Thunnus mccoyi*. While the targeting of southern bluefin tuna was halted in the region in the early 1970s, longlining in the region, mainly for yellowfin tuna, continued until 1997/98 when Japanese vessels were excluded from the 200 nm Australian Fishing Zone (AFZ). Previously, waters within 50 nm of Exmouth were closed to Japanese longlining in 1990/91 extending to a closure of all waters within 50 nm of Western Australia north of 35°S in 1992/93. At the same time, in areas beyond 50 nm, billfish other than broadbill swordfish were not to be deliberately targeted (Campbell *et al.* 1998).

Table 1 shows the reported annual catch of billfish (numbers) by Japanese bilateral and joint venture

Table 1

Fishing effort (number of hooks) and catches (number) of billfish caught by Japanese bilateral and joint venture longline vessels operating within the AFZ west of 125°E since 1979. BAM = black marlin, BUM = blue marlin, STM = striped marlin, SLF = sailfish, BBL = broadbill swordfish.

Year	Hooks	BAM	BUM	STM	SLF	BBL
1979	58,100	12	13	98	0	40
1980	769,804	241	127	625	0	727
1981	1,664,220	394	223	777	48	1,037
1982	1,069,224	550	314	622	20	600
1983	1,288,795	450	112	1,060	35	642
1984	2,803,353	2,256	1,027	6,299	203	1,250
1985	2,490,880	2,167	785	3,500	101	1,711
1986	2,798,925	1,166	710	934	160	1,200
1987	4,389,658	814	290	1,043	218	1,685
1988	957,716	603	365	232	173	416
1989	711,880	362	216	108	184	353
1990	1,223,450	291	301	103	29	711
1991	167,232	0	3	0	1	696
1992	533,024	0	0	3	0	308
1993	3,257,023	21	6	40	33	2,575
1994	2,495,635	250	246	143	45	1,419
1995	2,494,203	320	476	160	78	1,204
1996	756,135	4	18	51	5	1,754
1997	161,400	36	19	10	34	43

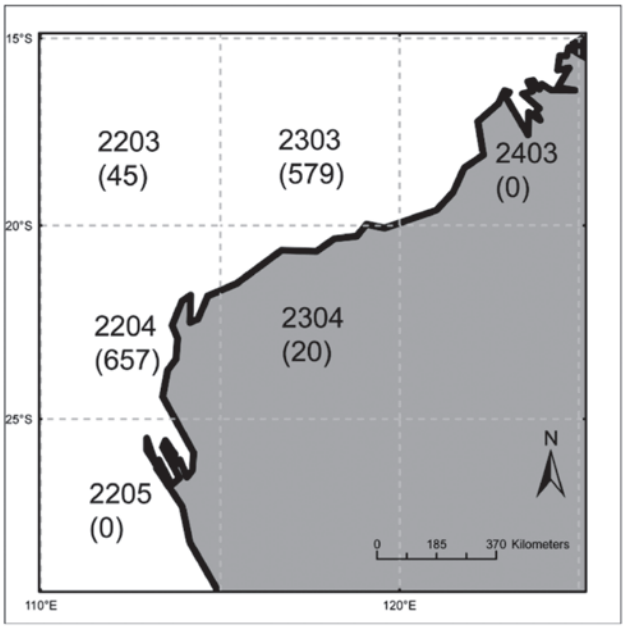

Figure 1. Numbers of sailfish & spearfish caught (in brackets) in 5° statistical areas off northwestern Australia by Japanese longline vessels between 1979 and 1998.

longline vessels operating within the AFZ west of 125°E since 1979 (from Campbell *et al.* 1998).

Between 1979 and 1997, compared with other istiophorids (black, blue and striped marlin), very few sailfish appear in catch records of Japanese longline vessels fishing in Western Australian waters. Several aspects of recording sailfish catches are important to note in this regard. Sailfish and shortbill spearfish (*Tetrapturus angustirostris*) were combined in Japanese logbooks, so the actual catch of sailfish recorded would be less than indicated. However, spearfish are uncommon in this region, so it is likely that the figures given for sailfish/spearfish in this instance do represent primarily sailfish. It is also noted that sailfish were not regarded as a desirable species to retain by Japanese longliners so it is likely that many were discarded at sea without being recorded.

Figure 1 shows areas where sailfish were historically recorded by Japanese longliners. No sailfish were recorded adjacent to Broome (grid 2403) and only a small number were recorded adjacent to Dampier (grid 2304). The largest numbers of sailfish were taken immediately adjacent to these areas (grid 2303) and in the grid adjacent to Exmouth (grid 2204).

The low catches of sailfish in areas where the species is caught in large numbers by the recreational fishery can be largely explained by the fact that Japanese longlining only took place at or beyond the boundary of the continental shelf, in waters normally deeper than 200 m (Campbell *et al.* 1998). This boundary is well outside the area where sailfish have been, and are targeted by the recreational fisheries off Broome and Dampier, but much closer to the sailfish grounds off the Exmouth Gulf (Fig. 2).

More importantly though, Japanese longline effort was historically almost entirely absent from northwestern Australia during the months of April to September, the peak period of encounter with sailfish by the recreational fishery off both Broome and Dampier (Fig. 3 and Fig. 9).

A large-scale Taiwanese gillnet fishery that targeted Carcharhinid sharks operated off northern Australia from 1972 to 1986. Before the declaration of the 200 mile Australian Fishing Zone in 1979, this fishery was active to within 12 nautical miles of the coast, and while the great majority of fishing effort was expended to the north of Arnhem Land, Northern Territory, a small amount of effort extended to the waters off the coast, just to the north of Broome (Stevens & Davenport 1991).

Australian observers monitored this fishery from 1984 and results indicated a significant bycatch of sailfish and juvenile black marlin throughout the region, averaging

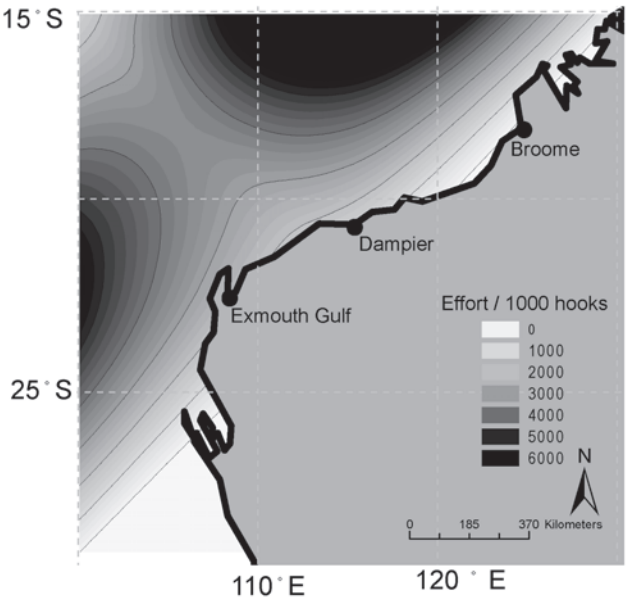

Figure 2. Contours representing number of hooks set by Japanese longline vessels off northwestern Australia between 1979 and 1998. Note that the fishing effort near Broome and Dampier was extremely low.

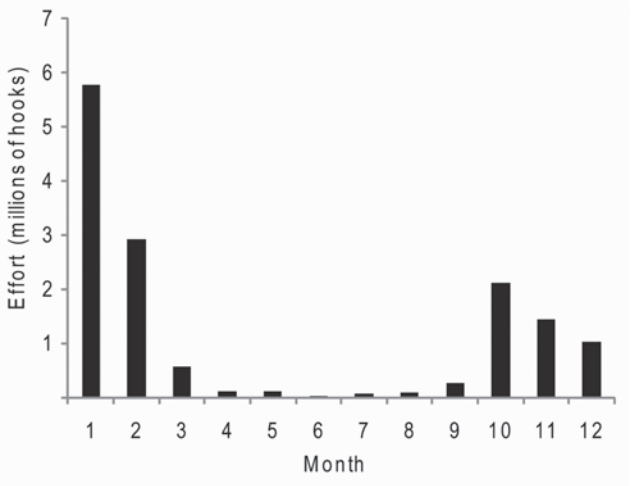

Figure 3. Cumulative effort (millions of hooks) by month of Japanese longline vessels off the coast of northwestern Australia (15–30°S; 110–125°E) between 1979 and 1998. A total of 14,510,849 hooks were set.

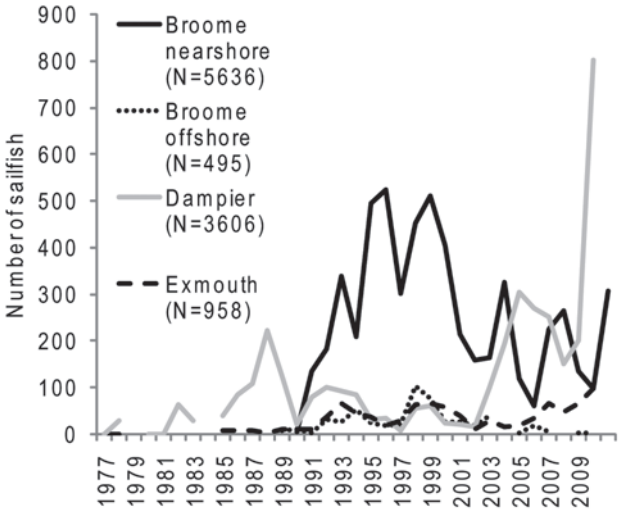

Figure 4. Total number of sailfish tagged by recreational anglers each year off four main regions of Western Australia.

one billfish per gillnet haul. Analysis suggested that the catch would have been of the order of 6 black marlin and 5 sailfish per 1000 km/hour of fishing effort (Campbell *et al.* 1998) which would convert to tens of thousands of both species of billfish over the life of the fishery. Campbell *et al.* (1998) caution against the use of these estimates but do state that the fishery was "probably a substantial source of billfish mortality" at the time. However, given the very small amount of fishing effort off Broome, and none further south, the catch of sailfish in the study area could only have been a small fraction of the total catch.

Recreational fishery for sailfish off northwestern Australia

The total catches of sailfish by recreational anglers off northwestern Australia are unknown. However, details of all sailfish tagged by anglers in the region since the 1970s are held by NSW Industry & Investment's Australian Gamefish Tagging database (Pepperell 2009). As of June 2009, the total number of sailfish tagged off Western Australia since 1978 was just over 11,190. Of these, 10,695 had been tagged off the northwest coast. Figure 4 shows the annual number of sailfish tagged in the waters off the three major centres of interest – Broome, Dampier and Exmouth, together with numbers of sailfish tagged wide of Broome (termed 'Broome offshore'), which is the region primarily around the Rowley Shoals, about 175 nm ENE of Broome).

Sailfish tagging in Western Australia commenced off Dampier in 1978, with numbers tagged generally being less than 100 fish year until the early 2000s when numbers tagged increased substantially to a peak of over 800 fish in 2009 – the highest recorded for any region off Western Australia. A total of 3,606 sailfish had been tagged off Dampier by the end of 2009.

Sailfish tagging off Broome commenced in 1988 with numbers tagged rapidly increasing to annual totals of around 500 fish in the mid 1990s. Numbers tagged then declined, fluctuating between about 100 and 300 fish in the 2000s. A total of 5,636 sailfish had been tagged off Broome by the end of 2009, more than any other area in Western Australia.

Catches off Exmouth have been low in comparison, with peaks of more than 50 fish tagged in some years, increasing consistently over the past several years. A total of 958 sailfish had been tagged off Exmouth by the end of 2009, most of these inside Exmouth Gulf.

Offshore sailfish taggings have been somewhat intermittent, presumably because of the remoteness of the Rowley Shoals. Nevertheless, nearly 500 fish had been tagged in offshore areas by the end of 2009, with most activity in the mid 1990s.

Sizes composition of the recreational catch

When a sailfish is tagged and released, an estimate of the size of the fish is nearly always recorded by the angler on the tag card. These estimates are generally agreed upon by all present on the boat, and while length estimates are sometimes included, the overwhelming majority of estimates are given as weights (kg).

Figure 5 shows the size distribution of all sailfish tagged off the four areas for all fish where weights were estimated. This suggests difference in sizes of sailfish tagged in different areas. Indeed, significant differences were found (Dunn's, $P<0.05$) in the mean estimated weights of sailfish tagged between all regions investigated, except between Broome offshore and Exmouth (Fig. 6). The mean size of fish is smallest off Broome, followed by those caught off Dampier, Exmouth and Broome offshore.

When mean weights of sailfish are disaggregated by quarter, a possible seasonal trend in increasing size of fish off both Broome and Dampier is seen, at least from the second to the fourth quarter (Table 2). This could indicate that fish are remaining on these grounds and growing in average size through the season.

Table 2

Average weights (estimated) of sailfish tagged-and-released throughout the study area.

	Broome nearshore			Broome offshore			Dampier			Exmouth		
Quarter	N	Mean	StdDev	N	Mean	StdDev	N	Mean	StdDev	N	Mean	StdDev
1	9	19.67	8.69	2	28.50	9.19	136	20.23	10.00	190	30.24	12.31
2	514	19.22	6.83	47	26.02	7.88	1068	19.11	9.21	74	32.80	11.19
3	4937	19.87	7.21	356	28.63	9.38	2211	22.45	7.18	199	30.69	9.60
4	176	21.03	6.28	90	31.39	9.43	191	22.78	8.19	495	25.68	10.16
Total	5636	19.85	7.16	495	28.88	9.34	3606	21.39	8.15	958	28.18	10.90

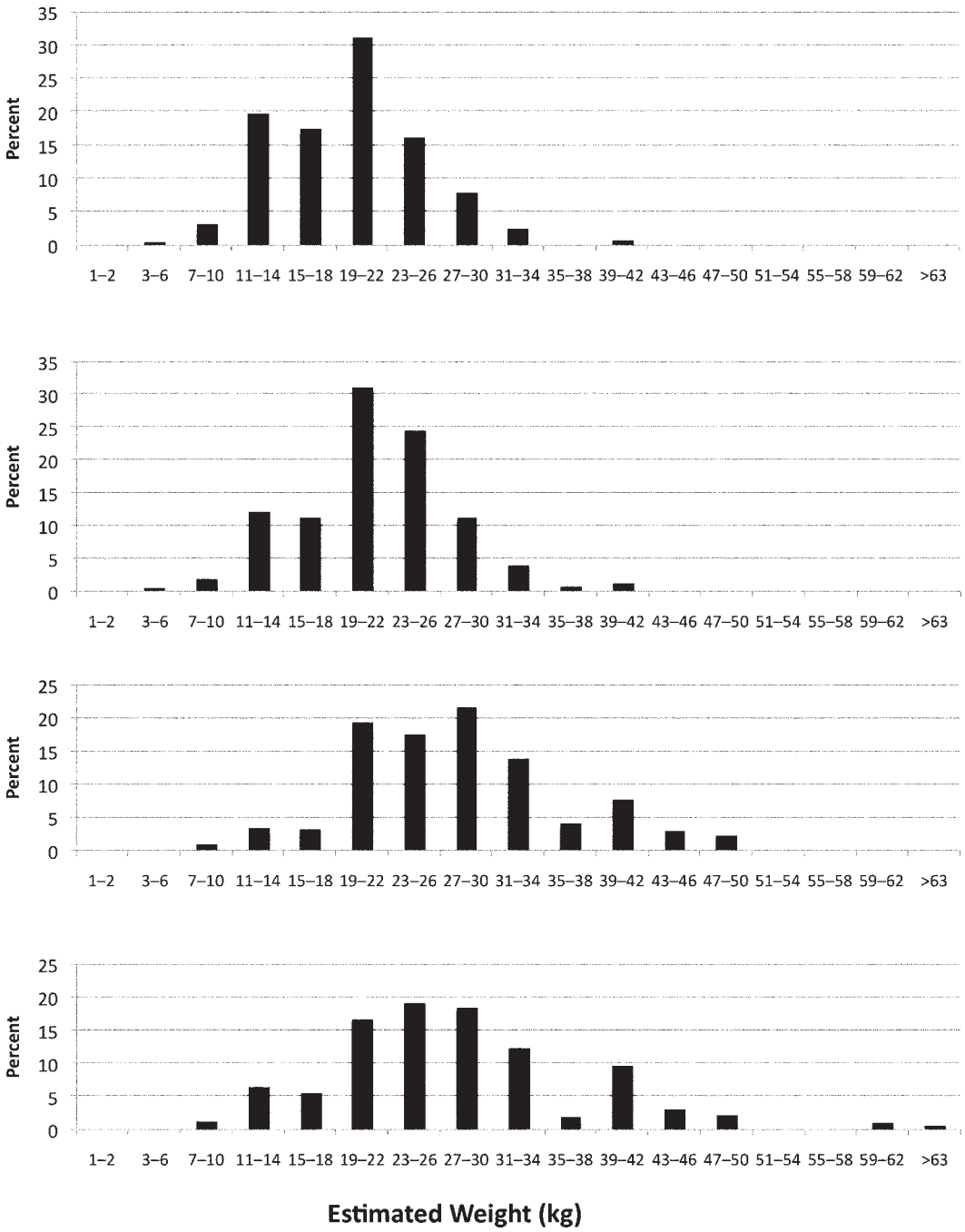

Figure 5. Size distributions (estimated weights of tagged fish) of sailfish tagged and released in the four main recreational fishing areas off Western Australia since 1989.

The Broome recreational sailfish fishery

Several data sets are available from the Broome area that are not available for the other recreational sailfishing areas in Western Australia. These include detailed records of all sailfish interactions (raised, struck, hooked and released) during the annual Broome Sailfishing Tournament, numbers of boats fishing each tournament day from 1997 to 2009, WA Fisheries records of charter boat catches of sailfish in the area 2004 to 2007 (see caveats below), and personal diary records of sailfish catches by two sailfish specialist charter captains from 1996 to 2009.

Catches through time

The rates (fish per boat day) of sailfish raised, struck, hooked and tagged during the annual Broome Sailfishing Tournament for 1997–2009 are shown in Figure 7. The numbers of fish raised per boat day are obviously the highest among these measures, but while this figure theoretically provides an index of abundance, in reality the same fish may be raised again and again by the same or different boats. Therefore, the hookup and release (tag) rates are considered to be better indicators of relative abundance.

Comparison (ANOVA on Ranks; Dunn's)	Q	P <0.05
Exmouth vs Broome inshore	26.7	Yes
Broome offsh vs Broome inshore	22.8	Yes
Exmouth vs Dampier	16.6	Yes
Broome offshore vs Dampier	15.3	Yes
Dampier vs Broome inshore	15.3	Yes
Broome offshore vs Exmouth	2.3	No

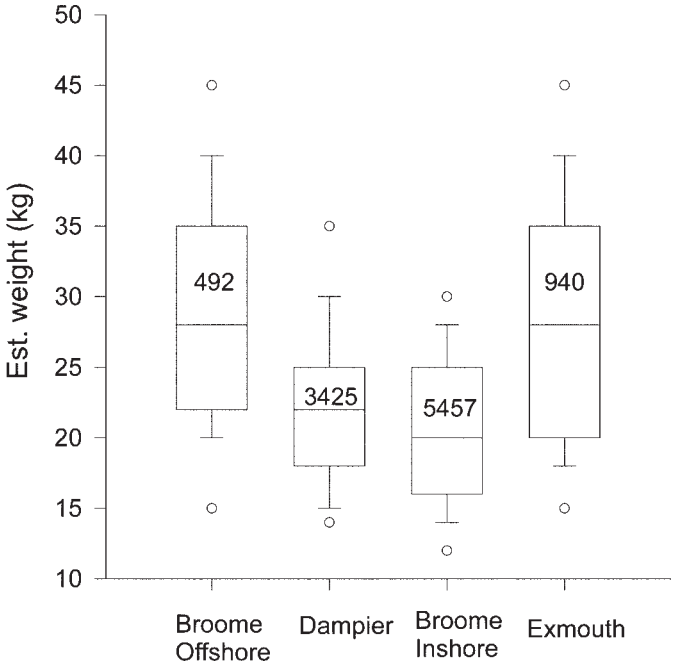

Figure 6. Median estimated weight of sailfish tagged-and-released at different locations off the coast of northwestern Australia between 1977 and 2009. N = sample size. Middle line represents the median and ends of boxes define the 25th and 75th percentiles. Error bars at 10th and 90th percentiles and 5th and 95th percentiles are represented by open circles.

There was no clear temporal trend in the rates of hook-ups and fish tagged per boat day. The highest number of fish interactions occurred in 2002 followed by two poor years, and then fairly consistent annual catches occurred thereafter.

Catch rates by charter boats

The two sets of personal records from the cooperating charter operators begin in the 1990s and as such, are valuable independent sources of information on catch rates through time. Also, because charter boats fish over a much greater part of the year than a given fishing tournament, their records are very useful in determining the seasonality of sailfish in the area. It is also important to note that while the charter operators do tag sailfish at certain times, most notably during tournaments, they do not necessarily do so at other times, but may simply release sailfish without tags. These are still recorded by the operators, resulting in their records of released fish being somewhat, but not entirely separate from release information recorded on tag cards. Regarding the representativeness of the data from these operators, examination of total sailfish releases shows that, for the years where mandatory logbook data were available (2004–2007), charter operator 1 accounted for 66.3% of all sailfish caught and released off Broome by all charter operators. It is further recognized that during the mid to late 1990s, operator 2 was by far the most active and successful sailfishing charterer in the region.

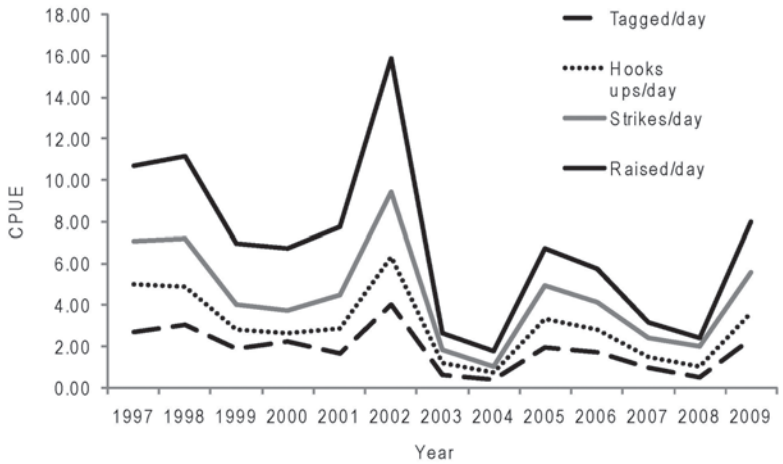

Figure 7. Numbers of sailfish raised, struck, hooked and tagged per day in the Broome Sailfishing Tournament, 1997–2009.

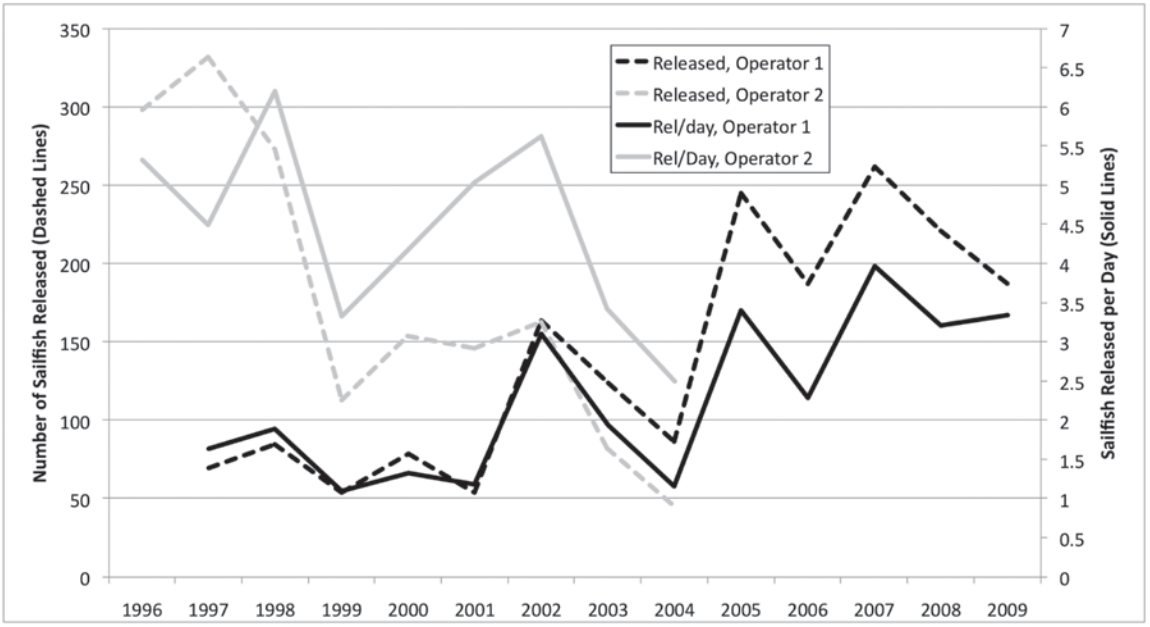

Figure 8. Catch and catch rate of sailfish by charter operators 1 and 2.

Figure 8 shows numbers of sailfish released each year and the annual catch rate (numbers released per day fished) by both charter operators (with the caveat that, for operator 2, the total number of days fished are unknown and therefore 'effort' is defined as the days on which at least one sailfish was released). For operator 1, there is a general trend of an increase in catch and catch rate through time while for operator 2, there is a downward trend in catch and catch rate to the end of the series (2004). This trend in catch rate is primarily due to the fact that the vessel was not necessarily targeting sailfish consistently in the last three years of the series, as indicated to the authors by the operator.

Seasonality of sailfish off Broome

The seasonality of the appearance of sailfish off Broome can be considered by examining the catches of charter operator 2, who recorded catches (releases) of sailfish by month during the years of operation off Broome. Figure 9 shows the numbers of sailfish released by month for selected years together with the totals summed for each month between 1996 to 2004.

This shows that, while at least some sailfish may be caught in every month of the year, there is a clear seasonality in the availability of sailfish off Broome, with the main months through this time series being June

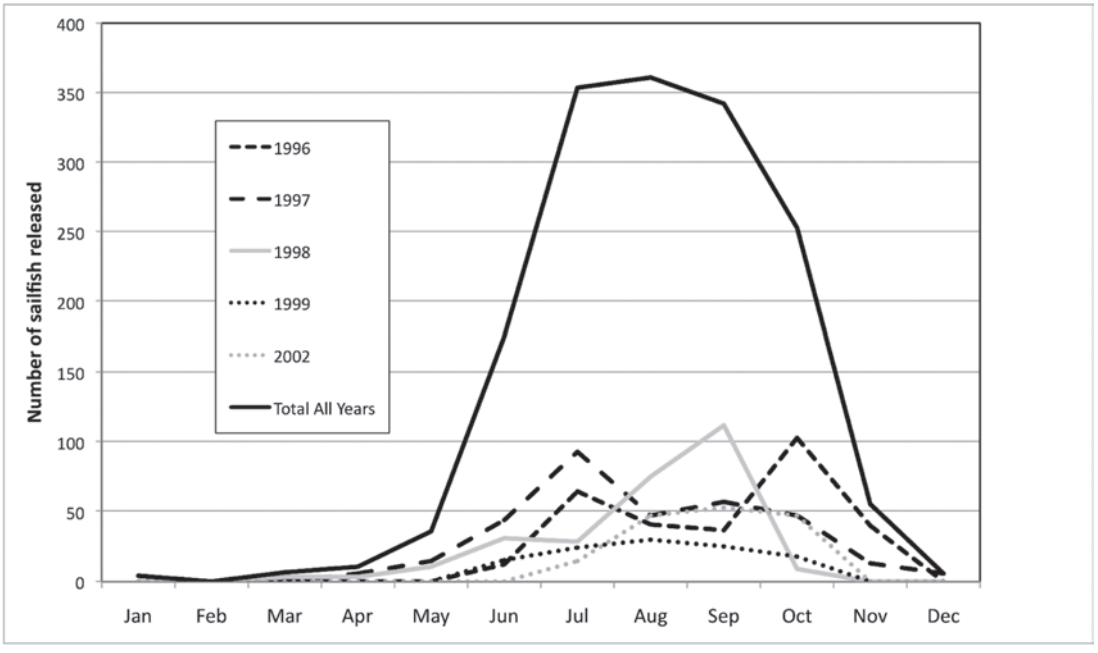

Figure 9. Releases of sailfish by month by charter operator 2. For purposes of clarity, not all years are shown

through October and the peak months being July through September. Interestingly, the three highest catches over this time period were recorded in separate months – July 1997, September 1998 and October 1996. It might be argued that catches are highest during this period because this is when fishing is mainly conducted. However, pelagic gamefishing is conducted from Broome in every month of the year, so the timing of the appearance, peaking and disappearance of sailfish from the area, as indicated in Figure 9, is considered to be a real.

Size distribution of sailfish off Broome

As noted above, the estimated size of sailfish caught off Broome (derived from tag cards) is significantly smaller than the other areas considered. Considering now the sizes of sailfish caught off Broome through time, Table 3 presents the weight frequency of all fish tagged off Broome from 1989 to 2009. This shows that the size range and modal size of sailfish released off Broome have been remarkably consistent for over 20 years. The majority of fish (87.2%) have been estimated to weigh between 11 and 25 kg even though the modes within this range vary slightly between years.

It is noteworthy that very small sailfish (1 to 5 kg) have been caught (released) off Broome in a number of years, most notably, in 1996, 2001, 2002, 2005, 2006 and 2009. At this size, these fish would only be several months old (Hoolihan 2006) and could indicate good recruitment years to the population. However, there does not appear to be any obvious relationship between those years when very small fish appeared and subsequent high catches of larger fish in succeeding years as this cohort moved through the fishery. Even so, a more in-depth analysis of this would be warranted since it could provide some predictability regarding the fishery in years to come.

Catches by location

The accuracy of locations given for releases of tagged sailfish recorded on tag cards is inconsistent, with many anglers simply recording a general area of their catch (such as 'Broome', 'Dampier' or 'Exmouth'). However, a substantial number of records do give locations, each of which has been converted to co-ordinates on the New South Wales I&I tagging program database. Figure 10 shows density plots of numbers of sailfish tagged off northwestern Australia by half-degree grids for the entire tagging database (1979 to 2009). Figure 10 also shows the grounds fished by the recreational fishing communities of the three primary recreational sailfishing areas, Broome, Dampier and Exmouth. It shows that sailfish were tagged near each of these ports, which is not surprising since those are the centres of fishing activity. However, this also shows that in each case, fish are tagged in greater numbers in a small number of half-degree grids.

These data do not allow particularly fine scale inspection of the locations of catches of sailfish. However, one set of data did allow this kind of treatment – charter log data as provided to the Western Australia Fisheries Department. These data are summarised for the Broome region for the years 2004 to 2007 in Figure 11. It is important to note that due to confidentiality arrangements, sailfish release data are not included if there were less than three charter boats operating in any given grid. This Figure shows density plots of numbers of sailfish released within 10 nautical mile grids between March and November, combined for the four years for which data were available. As is the case for the personal

Table 3

Numbers of sailfish in each estimated weight category tagged each year off Broome, WA

Wt (kg)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1-5	0	0	0	0	0	1	0	3	18	5	0
6-10	0	2	4	11	4	16	14	10	18	36	9
11-15	0	17	30	44	42	74	113	105	79	101	57
16-20	3	54	75	105	80	182	247	120	189	153	133
21-25	2	41	45	104	60	167	105	56	90	121	136
26-30	1	15	22	62	16	43	30	8	43	61	45
31-35	0	3	3	8	6	11	8	0	10	23	17
36-40	0	1	1	3	2	1	4	1	5	4	8
41-45	0	1	0	1	0	0	1	0	0	0	0
>45	0	0	3	0	0	1	2	0	0	7	0
Total	6	134	186	338	210	497	526	303	452	518	405

Wt (kg)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
1-5	0	0	21	29	1	2	44	18	5	5	33	185
6-10	3	1	1	0	2	0	15	8	4	3	2	163
11-15	18	27	31	27	32	13	98	55	64	33	53	1113
16-20	55	77	47	134	58	33	46	120	40	28	103	2082
21-25	88	39	40	93	19	11	12	49	14	16	64	1372
26-30	37	11	9	22	6	1	5	13	7	9	34	500
31-35	8	2	11	11	0	0	3	1	0	3	14	142
36-40	4	1	4	4	1	0	2	1	0	1	4	52
41-45	1	1	1	3	0	0	1	0	0	0	0	10
>45	0	0	0	3	0	0	0	0	0	0	1	17
Total	214	159	165	329	119	60	226	265	134	98	309	5636

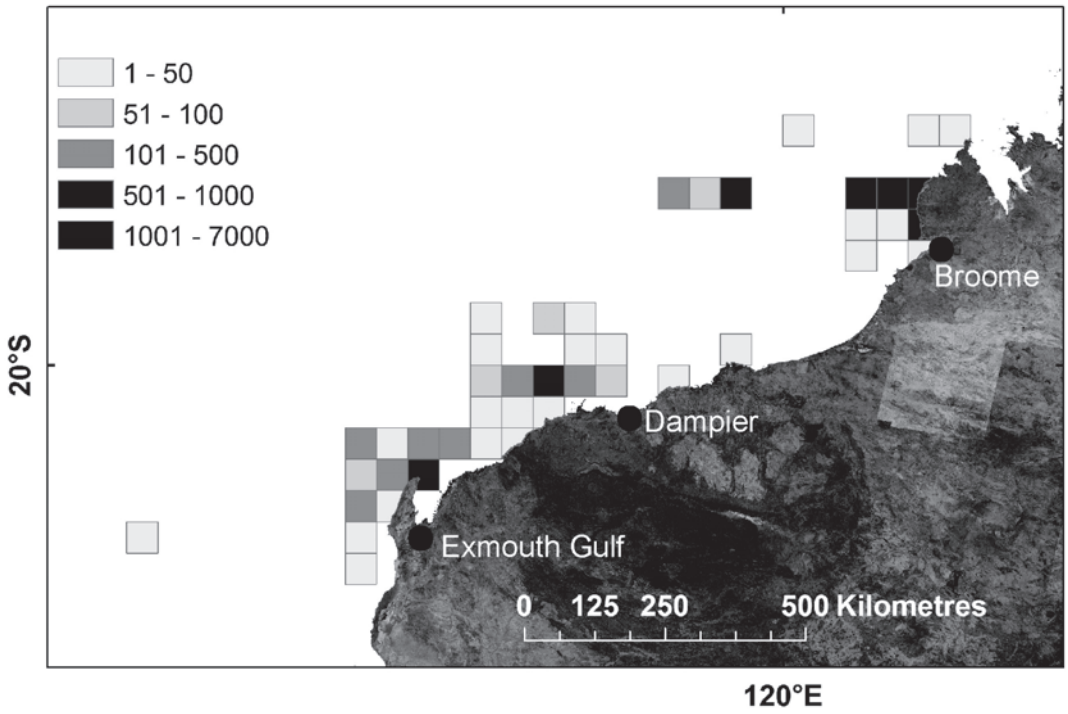

Figure 10. Distribution of recreational catch (taggings) of sailfish off northwestern Australia, 1979 to 2009. Shading of grids indicates numbers of fish tagged.

charter data, this shows that the main fishing seasons are winter and spring, with some variations in highest catches of sailfish between those two seasons. It is also clear that very few sailfish are caught by charter boats in Autumn, although it is likely that fishing effort is low at that time. There is a suggestion from inspecting these charts that more fish are caught in the northern parts of the main fishing grounds later in the fishing season (winter to spring). Combining data for all seasons shows that by far the greatest number of sailfish have been released in just four of the 15 grids where sailfish were caught.

Discussion

Of the five istiophorid species that occur off northwestern Australia, the sailfish is caught (released) in by far the highest numbers by the recreational fisheries of the region. The fishery is perceived to be important for the economies of Broome, Dampier and Exmouth, but until now, there has been no analysis of pertinent historic information on the relative abundance of sailfish in the region.

Historic Commercial Data

Japanese longline fishing was active off the Western Australian coast from 1979 to 1997. The main area where sailfish were caught was between 15° and 25°S and 110° to 120°E, an area encompassing the three recreationally important sailfishing centres of Broome, Dampier and Exmouth. However, few sailfish were taken off these areas, because of both the offshore nature of the fishery and the lack of fishing effort during what we now know to be the peak sailfishing season. A Taiwanese gillnet shark fishery that operated off northern Australia from 1972 to 1986 most likely caught tens of thousands of sailfish, but again, fishing effort off Broome and the other centres to the south was very small.

The true size of the historic commercial sailfish catch in the region is difficult to determine because of possible underreporting, however, the impact of historic commercial fishing on sailfish in the region is considered to be light.

Recreational catches and catch rates

Three sources of recreational fishery data examined to consider catches and catch rates of sailfish off Broome through time. (Broome was the only area from which these three data sets were available) were gamefish tagging data on released fish, radio reporting data from the annual Broome Sailfish Tournament and personal charter records of long term operators in the Broome area (1996 to present). These data may not be representative of the entire recreational fishery that may catch sailfish off northwestern Australia, but because of their consistency, provide valuable information on relative abundance and body size of sailfish through time. Two broad scale surveys of recreational fishing failed to detect sailfish in the catch in sufficient numbers to provide any estimates of total catch (Henry & Lyle 2003; Williamson *et al*. 2006) and this, together with the experience of the authors suggests that recreational catches of sailfish outside the data sets examined are small in comparison.

Catches of sailfish off Broome, as indicated by tag-and-release data (Fig. 4) have fluctuated considerably on an annual basis. The two major peaks were in 1992/1993 and in 1996/1997 (ie, two major years in succession in each case). It needs to be borne in mind that the tag data,

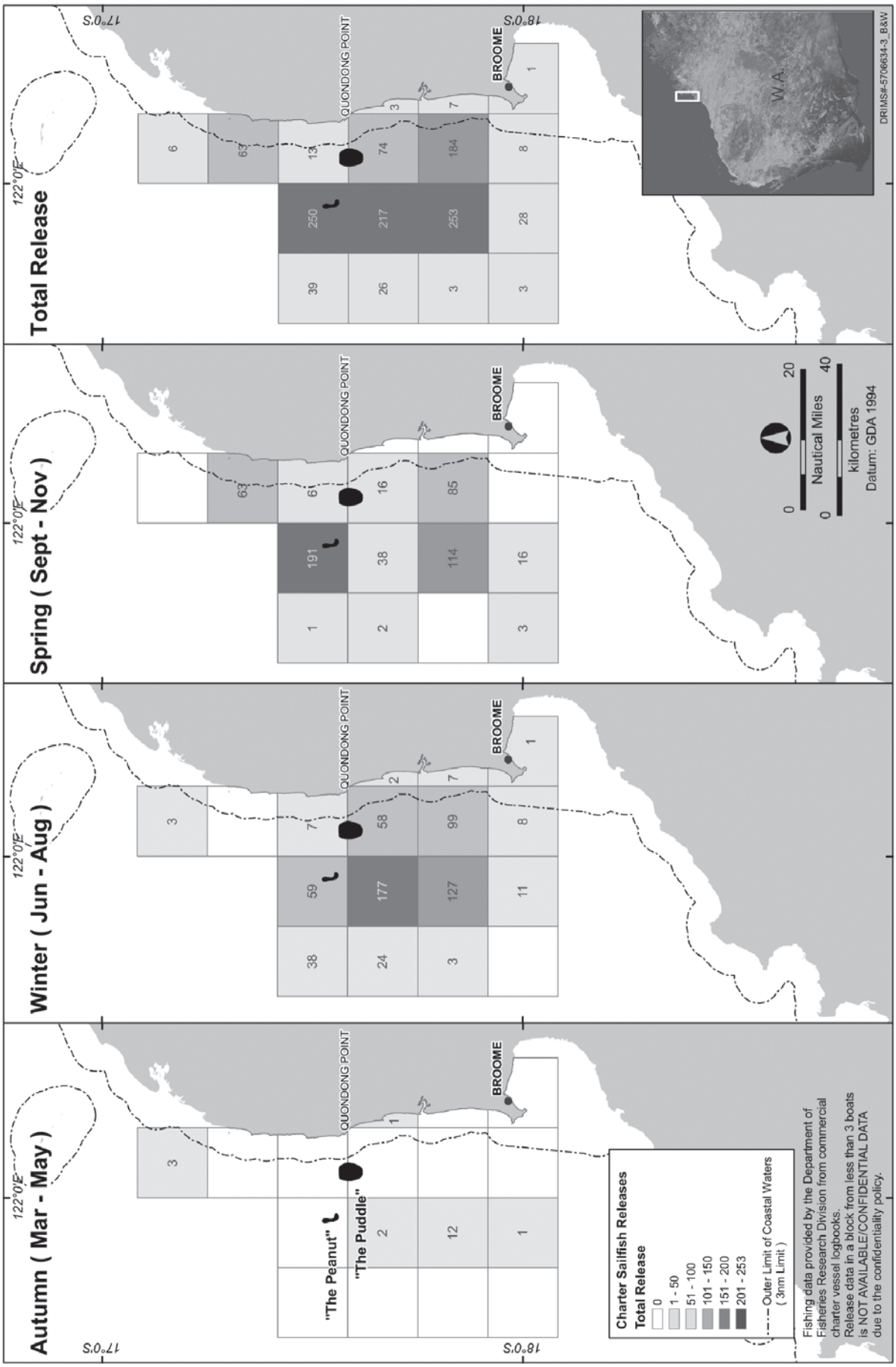

Figure 11. Catches (releases) of sailfish by Western Australian charter vessels, 2004 to 2007. Numbers of fish released are shown in each grid.

while dominated by the annual tournament which takes place over only one week, also would include any fish tagged outside that period, either by private boats or by charter vessels. When considering relative abundance of fish, tournament radio reporting data has the advantage of including effort data, so that catch rates (a surrogate for abundance) can be determined. Tournament data (Fig. 7) also show marked fluctuations of catch rates from year to year, although these are dampened somewhat if only hookup and release rates are considered. (These two measures are also thought to be better indices of abundance than fish raised or struck). Considering these data, there does not appear to be any trend in declining or increasing catch rates through time.

Catch rates of two long-term Broome charter operators examined to analyse catch rates extending well outside the peak tournament period also showed marked fluctuations through time, with similar timing of peaks and troughs during the overlapping periods of both operators. This suggests that their catch rates were indicative of relative abundance of fish through time. After 2004 there has been a consistent increase in catch and catch rate for the charter operator covering this period. This is also reflected to some extent in the tournament catch rates for the same period although 2007 is a good example of a year when tournament catch rate was relatively low, but the charter catch rate was high. This latter result shows the importance of collecting catch and effort data throughout a season.

The data from the charter operators were also valuable in considering the seasonality of the appearance of sailfish off Broome. It was clear from these data that, while sailfish were caught in most months throughout the time series considered, there was a peak season of abundance of fish between July and September inclusive, in some years extending into October.

Size of fish through time

The examination of sizes of fish caught through time can provide insights into such factors as impacts of fishing or growth rates over short and long terms. Sizes of fish from tag records do present some problems since they are only ever estimated by anglers, in most cases, an estimated weight. These estimates are agreed upon by crew members on the tagging vessel, but since fish are rarely weighed (virtually never off Broome), some doubts about the absolute validity of these estimates are sometimes raised. Nevertheless, it has been shown in other studies (primarily by examining actual weights of recaptured billfish against estimated weights at release) that angler estimates can be quite accurate. For example, tag-and-release weight estimates for striped marlin caught on the east coast of Australia and New Zealand match within 8% of the mean annual weight measured by certified scales (Kopf 2010).

The distribution of estimated weights of sailfish released in each of four regions (Fig. 5) indicates some overall differences in average sizes among regions through time. This translates as statistically significant differences in median sizes of fish among all four regions, other than between Exmouth and Broome offhore, as shown in Figure 6. When the size frequencies of fish tagged off Broome are examined (Table 3), it is clear that the size range of sailfish caught in the region is remarkably consistent through time.

The lumped mean estimated size data also suggest a general increase in size of fish through the year (second to fourth quarter) for both Broome and Dampier. This suggests that, at least in both of these areas, a cohort of sailfish may tend to stay in the general region for a number of months, growing noticeably during this time. Of course, this kind of residence would need to be determined on a year by year basis, ideally by electronic tagging, but it does lend weight to the notion that sailfish generally do not move very far *en masse*.

Prime catch areas

Charter boat logbook data, as supplied by Western Australia Fisheries (not including block data where less than three charter boats had supplied data), clearly show the areas where the majority of sailfish have been caught and released by the charter component of the Broome fishery. These prime sailfish grounds cover an area of about 30 to 40 nm^2, and include in the highest catch area a bottom feature known colloquially by recreational fishers as 'the peanut'. Another feature known as 'the puddle' does not appear to show consistently as high catches as adjacent grids to the west (Fig. 12).

Although the recreational tag data do not provide as well-defined locations of catches as do the charter data, they are spread over a much longer period, and also indicate the same general area as the region of highest catches through time (Fig. 11).

While no specific studies of sailfish (or other billfish species) in the region have been undertaken in the past, the collation of existing data on catches (releases) and fish sizes from a range of sources has enabled the gleaning of some important insights into the fisheries extending back to their origins. The recreational fishery off the areas of interest, especially off Broome, has proven to be consistent through time with respect to both catch rates and size distribution of the catch. Some evidence suggests that sailfish may have residence times of at least several months in the different regions considered, although there is also clear evidence of seasonality in appearance of fish in large numbers which also suggests movement to and from these areas on a regular basis.

Future studies of sailfish in the region could address a number of gaps. These include estimates of the total catches of sailfish and other pelagic species, analysis of the relative abundance of sailfish off northwestern Australia with respect to historic environmental cues, investigations of the short and long term movements of sailfish, and studies of growth rates and reproduction of sailfish across the region.

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