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Egress of Adult Sport Fish from an Estuarine Reserve within Merritt Island National Wildlife Refuge, Florida

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A tag-recapture study was conducted within Merritt Island National Wildlife Refuge in the waters surrounding Kennedy Space Center, Florida (where public access has been restricted since 1962), to document egress of adult sport fish from an estuarine reserve. A total of 3,358 sport fish were tagged within the restricted areas. The species tagged were red drum *Sciaenops ocellatus* (n = 1,366), spotted seatrout *Cynoscion nebulosus* (n = 927), black drum *Pogonias cromis* (n = 760), and common snook *Centropomis undecimalis* (n = 305). Results showed that adult sport fish moved from the restricted areas within Merritt Island National Wildlife Refuge to surrounding areas open to fishing. The recapture rates, based on angler responses outside of the restricted areas, were 3.1%, 0.8%, 2.9%, and 16.1% for red drum, spotted seatrout, black drum, and common snook, respectively. In general, red drum, spotted seatrout, and black drum were recaptured in waters adjacent to the restricted areas. Common snook, however, migrated from the restricted areas south to inlets. Tag recaptures for red drum, spotted seatrout, and black drum, together with a previous study that found greater abundance and size of sport fish in the restricted areas than in adjacent areas open to fishing, substantiate the fish replenishment zone function of the restricted areas. The restricted areas within Merritt Island National Wildlife Refuge protect fish populations and large adult sport fish egress to surrounding waters open to fishing.

The development of marine reserves (also referred to as no-take reserves, marine refuges, and marine sanctuaries) to protect and enhance fishery resources has recently been advocated as a holistic, cost-effective fishery management tool (Polacheck, 1990; Bohnsack, 1993, 1998; Carr and Reed, 1993; DeMartini, 1993; Dugan and Davis, 1993; Roberts and Polunin, 1993; Rowley, 1994; Man et al., 1995; Holland and Brazee, 1996; Roberts, 1997). A marine reserve is an area that is closed to human exploitation, namely commercial and recreational fishing. It has been theorized that a reserve can serve as a fish replenishment zone by protecting spawning stock, providing undisturbed spawning habitats, increasing egg and larvae production, maintaining high-quality feeding areas for fish and wildlife, and exporting biomass by migration of juveniles and adults to surrounding waters that are open to fishing (e.g., Bohnsack, 1998). Recent studies worldwide have documented fishery replenishment functions of marine reserves for several economically important marine invertebrates (Gitschag, 1986; Davis and Dodrill, 1989; Edgar and Barrett, 1999), reef fishes (Bell, 1983; Buxton and Smale, 1989; Cole et al., 1990; Holland et al., 1993; Polunin and Roberts, 1993; Roberts, 1995; McClanahan and Kaunda-Arara, 1996; Ratkin and Kramer, 1996; Russ and Alcala, 1996a, 1996b; Wantiez et al., 1997; Edgar and Barrett, 1999; McClanahan et al., 1999), and nearshore fishes (Attwood and Bennett, 1994), but studies that have addressed the role of reserves in replenishing estuarine fish populations are few (Johnson et al., 1999).

An estuarine reserve has been in effect within Merritt Island National Wildlife Refuge (MINWR) since 1962, where public access and fishing have been prohibited because of security operations at Kennedy Space Center (KSC) (Johnson et al., 1999). The MINWR restricted areas lie immediately adjacent to heavily fished areas of Indian River Lagoon, Mosquito Lagoon, and Banana River (Fig. 1). This provides a unique setting within which to test the functions of a no-take estuarine reserve in terms of replenishment of exploited sport fish species. A comparison of fish communities between open and closed fishing areas and a tag-recapture study were undertaken by the U.S. Fish and Wildlife Service, 1986–1992, to evaluate the effectiveness of MINWR reserve as a fish replenishment zone. Such an evaluation must consider several questions. (1) Do target fish species abundances increase within the reserve? (2) Does mean adult size increase within the reserve, such that protection is being conferred to potential spawners? (3) Do protected fish from within the reserve egress into local and/or more distant areas, contributing to ex-

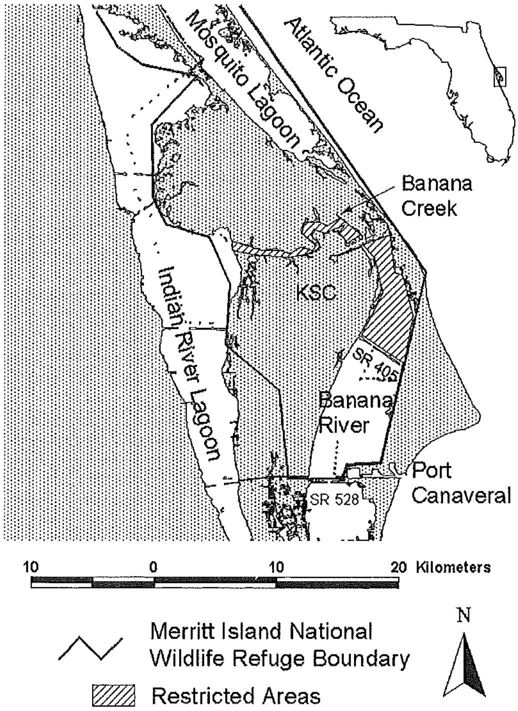

Fig. 1. Map showing restricted areas within Merritt Island National Wildlife Refuge.

ploited fisheries? (4) Does the existence of the reserve facilitate reproduction and juvenile recruitment in target species?

Johnson et al. (1999) have recently addressed questions 1 and 2, reporting greater abundance and larger mean fish size for selected sport fish within MINWR reserve, compared with data from adjacent areas, and provide incidental information concerning question 4, suggesting that sport fish spawn within the reserve. Regarding question 3, Johnson et al. (1999) report preliminary results of the U.S. Fish and Wildlife tag-recapture study, which shows a few sport fish (~14) leaving the restricted areas to be caught by anglers outside of the reserve. However, these preliminary results only reported recaptures returned during the 18 mo of the 1986–1988 tagging effort; and the fishery for red drum (*S. ocellatus*) was closed to harvest during 15 of these 18 mo. The present analysis reports the final results of the U.S. Fish and Wildlife tag-recapture program conducted during 1986–1988 and also 1990–1992 and reports recaptures up to 10 yr after tagging.

Study Site

The study areas, northern Banana River and Banana Creek, are located in the waters surrounding KSC, and are managed by MINWR (Fig. 1). These areas have been closed to public access since 1962 because of security operations at KSC. Southern Banana River is closed to motor powered vessels for manatee protection from the 405 causeway south to the 528 causeway (Fig. 1) but is otherwise open to the public (from shore or nonmotorized vessels). Historically, Banana River and Banana Creek were connected, but they are now separated by KSC launch facilities. The restricted areas within MINWR and adjacent waters, southern Banana River and northern Indian River Lagoon, lie at the upper reaches of the Indian River Lagoon system, which are isolated from oceanic waters and have little tidal range (Smith, 1986). Although a lock at Port Canaveral intermittently connects the Banana River to the Atlantic Ocean, the closest open ocean inlets are Ponce de Leon Inlet, 30 km to the north, and Sebastian Inlet, 62 km to the south. Short-term water levels and circulation are primarily driven by wind. Water depth in Banana River and Banana Creek is ~1 m. Mean salinities are 19.6 ppt for Banana Creek (3 ppt minimum) and 22 ppt for North Banana River (7 ppt minimum) (Johnson et al., 1999).

The waters adjacent to the restricted areas, southern Banana River, Indian River Lagoon, and Mosquito Lagoon to the north (connected to Indian River Lagoon at Haulover Canal) are open to fishing and receive heavy fishing pressure, primarily for spotted seatrout (*C. nebulosus*), red drum, black drum (*P. cromis*), and common snook (*C. undecimalis*). These species are valuable to the inshore fishery of the Indian River Lagoon and support a large, high-quality recreational guide fishery (Florida Sportsman Magazine, April 1989, February 1990, June 1990, June 1993, November 1993, April 1994, and June 1994).

Methods

The target sport fish species for the study were red drum, spotted seatrout, black drum, and common snook. Commercial and recreational species including striped mullet (*Mugil cephalus*), white mullet (*Mugil curema*), Florida pompano (*Trachinotus carolinus*), spot (*Leiostomus xanthurus*), southern kingfish (*Menticirrhus americanus*), sheepshead (*Archosargus probatocephalus*), tarpon (*Megalops atlanticus*), gray snapper (*Lutjanus griseus*), and Gulf flounder (*Paralichthys albigutta*) were also tagged but are not considered in the present analysis. Fish were captured by U.S. Fish and Wildlife Service personnel using trammel nets and angling within

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TABLE 1. Recapture rates for sport fish species tagged within the KSC-restricted areas of MINWR.

Species	Fish tagged in restricted areas (*n*)	Recaptures by project personnel in restricted areas (*n*)	Recaptures by anglers outside of restricted areas (*n*)	Recapture rate by anglers outside of restricted areas (%)	Total recapture rate (%)
Red drum	1366	29	42	3.1	5.2
Spotted seatrout	927	7	7	0.8	1.5
Black drum	760	21	22	2.9	5.7
Common snook	305	7	49	16.1	18.4
Total	3358	64	120	3.6	5.5

the restricted area (no public access) surrounding KSC (Fig. 1) from November 1986 to April 1988 and from October 1990 to April 1992. Captured fish were tagged with internal anchor tags (7 × 26 mm or 7 × 17 mm) with 55-mm external yellow streamers. Total length (TL), location, tag number, and tagging date were recorded for each tagged fish. Tags were imprinted with a return address and tag number on one side and with the wording "$5.00 Reward" on the opposite side. Posters advertising the reward were distributed throughout the area.

Tag returns from commercial or recreational fishermen usually contained all the pertinent information needed (location, date, total length, and weight). However, if information was lacking, project personnel attempted to obtain the missing information from fishermen either by telephone or by mail. Project personnel also recaptured fish in the restricted areas during the tagging program.

Tag-recapture information included tag number, species, tagging location (tag and recapture), length (tag and recapture), and date (tag and recapture). Days at large were then calculated. Distance traveled was determined by measuring the shortest linear distance via water on a nautical chart from capture location to recapture location. If a fish was recaptured in the Atlantic Ocean, then the shortest linear distance via water was determined from the tag location, to the nearest inlet, then to the oceanside recapture location. Statistical analyses comparing angler and project recaptures were not performed because of unequal fishing effort. For example, project personnel tagged fish primarily within restricted areas during a limited period (1986–1992), but angler recaptures have been reported for a period >10 yr after tagging and have been subject to fishing regulations such as length limits and closed seasons. Statistical analyses comparing relationships between sizes of fish at recapture, distances traveled, days at large, and seasons for angler recaptures were not performed because size limits and season closures confounded results.

RESULTS

The number of tagged fish, number of recaptured fish within the no-fishing area by project personnel, number of recaptured fish taken by recreational anglers in open fishing areas, and recapture rates are presented in Table 1. Recaptures were reported for red drum ($n = 71$), common snook ($n = 56$), black drum ($n = 43$), and spotted seatrout ($n = 14$). Recapture rates were similar for red drum and black drum (5.2% and 5.7%, repectively), lowest for spotted seatrout (1.5%), and highest for common snook (16.1%).

Mean sizes, mean distances moved, and mean days at large for angler recaptures are presented in Table 2. Common snook moved greater distances (148 ± 12.2 km) than red drum (47.6 ± 6.6), spotted seatrout (10.0 ± 2.4), and black drum (44.7 ± 18.2). The mean recapture sizes for spotted seatrout (446 ± 18 mm TL), black drum (828 ± 25 mm TL), and common snook (723 ± 17 mm TL) are larger than the sizes at which each species could be considered sexually mature (444, 650, and 503 mm TL, respectively). Thus, the fishes recaptured were adults. The mean recapture size reported by anglers for red drum (645 ± 13 mm TL), however, is smaller than the size that red drum could be considered sexually mature (653 mm TL). A maximum red drum harvest size limit (686 mm TL) was in effect during the study period.

Red drum.—Figure 2 shows recapture locations for red drum. In general, red drum movements were limited to the Indian River Lagoon system, with the greatest concentrations occurring at the edge of the Banana River no-motor zone and at Sebastian Inlet (the nearest inlet to the south). The farthest return for red

TABLE 2. Mean sizes, distances moved, and days at large for angler recaptured sport fishes tagged within the KSC restricted areas of MINWR. Mean and SE are shown.

Species	Mean size of fish at recapture (mm TL)	Mean size of recaptured fish when tagged (mm TL)	Mean distance between tag and recapture locations (km)	Mean days at large (d)
Red drum	645 ± 13	540 ± 22	47.6 ± 6.6	598 ± 51
Spotted seatrout	446 ± 18	382 ± 38	10.0 ± 2.4	220 ± 65
Black drum	828 ± 25	726 ± 18	44.7 ± 18.2	1100 ± 253
Common snook	723 ± 17	495 ± 13	148.2 ± 12.2	622 ± 56

drum was 155 km north to Matanzas Inlet during 781 d at large.

Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for red drum are shown in Figure 3. Size limits and closed seasons are also shown. Only three reported angler recaptures lie outside of the size limits (Fig. 3A), and no angler recaptures are reported for fish during the closed season (Fig. 3C). The largest red drum recaptured by anglers outside of the restricted areas was 889 mm TL (Fig. 3A). Twelve red drum recaptured within the restricted areas by project personnel were >686 mm TL (the maximum size limit for angler restrictions) (Fig. 3A). Two red drum were tagged in the Banana Creek restricted area and recaptured in the Banana River restricted area. These bodies of water are not connected; therefore, the fish must have migrated from the Banana Creek restricted area and later entered the Banana River restricted area, resulting in distances moved of 40.6 and 51.9 km (Fig. 3A, B). The maximum days at large was 1,863 d (recaptured 4.8 km from tagging location), and most recaptures occurred within 1,000 d (Fig. 3B). Angler recaptures were greatest during the fall months (Fig. 3C).

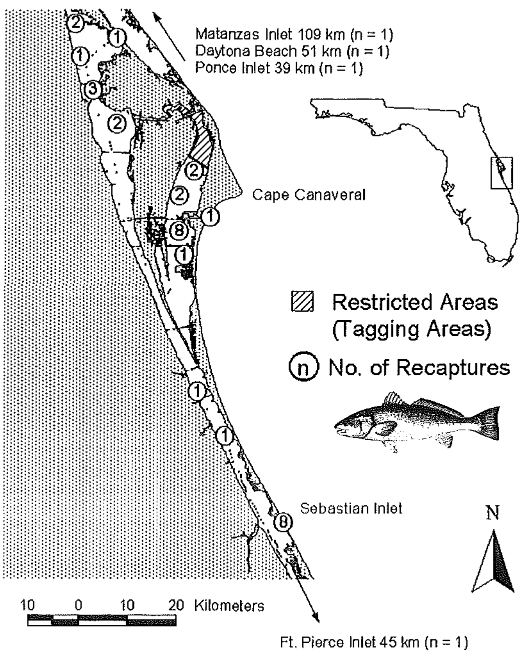

Fig. 2. Angling recapture locations for red drum (n = 42). Project personnel recaptured an additional 29 red drum within the restricted areas.

Spotted seatrout.—Figure 4 shows recapture locations for spotted seatrout. The 14 recaptured spotted seatrout did not move far from the original tagging site (Fig. 4). The farthest return for spotted seatrout was 20.8 km during 216 d at large. Project personnel in the restricted areas recaptured two spotted seatrout more than once. One spotted seatrout was tagged within the Banana Creek restricted area during February 1992 and then recaptured twice, 13 and 46 d later, at the same location. The second spotted seatrout was tagged during September 1987 within the Banana Creek restricted area and recaptured twice, 32 and 33 d later, at the same location.

Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for spotted seatrout are shown in Fig. 5. The maximum days at large was 480 d (recaptured 12 km from tagging location) (Fig. 5B). The seven angler recaptured seatrout were caught during April–August (Fig. 5C).

Black drum.—Figure 6 shows recapture locations for black drum. The farthest return for black drum was 326 km north to Fernandina Beach after 505 d at large. All other angler returns were limited to the Indian River Lagoon system, with concentrations occurring in the Banana River no-motor zone south just south of the Banana River restricted area. Half of total recaptured black drum (49%) were recaptured by project personnel within the North Banana River restricted area.

Distance vs. size (A), distance vs. days at

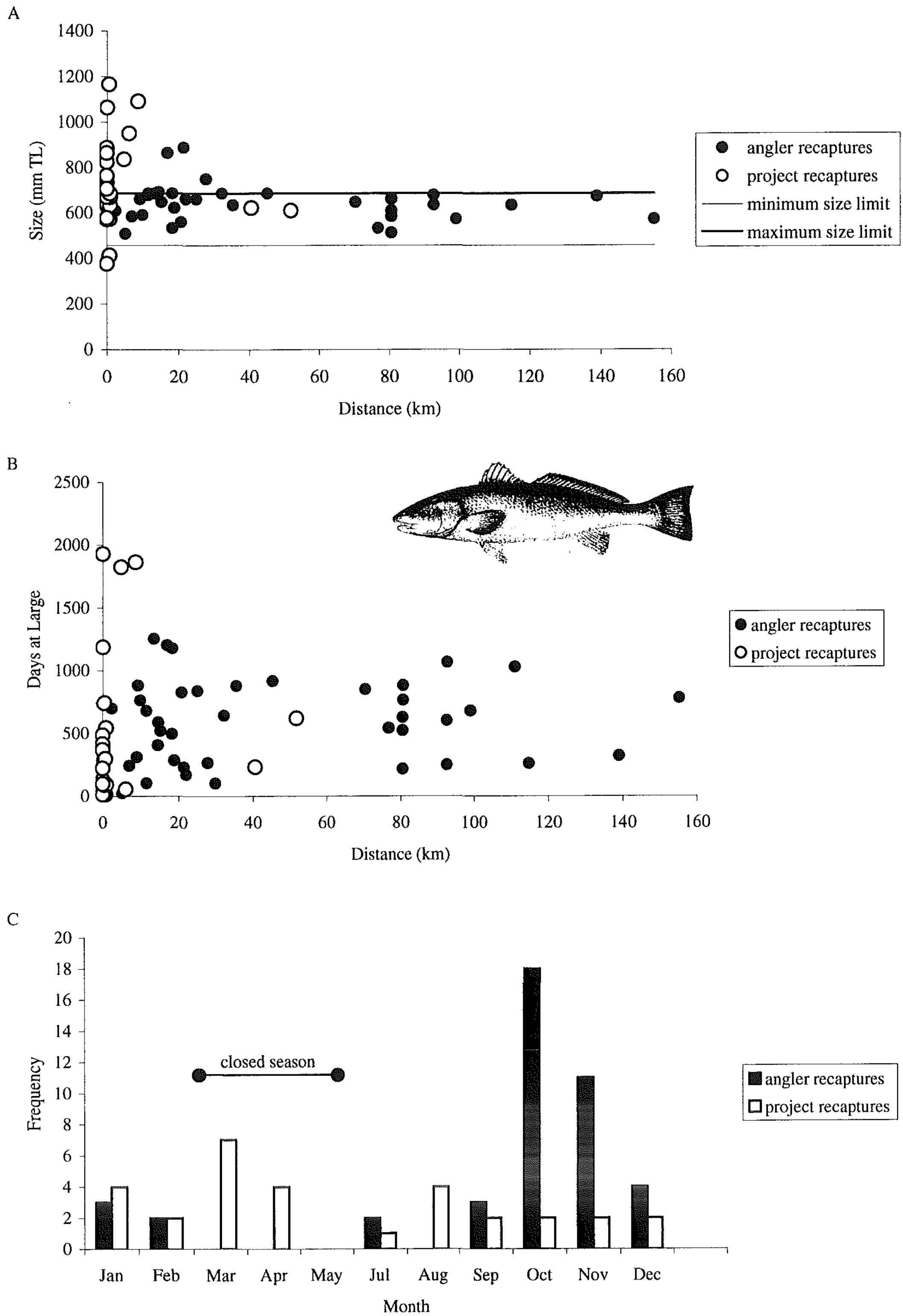

Fig. 3. Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for red drum.

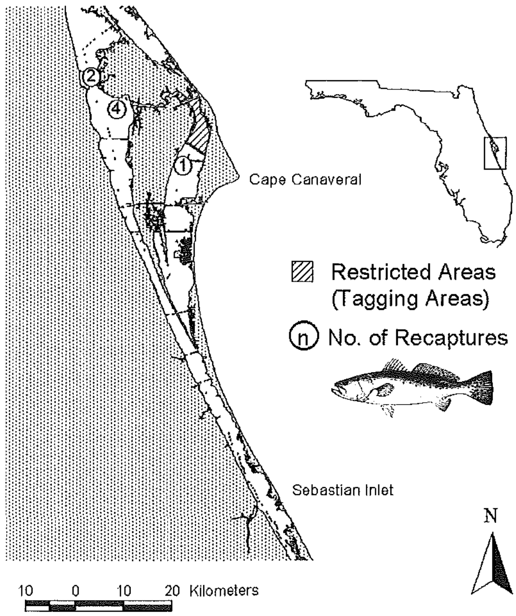

Fig. 4. Angling recapture locations for spotted seatrout (n = 7). Project personnel recaptured an additional seven spotted seatrout within the restricted areas.

large (B), and month recaptured vs. frequency (C) for black drum are shown in Figure 7. The minimum size limit for the black drum fishery is shown in Fig. 7A. A maximum size limit of 609 mm TL was enacted in July 1989, but one fish per day over the maximum size limit could be taken. All of the recaptured black drum were substantially larger than the minimum size limit for anglers (Fig. 7A). The largest black drum recaptured by anglers was 965 mm TL (Fig. 7A). The maximum days at large was 3,505 d (recaptured 8.1 km from tagging location), and five of the recaptured black drum were at large for >2,000 d (Fig. 7B). Angler recaptures were reported during late winter/early spring and late fall/early winter (Fig. 7C).

Returns suggest that black drum maintain aggregation integrity for extended periods. For example, two fish tagged on March 4, 1988 in Banana River were recaptured together 2 mo later (distance of 1.1 km), two fish tagged on January 8, 1987 in Banana River were recaptured on consecutive days 9 mo later (distance of 24 km), four fish tagged on January 8, 9, and 10, 1987 in Banana River were recaptured together 14 mo later (distance of 2 km), two fish tagged on March 10, 1987 in Banana River were recaptured on consecutive days 15 mo later (distance of 0.9 km), and two fish tagged on April 14, 1988 in Banana River were recaptured together 7.5 yr later (distance of 13.5 km).

Common snook.—Figure 8 shows recapture locations for common snook. Only two of 49 common snook recaptured by anglers were reported from waters adjacent to the restricted areas (Fig. 8). These two fish were 457 and 610 mm TL. The general pattern of movement for common snook was to the south (Fig. 8). One fish was recaptured at Long Key Bridge, a distance of 479 km after a period of 785 d. Half of the recaptured common snook (9.2% of total tagged snook) were taken by recreational anglers at inlets (14 common snook recaptured at Sebastian Inlet, 5 at St. Lucie Inlet, 5 at Ft. Pierce Inlet, 2 at Jupiter Inlet, 1 at Port Everglades, and 1 at Hillsborough Inlet).

One common snook was recaptured more than once. This fish, tagged within the Banana Creek restricted area during March 1988 (505 mm TL), was recaptured by project personnel 125 d later (1.6 km from tagging location, 571 mm TL) and then recaptured in Banana River by an angler 138 d later (10.4 km from tagging location, 610 mm TL). Common snook, a tropical species, were present within MINWR during winter months. Twenty-six (53%) of 49 recaptured snook were originally tagged during December and January.

Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for common snook are shown in Figure 9. The minimum size limit (609 mm) for the common snook fishery during the study period is shown. A maximum size limit of 863 mm was also in place, but anglers could take one fish per day over this limit. All project recaptures were smaller than the minimum size limit, but anglers reported only two common snook recaptures smaller than the minimum size limit (Fig. 9A). The largest size of common snook recaptured by anglers was 1,016 mm TL (Fig. 9A). The maximum days at large was 2,484 d (166.7 km from tagging location), but most returns were reported within 1,000 d (Fig. 9B). Closed seasons for the common snook fishery during the study period are shown in Fig. 9C. Few common snook recaptures occurred during the closed seasons. Of the 49 total common snook recaptured by anglers, 35 fish (71%) were recaptured from August to December (Fig. 9C).

Discussion

Sport fish movement.—In general, spotted seatrout, black drum, and red drum (<686 mm

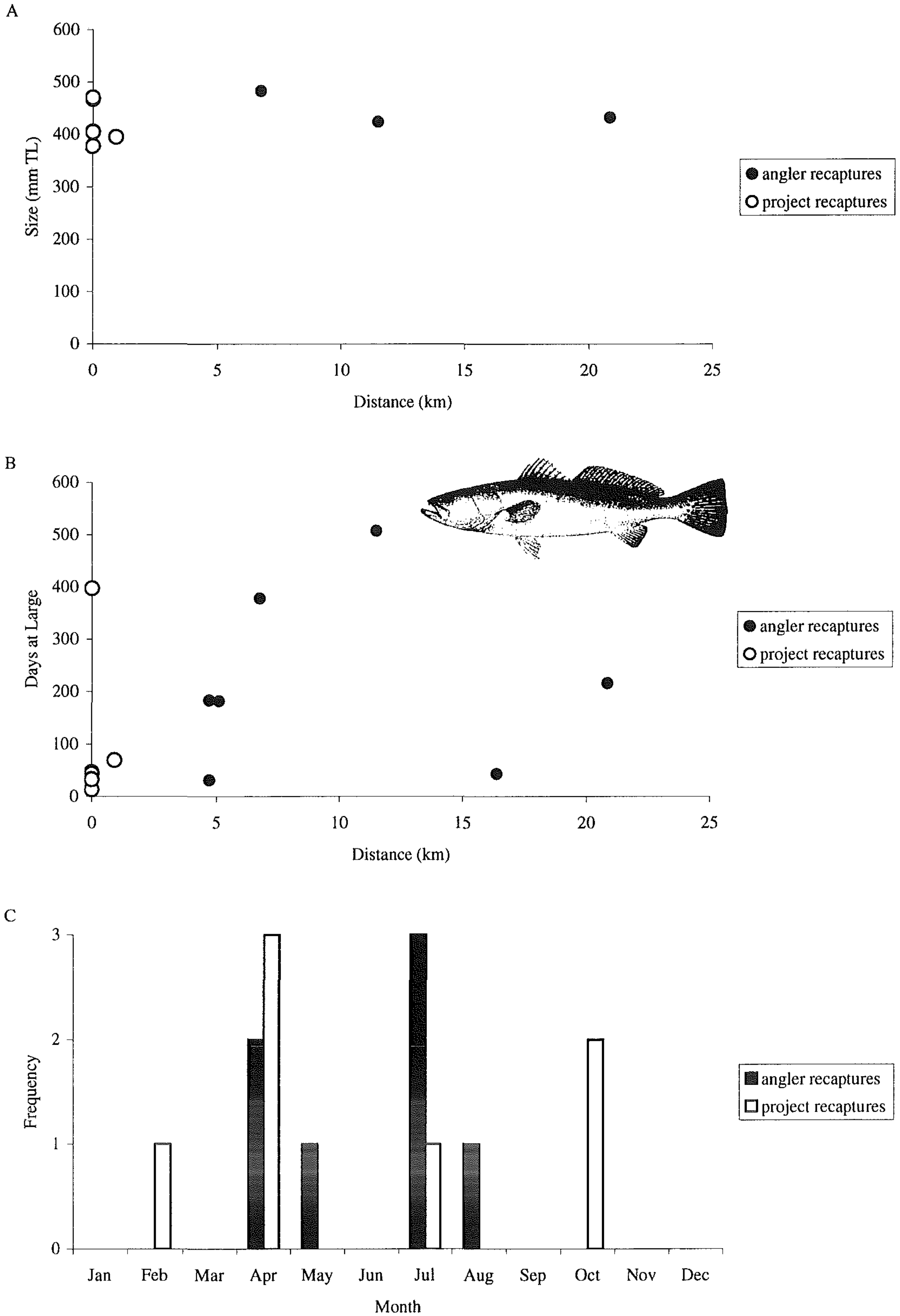

Fig. 5. Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for spotted seatrout.

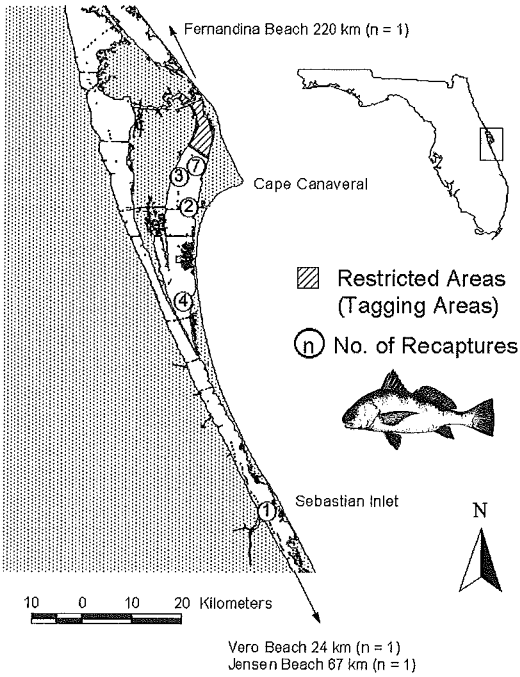

Fig. 6. Angling recapture locations for black drum ($n = 22$). Project personnel recaptured an additional 21 black drum within the restricted areas.

TL) showed little movement, remaining within MINWR and the adjacent Indian River Lagoon. These results are consistent with other tagging studies conducted in Florida (Ingle et al., 1962; Iverson and Tabb, 1962; Topp, 1963; Beaumariage, 1969; Bryant et al., 1989). Angling tag returns for red drum >686 mm were scarce due to this maximum size limit at harvest. However, the year-round occurrence of large, mature red drum in the restricted areas (Johnson et al., 1999) and the recapture of red drum >686 mm in the restricted areas by project personnel provides evidence that large red drum also remain in the vicinity of MINWR.

Low recapture rates for spotted seatrout may, in part, result from low survivorship after catch and release (Murphy et al., 1995). A higher recapture rate by project personnel should be expected, given that spotted seatrout only move a few kilometers (Ingle et al., 1962; Iverson and Tabb, 1962; Topp, 1963; Beaumariage, 1969; Bryant et al., 1989), and a large number of tagged fish would likely remain within MINWR restricted areas. Nonetheless, two spotted seatrout were recaptured twice by project personnel, which suggests that at least a portion of spotted seatrout survived the tagging effort.

The majority of black drum returns were the result of project recaptures and angler recaptures in the Banana River no-motor zone near the edge of the restricted area. Johnson et al. (1999) report that black drum abundances were greatest in the Banana River restricted area, relative to the Banana Creek restricted area and adjacent fished areas. These data suggest MINWR black drum populations are abundant locally in Banana River, and movements outside of Banana River are limited.

Common snook moved long distances migrating from the protected waters within MINWR to natural inlets. Tagging studies have shown that common snook movement patterns differ substantially between Florida Gulf and Atlantic Coasts (Tringali and Bert, 1996). Florida Gulf common snook remain within their home estuaries and only occasionally move long distances (99.5% of 2,053 tagged and recaptured Florida Gulf common snook moved <10 km). Conversely, Florida Atlantic common snook are highly migratory (40% of 1,947 tagged and recaptured Florida Atlantic common snook migrated 50–350 km along the Florida east coast). Florida Atlantic common snook populations are also hypothesized to contribute fish to the Florida Keys on the basis of tag-recapture data, the absence of juvenile common snook in the vicinity of the Florida Keys, and genetic analyses (Tringali and Bert, 1996). The present study provides another source of data indicating that Florida Atlantic common snook migrate from the northern Indian River Lagoon to locations as far as South Florida, including the Florida Keys.

The northern Indian River Lagoon and the MINWR area may be an important habitat region for juvenile common snook. The MINWR area provides ideal environmental conditions and habitat characteristics for juvenile common snook, such as reduced salinity, shallow, quiescent waters, and extensive seagrass and saltmarsh habitats (Gilmore et al., 1983). As MINWR juvenile common snook mature, they may move south to the vicinity of inlets where spawning occurs and remain there. Several lines of evidence support this: Johnson et al. (1999) report that 74% of common snook caught within the restricted areas were immature, all of the recaptured common snook within the restricted areas were immature, and large adult common snook recaptures occurred south of MINWR near inlets.

Alternatively, severe winters that occurred just prior and during the study period, 1981, 1983, 1985, and 1989 (Winsberg, 1990), may have influenced the abundance and size distribution of common snook. MINWR lies at the

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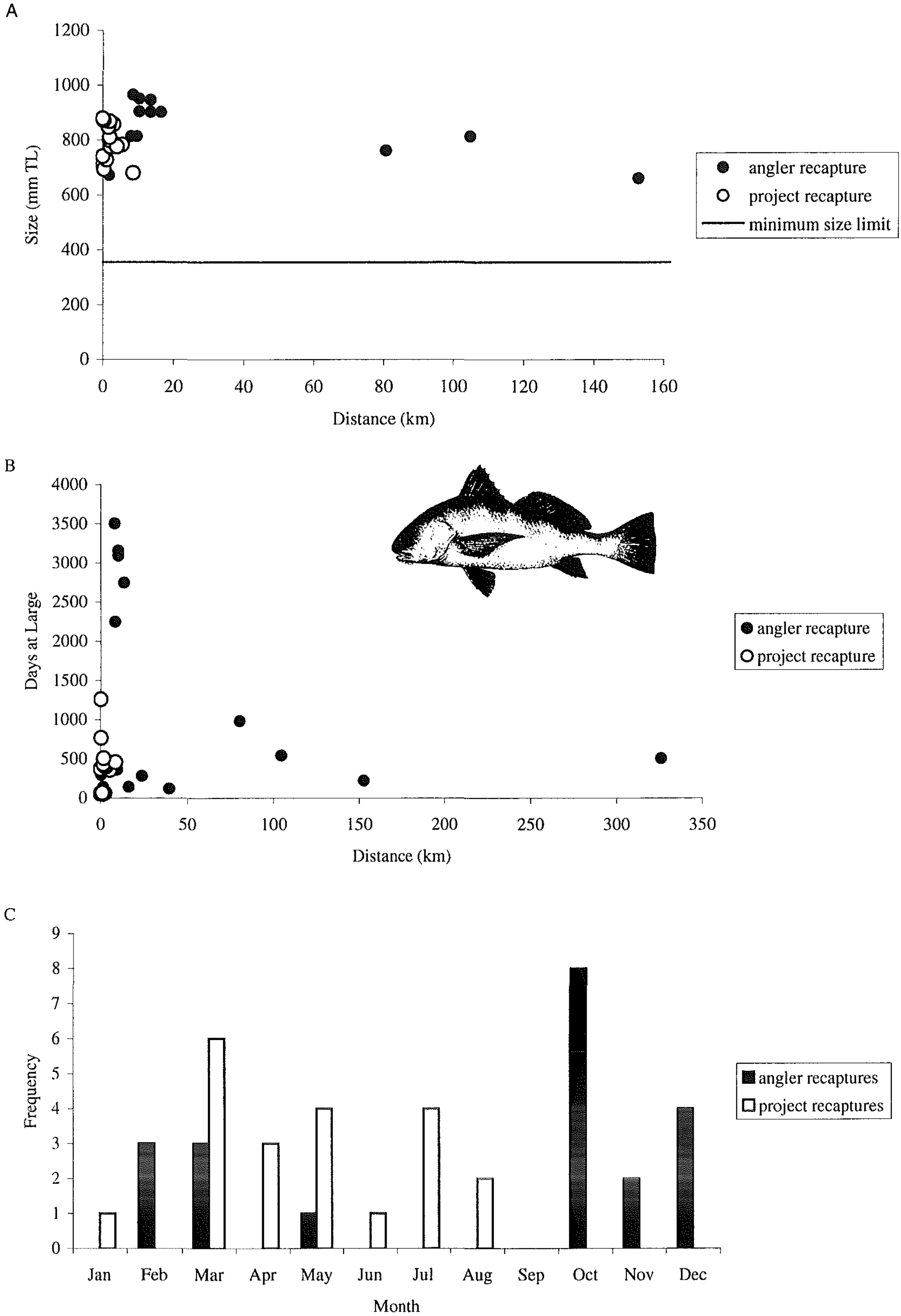

Fig. 7. Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for black drum.

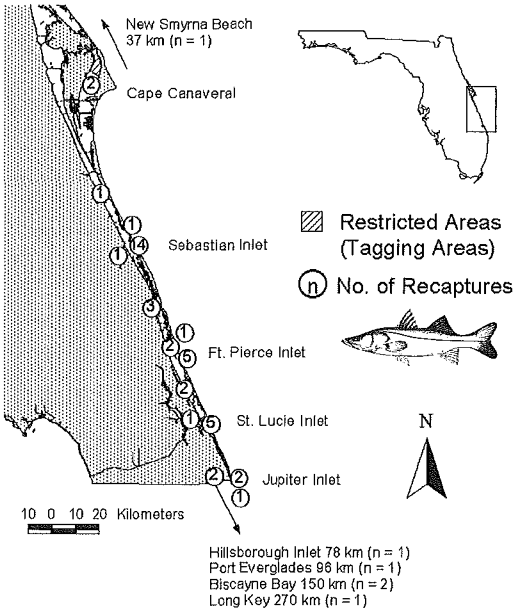

Fig. 8. Angling recapture locations for common snook (n = 49). Project personnel recaptured an additional seven common snook within the restricted areas.

northernmost range of common snook, which are susceptible to low water temperatures (e.g., Gilmore et al., 1983). If larger common snook were present at MINWR in greater abundance prior to these severe winters, they could have been killed by low water temperatures or could have migrated south. However, more than half of the recaptured common snook were originally tagged during winter months, and 90% of recaptured common snook that were tagged during 1986–1988 were recaptured south of MINWR before the next severe winter in 1989. These data suggest that common snook recaptures occurred south of MINWR as a result of ontogeny rather than freeze related migrations.

The restricted areas within MINWR as fish replenishment zones.—Individuals of each sport fish species tagged during the study egressed from the restricted areas within MINWR to areas open to fishing. The species with the highest angler recapture rate was common snook. However, Johnson et al. (1999) did not find an increased abundance of common snook within the MINWR restricted areas relative to adjacent fished areas, and the tag-recapture data suggests that common snook migrate out of the restricted areas as they reach maturity. Although the MINWR restricted areas may not maintain adult common snook in greater abundance than adjacent fished areas, they may benefit the species by providing protected juvenile habitat.

For the study species with small home ranges, such as spotted seatrout, red drum, and black drum, the restricted areas within MINWR appear to replenish the local fishery, by first protecting sport fish populations from exploitation (Johnson et al., 1999) and subsequently contributing adult sport fish to surrounding water open to fishing. The relative abundance (standardized catch per unit effort) of spotted seatrout, red drum, and black drum were 2.4, 6.3, and 12.8 times greater in the restricted areas than in adjacent areas open to fishing (Johnson et al., 1999). The size of red drum and spotted seatrout in the restricted areas was also greater than areas open to fishing (Johnson et al., 1999). The present tag-recapture results show that large adult sport fish egress from the restricted areas within MINWR to nearby water, contributing to the recreational fishery of the Indian River Lagoon, Banana River, and Mosquito Lagoon.

The final question that remains with respect to estuarine reserves as fish replenishment zones is whether reserves facilitate reproduction and recruitment in target species. The MINWR restricted areas contribute large sport fish to nearby water, and thus add potential spawners to the species spawning pool in adjacent fished areas. It seems probable, however, that spotted seatrout, red drum, and black drum also spawn within the MINWR restricted areas (Johnson et al., 1999). If so, the greater abundance and size of adult sport fish compared with adjacent fished areas would likely result in greater spawning potential and stock fecundity, potentially increasing egg and larvae production. These benefits could have regional effects, enhancing juvenile recruitment in adjacent fished areas (Polacheck, 1990; Bohnsack, 1993, 1998; Carr and Reed, 1993; DeMartini, 1993; Dugan and Davis, 1993; Roberts and Polunin, 1993; Rowley, 1994; Man et al., 1995; Holland and Brazee, 1996; Roberts, 1997). Further research is needed to document spawning behavior, larval dispersal, juvenile recruitment, and juvenile survival in target species within the MINWR restricted areas to further determine the effectiveness of estuarine sanctuaries as fish replenishment zones and to quantify the relative contribution of the MINWR reserve to local and regional fisheries.

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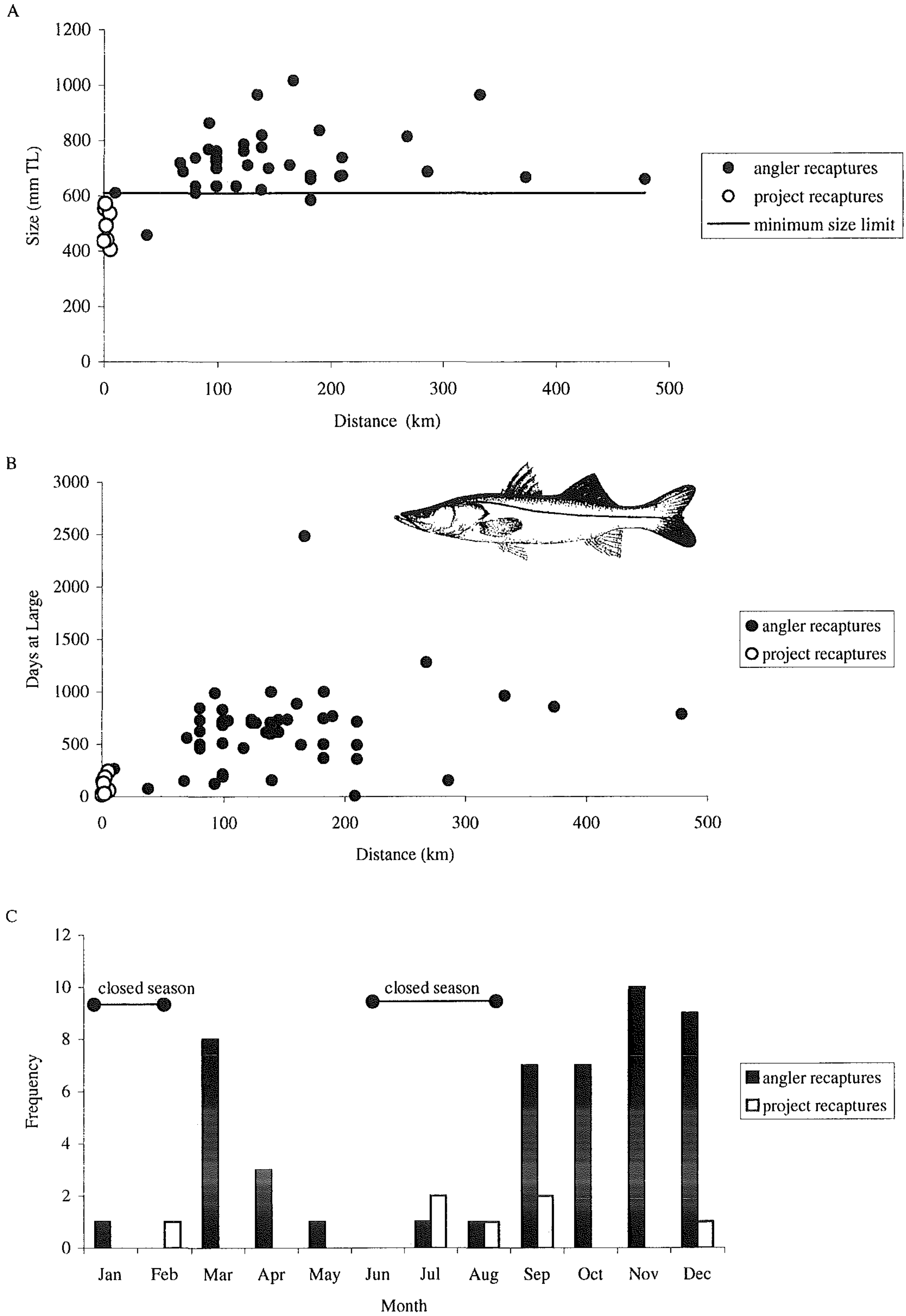

Fig. 9. Distance vs. size (A), distance vs. days at large (B), and month recaptured vs. frequency (C) for common snook.

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