A STUDY OF RIP CURRENT DROWNINGS AND RELATED WEATHER FACTORS

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Abstract

Annually, a number of people in the United States drown in the surf zone. This study determines the number of surf drownings each year, mainly in Dade and Broward counties of southeast Florida, that are attributable to rip currents. Certain meteorological and oceanographic factors are examined to determine their relationship to rip currents.

The study indicates that the number of probable rip current drownings in the two southeast Florida counties averaged more than nine per year for the period 1979 through 1988. It is estimated that 25 to 35 rip current drownings per year occur in the state of Florida. Preliminary estimates, indicate that North Carolina averages nine and Alabama three rip current drownings annually, while nationally, the number is near 150.

A good correlation is established between rip currents and local wind direction and speed, and also between rip currents and tidal heights. An experimental scale is formulated which categorizes the degree of danger in the surf zone from rip currents and indicates appropriate actions to be taken. An independent data set is used to verify the conclusions reached from the ten year data sample.

1. Introduction

Annually, about 330 million people visit beaches in the United States. Many beach goers are unaware that rip currents in the surf zone are a potential danger. A literature search indicates that little has been published about this danger or about attempts to forecast the occurrence of rip currents. Furthermore, the U.S. coastal population is increasing at a much faster rate than the population as a whole (NOAA 1990a).

A rip current is defined in the *Glossary of Meterology* (1959) as "a strong water-surface current of short duration flowing seaward from the shore." The rip current is popularly called a rip tide, undertow, runout, washout or seapuss. Many drownings, especially those along the beaches of the Gulf of Mexico and portions of the United States east coast, occur when a person on or inside of the nearshore sand bar is pulled into deeper water by a strong rip current.

Figure 1 shows a photograph and schematic of a rip current. Rip currents help transport excess water ("set-up") from the zone shoreward of the breakers into deeper water. The region of maximum current ("neck") is often 10 to 30 yards wide and has speeds measured by Sonu (1972) at 4 knots. Rip currents can often be identified in the surf zone by a combination of factors including: a sandy brown discoloration of the water extending seaward from a sand bar, a foam or seaweed line extending offshore, and a choppy and somewhat suppressed wave height.

Modern research into rip currents was begun by Shepard et al., (1941) who studied them from a geological point of view along the south California coast. Sonu (1972) did a field study of them along the Florida panhandle. Komar (1976) provides an excellent summary of research into rip currents. These studies indicate that the formation of rip currents is related to either a variation in breaker height or irregularities in the topography of the near shore sea bed. Although usually found in salt water surf zones, large bodies of fresh water can also experience rip currents (Schlatter 1990).

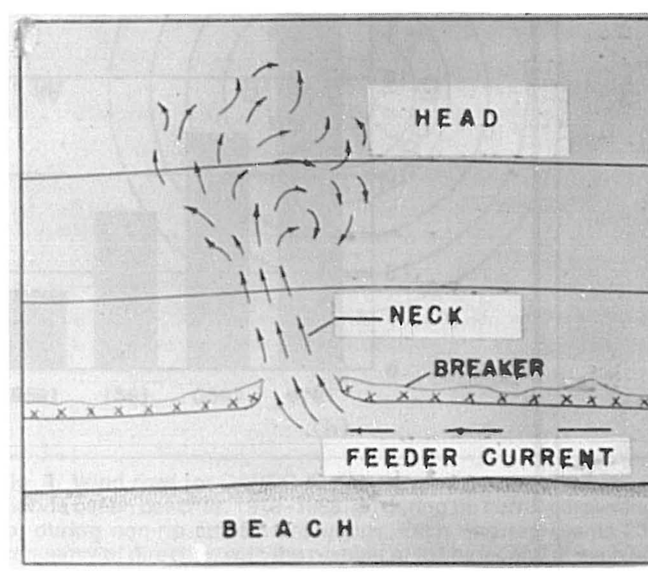

Fig. 1. Overhead photograph (left), and schematic (right), of a rip current, along the California coast. Courtesy of Robert L. Wiegel, Council on Wave Research, University of California.

A three step approach to this study was undertaken. First, the number of drownings associated with rip currents, principally in Dade and Broward counties of southeast Florida, was determined. Second, an association of rip currents to wind, tides and swells was established. Third, an experimental scale which defines the degree of danger in the surf zone from rip currents was formulated and tested.

2. Data

a. Medical Examiner's Information, Beach Patrol Rescue Logs and Newspaper Clippings

The Medical Examiner's death records for Dade and Broward counties in southeast Florida for the ten year period from 1979 through 1988 were examined for ocean surf drownings. The death records for the approximately 210 ocean drownings during this period were examined for information concerning the likelihood that the drowning was primarily rip current related. Discarding drownings obviously not linked to rip currents, such as those involving boating, diving, etc, reduced the number to 148 potential rip current drownings. Drownings during the period from January through July 1989 were tabulated separately to be used as an independent data set.

Beach patrol rescue logs in Dade and Broward counties were gathered for all of 1988 and the first six months of 1989. In addition selected rescue logs were examined for the period from 1979 through 1987.

To explore rip current drownings elsewhere in Florida, newspaper clippings, detailing probable rip current drownings, were collected from June 1989 through August 1991. Information from death certificates of surf drowning victims, in all but one of the coastal counties of North Carolina and in both coastal counties of Alabama, were collected for the period 1979 through 1989.

b. Meteorological and Oceanographic Data

Three agents which may be involved in making rip currents dangerous are wind waves, tides, and swells. National Data Buoy Center (NDBC) buoys off of the Florida east central and northeast coasts operationally measure wave heights, directions, periods and even spectral energy density, (NOAA 1990b), but no real-time wave measurements are available along the coasts of Dade and Broward counties of southeast Florida. However, because, in the absence of swells, there is a direct relationship between wave height and wind speed, the local wind rather than the wave height was compared to rip currents in this study.

To investigate the association between wind and rip cur-

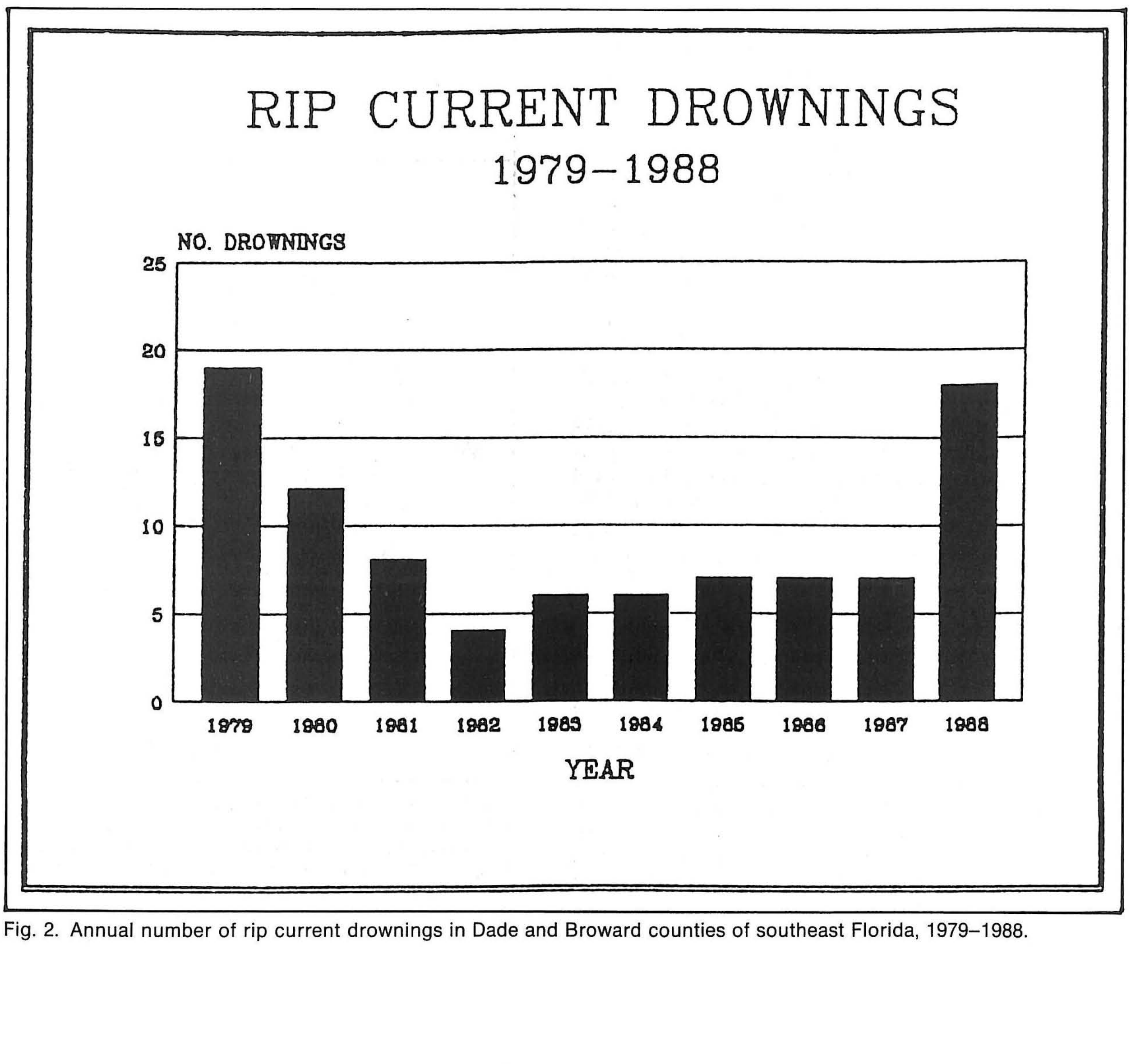

Fig. 2. Annual number of rip current drownings in Dade and Broward counties of southeast Florida, 1979–1988.

rents, observations during the ten year period from 1979 through 1988 from the Miami Beach DARDC (Device for Automatic Remote Data Collection) were tabulated.

To correlate rip currents and tides, the time and height of high and low water, and the speed and direction of the tidal current, during the ten year period was obtained from the National Ocean Service's (NOS) *Tide Tables—High and Low Water Predictions* and from the *Tidal Current Tables*.

In southeast Florida, large swells, except from nearby tropical cyclones, are rare due to the sheltering effects of the Bahama Islands and Cuba. The northeast Florida coast experiences more swells than elsewhere in the state, but currently, because of a small number of rip current observations in this area, only a limited comparison between swells and rip currents could be made.

3. Analysis, Results and Discussion

a. Rip Current Drownings

After careful screening of the Medical Examiner's records, it was determined that 94 of the 148 potential rip current drownings in southeast Florida during the ten year period 1979 through 1988 were actually rip current related. A graph of the annual rip current drownings from 1979 through 1988 in southeast Florida is plotted in Figure 2.

Using newspaper accounts, an estimated 30 to 40 drownings in the whole state of Florida were estimated to have been caused by rip currents in 1989. There were 23 rip current drownings in 1990, and, through August 31, 20 drownings in 1991. The fewer statewide drownings in 1990 and 1991 are probably due to fewer drownings in Dade and Broward counties where there were only three victims in 1990 and four in 1991. Beach patrol personnel (personal conversation with Marcus Breece, Dade County Beach Patrol, 1991) attributed the fewer drownings in southeast Florida in 1990 and 1991 to extensive media coverage spurred by the issuance of marine weather statements by the Miami WSFO. Of course a much longer period of data will be necessary to validate this assertion. These nearly three years of data indicate that 25 to 35 Floridians drown in rip current annually.

Other areas of the United States experience significant rip current drowning problems (personal conversation with John Fletemeyer, United States Lifesaving Association, 1990). Death certificate data from North Carolina indicate an average of nine rip current related drownings each year from 1979 through 1988. In Alabama, an estimated three persons a year have drowned in rip currents from 1979 through 1989. Based on indirect evidence from studies by the Metropolitan Life Insurance Company (1977) and the National Safety Council (1990), an estimated 150 persons a year drown in rip currents in the United States.

b. Wind Relationship to the Occurrence of Rip Currents

To examine the association between wind, and the occurrence of rip current drownings, data from the Miami Beach DARDC were tabulated. An association was made only on the 72 occasions from 1979 through 1988 when Medical Examiner's records or beach patrol rescue logs indicated the likelihood that rip currents had occurred. A wind rose (Fig. 3a) that was constructed during times of rip current drownings shows that all of the wind directions were onshore and the majority were nearly normal to the coast. The southeast Florida coast is oriented nearly north-south. The average wind speed was 13 knots. For comparison purposes, the wind that was measured closest in time to the surf drownings that were not rip current related, are plotted in Figure 3b. This shows a much wider distribution of wind directions and weaker wind speeds. Schlatter (1990) notes a similar wind-rip current relationship in Lake Michigan.

An exception to this relationship occurred at the end of a multiday period of moderate-strong directly onshore wind.

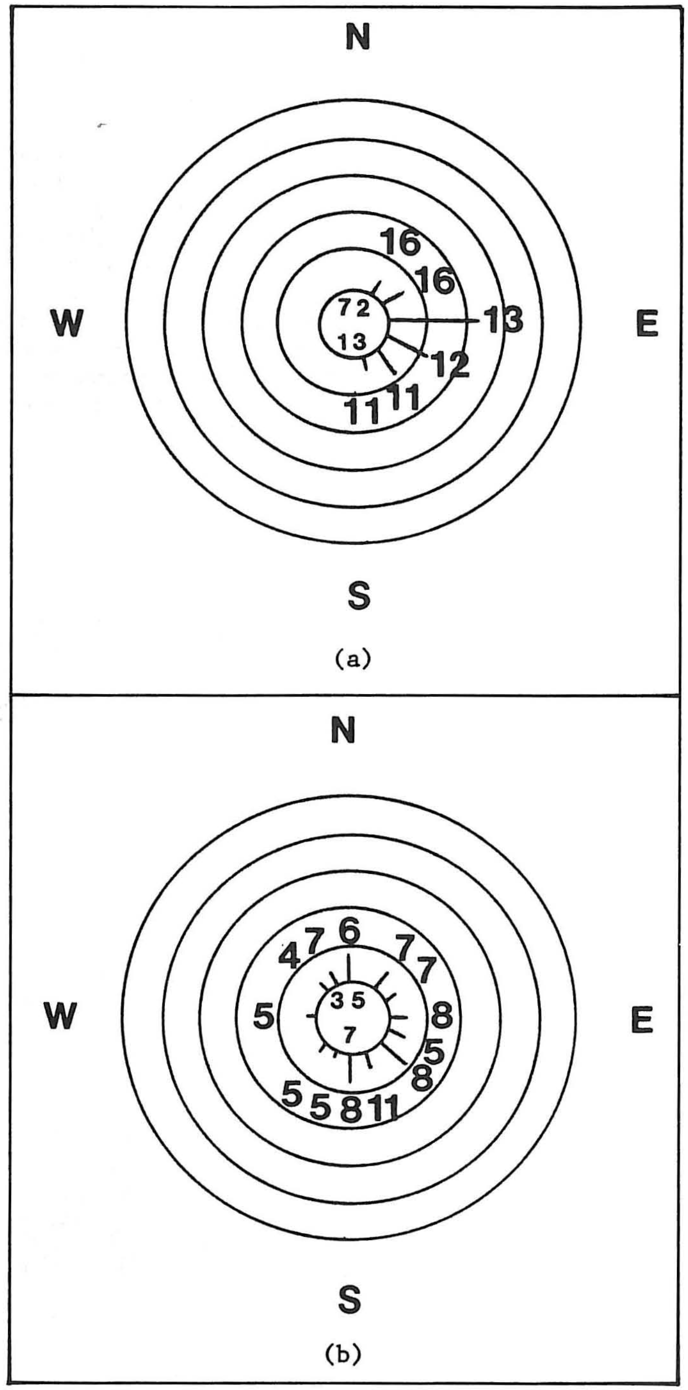

Fig. 3. Wind rose for DARDC sustained wind (knots) at southeast Florida ocean beaches, 1979–1988. (a) during rip current drownings (b) during non-rip current drownings. Each ring represents 20% frequency of direction with the number at the outer end of each line being the average scaler wind speed for that direction. Inside the center are the number of observations (top) and the average scalar wind speed for all the directions (bottom).

During the approximately 12 hours after the wind weakened or veered, rip currents often continued to occur. This could be due to either the momentum of the rip currents being sustained for a certain length of time, or by new rip currents forming from the interaction of wave trains coming from two different directions as theorized by Dalrymple (1975). The rip currents that took place during the period of weaker winds following an episode of strong winds were designated as "residual" rip currents and accounted for 24 of the 94 drownings along the southeast Florida coast.

When rip current drownings took place, the wind direction was onshore 100% of the time. Furthermore, the direction was onshore and within 30 degrees of normal to the coast about 90% of the time.

The relationship to wind direction is not as consistent as with wind speed. Using the DARDC wind speeds, and excluding residual cases, a frequency plot was drawn for all the rescue and drowning reports from 1979 through 1988 (Fig. 4). This plot shows 90% of the winds with speeds of 10 knots or greater and 67% with 12 knots or greater.

The history of the wind during an "episode" in which rip currents were present was investigated. An episode was defined as the time from which a strong onshore wind began to the time at which the onshore wind weakened or ended. A total of 83 episodes were identified during the period 1979 through 1988. The length of the episodes ranged from one to 36 days with the median length between 5 and 6 days. The drownings took place from a minimum of 3 hours to a maximum of 33 days after an episode began with a median between days two and three.

These statistics imply three significant things about the danger from rip currents. *First, the danger does not usually begin immediately at the onset of an onshore wind, but increases during the first two or three days. Second, the danger does not end immediately with a decrease or shift in wind, but takes about 12 hours after the wind changes to end. Third, the danger occurs, for the most part, during multiday episodes of onshore gradient wind, and thus the daily onshore sea breeze is not a major factor in making rip currents dangerous.*

c. Tide Relationship to the Occurrence of Rip Currents

An investigation was made into the relationship between rip currents and (a) the time of high and low tide, (b) the

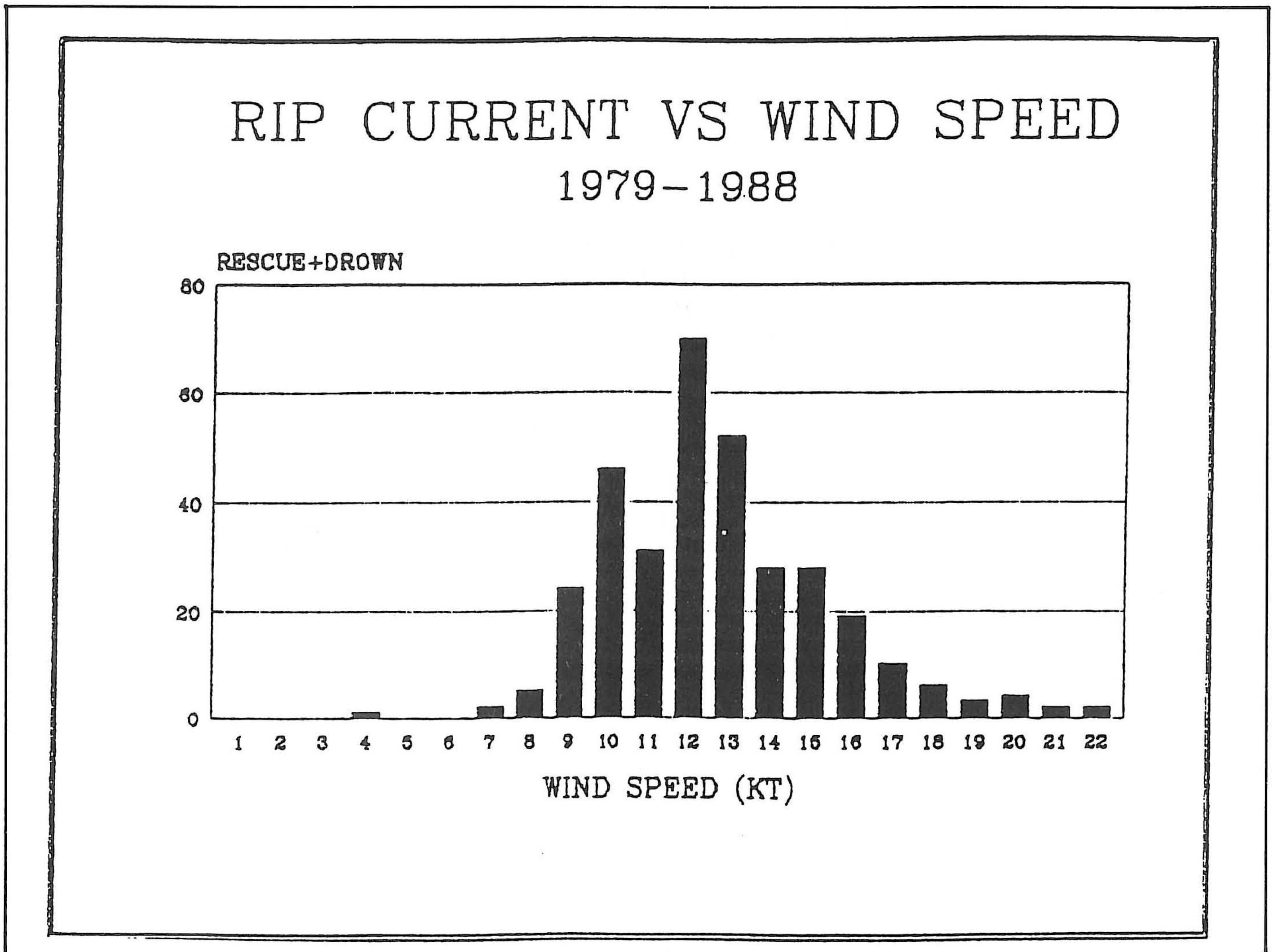

Fig. 4. Frequency of DARDC sustained wind speed (knots) for combined rip current rescues and drownings at southeast Florida beaches, 1979–1988.

height of high and low tide, and (c) the tidal current speed and direction.

A graph relating rip current drownings to times of high and low tide is plotted in Figure 5. This graph shows that 54 of the 72 (75%) likely rip current drownings happened in the six hour period from two hours before to four hours after low tide. Komar (1976), notes a similar relationship between low tide and rip currents along the Oregon coast. The reason for this correlation may be due to either stronger rip currents, or more people going into the surf during the time of low tide, or a combination of these two factors. As a control group, the surf drownings during the 1979 through 1988 period that were not rip current related were plotted against the time of high and low tide (figure not shown). These deaths showed a more uniform distribution with respect to tide indicating that the higher number of rip current drownings near low tide was more likely due to increased strength of the rip currents rather than the number of people in the water.

Numerical tidal heights showed no relationship to rip currents, and tidal currents showed less of a correlation than did the time of high and low water.

d. Swell Relationship to the Occurrence of Rip Currents

Rip currents generated by swells, especially when the swell heights are decreasing, can be particularly hazardous, because local winds may be light. This may deceive bathers into thinking surf conditions are safe.

Along Florida's east coast, to the north of Palm Beach, swells occur during the summer when tropical cyclones, moving in a northward direction, pass east of the area, and in the winter months when strong extratropical lows develop off the coasts of the Georgia or the Carolinas. Two rip current drownings and several hundred rescues occurred when swells from hurricane Bertha, which was skirting the United States east coast in August 1990, affected the northeast Florida coast. One rip current death in September 1989 occurred at Daytona Beach in conjunction with swells generated by Hurricane Hugo. Since only meager data were available to correlate swells with rip currents in Florida, it can only be speculated that in general, like the United States west coast, Hawaii and Puerto Rico, the larger the swells, the greater the rip current danger.

e. Rip Current Scale

An experimental scale to quantify the threat of rip currents was devised that was founded on the relationships between rip currents and wind, tide and swells. The scale rates the rip current danger by categories from zero to five. Category zero indicates no weather related rip current danger, and category five indicates high danger. The name LURCS LUshine Rip Current Scale was coined to convey a somewhat sinister or

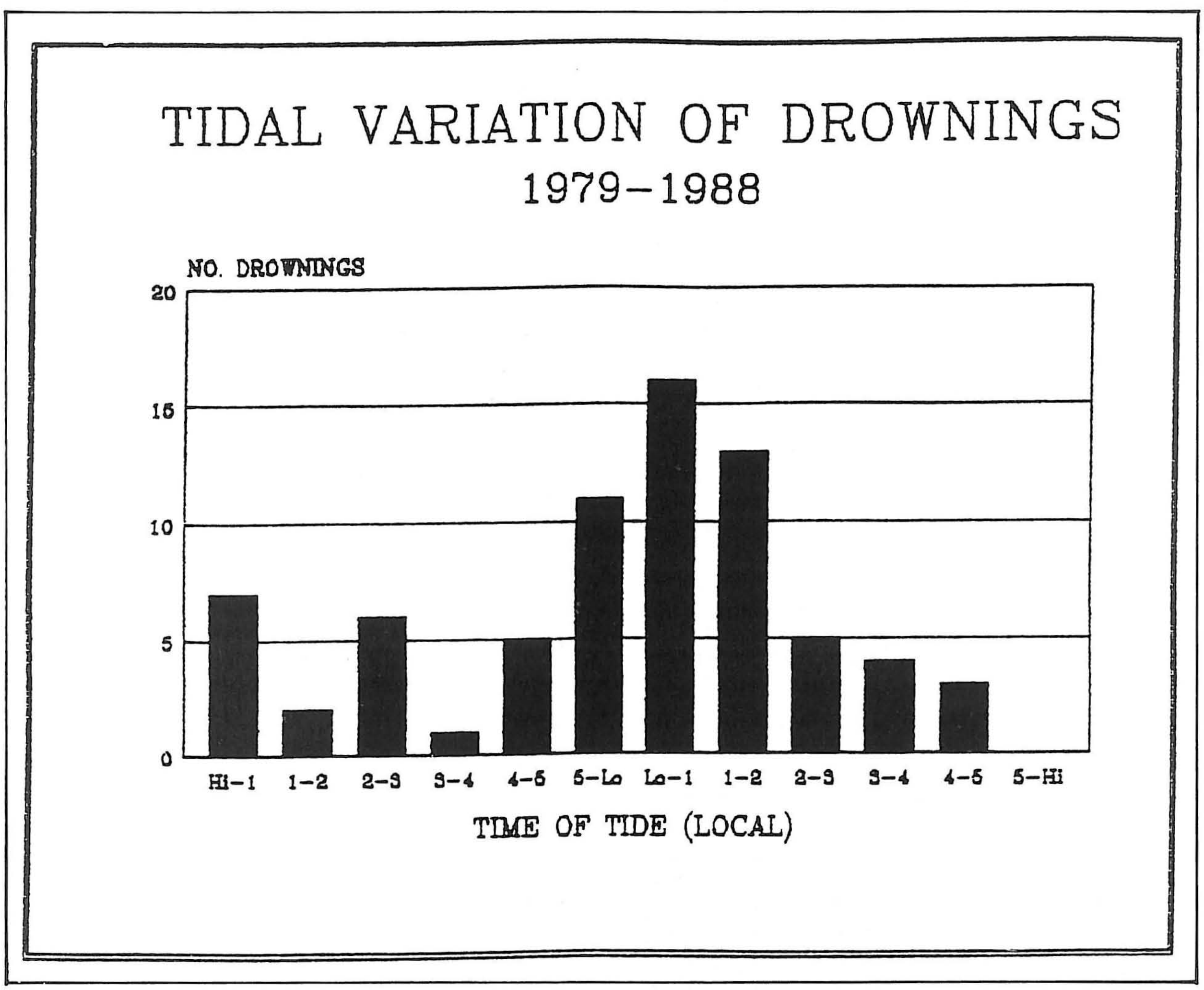

Fig. 5. Number of rip current drownings at southeast Florida ocean beaches, 1979–1988, relative to time of high and low tide.

dangerous sound. If used in operational forecasting, each LURCS, category could be color-coded to be compatible with the colored flags used by beach patrols to indicate hazards in the surf.

The relationship between rip currents and wind was chosen as the foundation of the scale. Rip current drownings and rescues began when the wind direction was nearly directly onshore (within an angle of 30 degrees normal to the coast), and with a wind speed of about 10 knots. The danger from these rip currents, especially on the first day of an onshore wind, was relatively small. As the direct onshore flow increased to 10–15 knots, the danger from rip currents increased.

Table 1a. Definition of LURCS Categories

Category Numbers

Wind Speed (Knots)		Wind Direction: Direct Onshore	Wind Direction: Oblique Onshore
<10		0.0	0.0
10		0.5	0.0
11–14		1.0	0.5
15		2.0	1.0
16–19		3.0	2.0
20		4.0	3.0
21–24		4.5	3.5
25–34		5.0	4.5
35–50		5.0	5.0
Swell Ht (Feet)			
>2–4	Add 2 Categories		
>4–7	Add 3 Categories		
>7–10	Add 4 Categories		
>10	Add 5 Categories		
Tidal Factor	Add 1.0 Category within −2 to +4 hours of low tide		
Persistence Factor	Subtract 0.5 Category on first day LURCS is >0.0; add 1.0 Category for second or subsequent day if LURCS increases 2.0 or more categories		

1. Use the observed or forecast wind to the nearest 5 knots and nearest Cardinal direction to determine the wind category.
2. If any swells will affect the area, add swell categories.
3. For wind or swell categories of 0.5 or greater, include tidal factor.
4. If yesterdays LURCS category was >0.0, include persistence factor.
5. Round off the sum of these numbers downward to the nearest whole category.

Definitions and limitations:
1. Wind is the prevalent, large-scale flow.
2. Wind directions are defined as:
   (a) Direct onshore = within 30 degrees of normal to coast.
   (b) Oblique onshore = more than 30 degrees normal to coast.
4. If direct onshore wind, and strong at night, use this wind during the entire ensuing daytime period.
5. Maximum category is 5.0.

Table 1a. Table to determine the LURCS category of rip current danger.

With a 15 knot nearly direct onshore wind, a near critical danger condition from rip currents seemed to be reached. This was due probably to a combination of physical and sociological factors. The physical factor was that rip currents were likely to be stronger with an increase in the "set-up." The sociological factor was that the surf was not rough enough to discourage people from venturing into the surf. At 15–20 knots of nearly direct onshore wind, rip currents are probably almost always present and quite strong, but fewer people, especially those of limited swimming ability, venture into the surf due to the higher waves. The relationship between rip currents and wind with speeds of greater than 20 knots is tentative due to the sparcity of occurrences. If the wind is onshore but oblique to the coastline, (at an angle greater than 30°), the danger from rip currents occurs at a 5 to 10 knot higher wind speed than when the wind is directly onshore.

To account for the effects of swells on rip current generation, a crude relationship between swell height and rip currents was formulated. Swell heights equivalent to wind wave heights (sea) were used to add categories to the LURCS. Since the danger from rip currents is higher near low tide, a factor was included to take this into account. After determining the observed or forecast wind, swell, tide and persistence factors, Table 1a is used to calculate the LURCS category. With the help of beach patrol personnel in southeast Florida, the rip current scale categories were matched with likely conditions observed in the surf, and recommended actions under these conditions were given. (See Table 1b).

f. Verification

Using the LURCS derived criteria for rip current dangers, a verification of an independent data sample was done. The presence of rip currents in southeast Florida during the 212 days from 1 January through 31 July 1989 was inferred through Medical Examiner's reports and beach rescue

Table 1b. LURCS Description

Category	Color Code	Description	Recommended Action
0		No weather-related rip current danger	None
1	Yellow	Caution for weak or non-swimmers Weak rip currents possible	Weak swimmers stay in shallow water
2	Yellow	Caution for all Moderate rip currents possible	All swimmers stay in shallow water
3	Red	Danger for weak or non-swimmers Moderate rip currents likely	Weak swimmers don't enter water above knees
4	Red	Danger for all Strong rip currents possible	All swimmers don't enter water above knees
5	Black	High Danger for All Strong rip currents likely	Stay out of water

Table 1b. Description of LURCS categories, color code and recommended action.

reports. Drownings and near-drownings from elsewhere in Florida for the period from June through October 1989 were also examined for verification.

For southeast Florida, a LURCS category was calculated for the daylight period of each of the 212 days, based on an average wind from the Miami Beach DARDC wind instrument, a tide table, and a persistence factor. Eighty-two of the 212 days were calculated to have had a LURCS category of 1.0 or higher, indicating some danger from rip currents, while the remaining 130 days had a LURCS category of 0.0, indicating no weather related rip current danger. During this period, there were nine days which had rip current drownings, and 36 days which had rip current related rescues.

A measure of the accuracy of the LURCS categories was made using criteria frequently applied to NWS severe weather warning verification. In severe weather verification, three values, the Probability of Detection (POD), the False Alarm Ratio (FAR) and the Critical Success Index (CSI), are used to assess the accuracy of warnings issued (Grenier et al., 1989). Basically, the POD gives the percentage of all events that are detected. The FAR is a measure of overwarning, and the CSI is an indicator of forecast skill.

Using LURCS categories of 1.0 or greater during the 212 day period in 1989 in southeast Florida as a measure of the need to warn for rip currents, the POD was calculated to be .92, the FAR was .44 and the CSI was .55. LURCS categories of 2.0 or greater and 3.0 or greater yield PODs, FARs and CSIs of .95, .53, .45 and .92, .39, .58 respectively. LURCS categories 4.0 and 5.0 have too few cases to be reliable. By comparison, the statistics for severe weather warnings (tornado and severe thunderstorm) in the United States for 1988 (Grenier, et al., 1989), which yielded the best results in the past 10 years, showed a POD of 57%, a FAR of 58%, and a CSI of 32%. The FAR for rip current detection is misleading in that rip currents may well have been present, but no drowning or rescue occurred, and thus, they did not "verify."

Although the information on rip current drownings and near drownings elsewhere in Florida were not nearly as complete as those in southeast Florida, all 12 events during 1989 had a LURCS category of 3.0 or higher indicating the applicability of the LURCS derived criteria outside of southeast Florida. No determination of the POD, FAR or CSI could be made from these data because of, among other things, the lack of Medical Examiner's information, beach rescue reports or easy accessibility to reliable wind data.

No formal verification has been attempted outside Florida, however, the Weather Service Office at Cape Hatteras, North Carolina, used a preliminary version of the LURCS to warn of dangerous rip currents during Labor Day weekend of 1990 during which two people drowned (personal correspondence with Ron Jones, Weather Service Specialist, 1990).

4. Summary and Conclusions

A study was undertaken to estimate the number of rip current drownings along United States beaches, principally in southeast Florida. Using Medical Examiner's records in Dade and Broward counties of southeast Florida, it is estimated that an average of more than 9 people a year drowned in rip currents between 1979 and 1988. Using newspaper clippings, estimates of likely rip current drownings statewide in Florida totalled between 73 and 83 during the period 1989 through August 1991. In the United States an estimated 150 persons annually drown in rip currents.

The danger from rip currents is strongly related to onshore wind flow. When the wind is directly onshore, a gradient wind speed of 10 knots is sufficient to create some rip current danger, and the danger increases with increasing wind speed. An oblique onshore wind direction is also correlated to rip current danger, but requires a higher wind speed than that associated with the direct onshore flow.

The danger from rip currents usually begins on the second day of a period of onshore flow, and does not end until 12 hours after the wind weakens or becomes offshore. The danger from rip currents is greatest around the time of low tide and is related to the size of oceanic swells.

The association between rip currents and both wind, swells and tide, resulted in the formulation of an experimental scale which could be used to forecast the degree of danger from rip currents.

A technique to forecast rip currents would be beneficial, and the LURCS might provide, after additional testing and evaluation, a valuable tool.

Author

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References

Bowen, A. J., 1969: Rip currents, theoretical investigations, *J. Geophys. Res.*, 74, 5467–78.

Dalrymple, R. A., 1975: A mechanism for rip current generation on an open coast, *J. Geophys. Res.*, 80, 3485–87.

Grenier, L. A., J. T. Halmstad and P. W. Leftwich, 1989: Severe local storm warning verification: 1988, *NOAA Technical Memorandum NWS NSSFC-23*, 20 pp.

Huschke, R. E., 1959: *Glossary of Meteorology*, American Meteorological Society, Boston, Massachusetts, 484.

Komar, P. D., 1975: *Beach Processes and Sedimentation*, Prentice-Hall, Englewood, New Jersey, 168–202.

Metropolitan Life Insurance Company, 1977: Accidental drownings by cause and site (Special Series Pt. 2), *Statistical Bulletin*, 58(6), 9–11.

National Oceanic and Atmospheric Administration, 1990a: Fifty years of population change along the nation's coasts, 1960–2010, U.S. Department of Commerce, Washington, D.C.: U.S. Government Printing Office, 44 pp.

National Oceanic and Atmospheric Administration, 1990b: NDBC real-time direction wave information user's guide, U.S. Department of Commerce, Stennis Space Center, MS. 24 pp.

National Safety Council, 1990: *Accident Facts* 1990 edition, Chicago: Author, 18.

Schlatter, T., 1990: Weather Queries. *Weatherwise*, 43, no. 3: 165.

Shepard, F. P., K. O. Emery, and E. C. LaFond, 1941: Rip currents: A process of geological importance, *J. Geol.*, 49, No. 4: 337–69.

Sonu, C. J. 1972: Field observations of nearshore circulation and meandering currents, *J. Geophys. Res.*, 77: 3132–47.